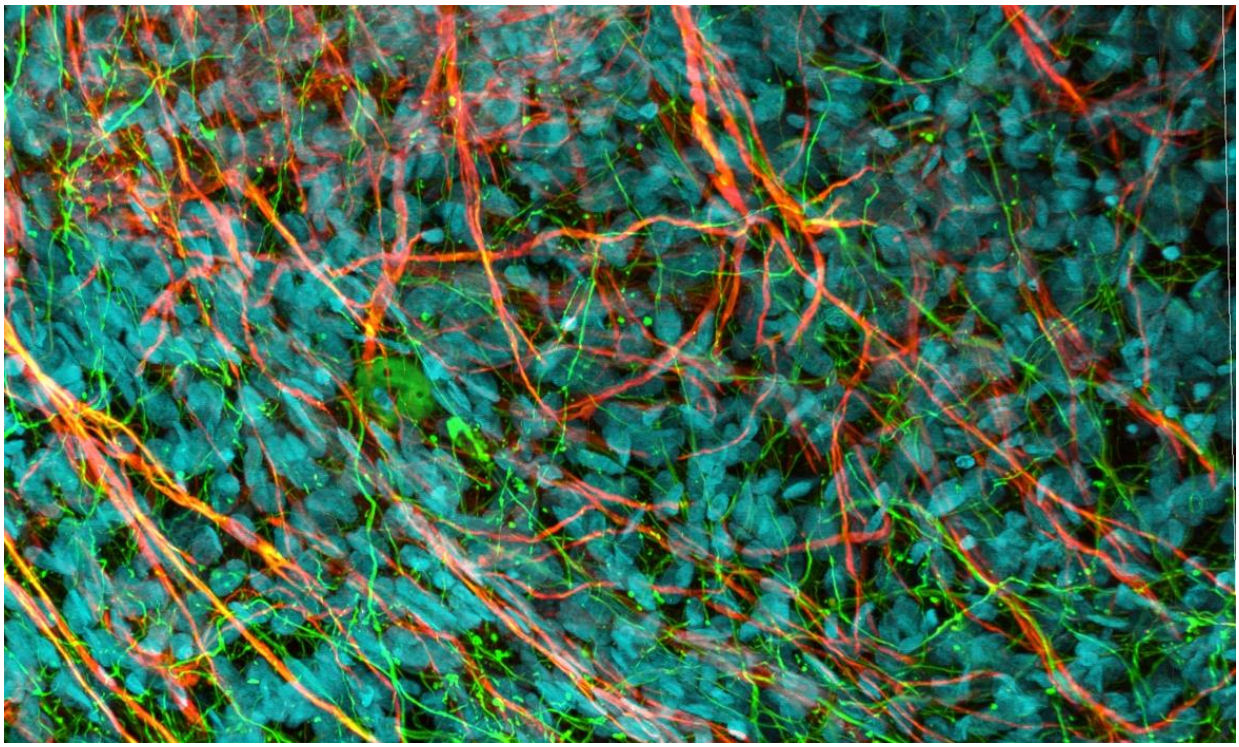
Stem Cells Australia
At the Frontier of Tomorrow's Medicine

Teaching Resource for Australian Secondary School Teachers



Dr JENNIFER MANSFIELD PhD, GradDip Ed, BSc (Hons)[1] and Professor MEGAN MUNSIE PhD, MRepSc, BAppSc[2]

[1]Monash University, Faculty of Education
[2]University of Melbourne, Faculty of Medicine, Dentistry and Health Sciences

STEMCELLS AUSTRALIA

MONASH University

POSTERA CRESCAM LAUDE
THE UNIVERSITY OF MELBOURNE

About the authors:

Dr Jennifer Mansfield is a science teacher educator in the Faculty of Education at Monash University, Australia. Her passion for science and science education has seen her work as a scientist and secondary school science teacher before transitioning into pre-service teacher education. Her research interests include the development of teachers' professional knowledge of practice and the development of teachers understanding and attitudes about science education, in particular science as a human endeavour and the nature of science.

Professor Megan Munsie is the Convenor of Stem Cells Australia at the University of Melbourne where she heads a research program in the ethical, legal and social implications of stem cell research. As a trained developmental biologist, Megan combines her scientific expertise with a deep understanding of the ethical and regulatory considerations required to facilitate responsible research in stem cell science and its clinical translation.

Acknowledgements:

The authors would like to acknowledge Ms KATERINA MITSINIKOS BBiomed (Hons) for her generous contributions to drafting and critical revision of content and Ms GEORGIA CARNEY BBiomed (Hons) for her assistance in preparing the resource.

Funding:

This project was supported by funding provided by Monash University to the then Education, Ethics, Law and Community Awareness Unit of Stem Cells Australia, the Australian Research Council's Special Initiative in Stem Cell Science. Additional support was provided by the University of Melbourne.

How to reference:

Mansfield J, and Munsie M. At the Frontier of Tomorrow's Medicine Teaching Resource for Australian Secondary School Teachers. Melbourne, Australia. Stem Cells Australia; 2021.

© Mansfield J and Munsie M 2021

Table of Contents

Teaching Resource for Australian Secondary School Teachers ***1***

Welcome to the Stem Cells Australia Teaching Resource **4**

1. The Heart **8**

1.1 The Ramialison Group: How to mend a broken heart 8

1.2 The Powell Group: Studying heart development one cell at a time 18

1.3 The Porrello Group: Fixing hearts by finding out what makes them tick 30

1.4 The Palpant Group: Studying heart development one cell at a time 38

1.5 The Harvey Group: Pathways to heart repair 49

1.6 The Chong Group: A heart-felt desire to advance stem cell science 61

2. The Neural System **71**

2.1 The Bourne Group: Building tools for brain repair 71

2.2 The Pouton Group: Enlisting the brain's immune cells to fight MS 82

2.4 The Merson Group: Using stem cells in the brain to combat MS 96

2.5 The Parish and Thompson Group: Towards stem cell therapies for Parkinson's 107

3. The Eye **118**

3.1 The Pébay Group: Seeing eye disease clearly with robotics 118

3.2 The Watson and Di Girolamo Group: Clearing corneas and restoring vision 134

3.3 The O'Connor Group: Micro-lenses bring new cataract treatments in sight 145

4. The Kidney **158**

4.1 The Little Group: Mini-kidneys tell two sides of a genetic story 158

5. The Blood **174**

5.1 The Elefanty, Stanley and Ng Group: Making the right cells from stem cells 174

5.2 The Nilsson Group: Expanding horizons for stem cell transplants 182

6. The Gut **193**

6.1 The Abud Group: Having the guts to make a difference 193

7. Reprogramming and Pluripotency **207**

7.1 The Laslett Group: The plentiful promise of the pluripotent 207

7.2 Wolvetang Group: How reprogramming cells turns back time 217

7.3 The Polo Group: Understanding and controlling cell reprogramming 232

7.4 The Wells Group: Big data points the way to custom stem cells 244

7.5 The Mar Group: Discoveries hidden in big data 255

8. Stem cells and Ethics **265**

8.1 The Munsie Group: Who will help me? 265

Appendix: Overview of links to the curriculum **276**

Welcome to the Stem Cells Australia Teaching Resource

Introduction:

The Stem Cells Australia Teaching Resource was created to bring real world and engaging stories of scientific endeavour into the classroom. This resource has been designed around stories of the work from 23 prominent stem cell research laboratories across Australia featured on the Stories from the labs page and the Australian Stem Cell Research video wall page of the Stem Cells Australia website. These exemplars offer the opportunity to connect secondary school students to real world examples of the work of scientists as they address current issues and authentic needs in biomedical science.

This comprehensive resource is organised as a series of 'Cases' which feature stories of innovative research and candid interviews with diverse stem cell scientists. These Cases offer exciting and real-world contexts for illustrating the nature of science. Diversity, collaboration, failure and problem solving are highlighted as the realities of scientific work. Each Case celebrates the important dispositions and characteristics of scientists such as passion, curiosity, interest and a desire to help others.

Through these Cases teachers and students explore what it feels like to work in a research laboratory and consider the preparation and pathways to becoming a scientist. Students will use critical and creative thinking, ethical reasoning, and collaboration, which are essential for the development of scientific literacy. Being scientifically literate means to be interested in, and able to engage with science in our everyday lives to make reasoned and informed decisions. This helps students to understand science as a way of *knowing and doing*, not just a static body of knowledge.

This innovative resource opens the laboratory door and actively positions students within the human work that is science. The experiences provide opportunities for students to consider how science may be part of their future. Pursuing a career in science is a global imperative as the Australian Chief Scientist, Professor Foley contends:

> *"Science is critical to solving humankind's greatest challenges… We need people who are creative thinkers, who will use their imagination to push the boundaries.*
>
> *Our young people need to know where to obtain trusted information. Know how to make sense of information. Have the ability to challenge information based on evidence and understanding. Above all, we need them to know how to combine many bits of information into a broad picture of the world (1)."*

Reference:

1. Office of the Chief Scientist 2021, Achieving impact from Australian Science. National Press Club Address. Australian Government, Canberra. Available at: https://www.chiefscientist.gov.au/sites/default/files/202103/17%20March%202021%20-%20Address%20to%20National%20Press%20Club.pdf

An overview of the resource:

The ideas suggested for teaching in this resource emphasise Science as a Human Endeavour (SHE), of which there are two key aspects: the nature and development of science and the use and influence of science. Characteristics of these two aspects of SHE, which are explored in this resource, are outlined in the table below.

The nature and development of science	The use and influence of science
• The tentative yet durable nature of scientific knowledge • The role of failure, uncertainty, testing, risk, experimentation, investigation and serendipity which occur when pushing the boundaries of what is already known • Features of scientific endeavour, such as the role of interest, agency and values, and critical and creative thinking • Various types of modelling are common in science • Social and cultural embeddedness of science • Collaboration within and between laboratory groups locally, nationally and internationally • Interdisciplinary collaboration	• Science is influenced by social, cultural, economic and ethical considerations • Science is influenced by values • Scientific research is directed towards areas where there is perceived value and need • Solutions to issues are found using science and technology. Scientific endeavour is interdisciplinary. Advances in one field (e.g. technology), can lead to advances in another (e.g. science). • Science knowledge and skills can be applied in various occupations and real-world scenarios • Scientific knowledge can be used to make predictions and informed decisions • Science is a global enterprise which relies on clear communication and conventions, such as evidence, peer review and various forms of communication

The video and print media for each research group offers a rich context to draw out these aspects of SHE and also provide a context for teaching a variety of scientific concepts, such as cells, tissues, organs and systems of the body, cells and cellular processes (e.g. mitosis) and genetics.

Structure of the Teaching Resource:

This resource is divided into sections nested under one of three broad themes: a different organ or system of the body (i.e. the heart, neural system, eye, kidney, blood and gut), cell reprograming and pluripotency, and stem cells and ethics. Each section consists of one or more Cases which epitomise the section theme and provide a rich context for teaching and learning.

To support teachers when creating a teaching sequence, links are made to the Australian Curriculum: Science F-10 (AC) and the Australian Curriculum: Senior Biology (ACS), Science as a Human Endeavour (SHE) and Science Understanding (SU) strands.

For an overview of the curriculum links, and where these links are aligned with the material in the Teaching Resource, please refer to the table in Appendix 1.

Structure of each Case:

For consistency, each Case follows a similar structure, beginning with an introduction to the research Group outlining the scientists featured in the video, where the Group is based and an introduction about the work of the scientists (highlighted in peach). There are direct links to videos and related articles.

A summary section for each Case follows the introduction and is organised under three subheadings:

- **What is the focus of the research group?**
- **What is the science?** (Either highlighted by the video or concepts associated with the work in the lab)
- **Where is the Science as a Human Endeavour?** (A list of various ways this video illustrates science as a human endeavour (SHE))

After the summary section, suggested teaching and learning activities and teacher notes specific to the Case are outlined in a colour-coded table. The table consists of the following columns:

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level /s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)

Column 1: Highlights the curriculum area of Science Understandings (SU) or Science as a Human Endeavour (SHE) from the Australian Curriculum: Science F-10 or the Australian Curriculum: Senior Secondary Biology

Column 2: The year level. This resource is aimed primarily at years 7-12

Column 3: Specific curriculum descriptors and codes from Australian Curriculum: Science F-10 or the Australian Curriculum: Senior Secondary Biology

Column 4: Notes for teachers. This column explains the key knowledge that links the content of the video/article and the curriculum descriptors. This information provides teachers with background context or elaboration of the ideas. Although this information is aimed at teachers, it could be used with students during a teaching program.

Column 5: Suggested teaching and learning activities. This column consists of specific questions, activities, links and resources for unpacking key ideas in column 4 and addressing the curriculum descriptor/s in column 3. Teachers can choose from a range of activities or mix and match to suit their teaching context and specific student needs.

Year level sections:
The body of the table is organised by year level for ease of locating age-appropriate activities. A key for the colour coding of specific year levels is as follows.

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s.			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

For each year level suggested questions, activities and external support links are provided. Although these suggested activities were created with certain year levels in mind, this does not exclude their use across other levels.

There are multiple possibilities for **differentiation**, such as drawing on ideas from a year level above to support learners who may benefit from extension activities or a year level or two below, to provide more simplified versions of an activity. Teachers are encouraged to pick and choose activities which best suit their current teaching program and the needs of their learners.

SHE and SU sections:
The table is further sectioned into activities related to Science as a Human Endeavour (SHE) and Science Understandings (SU). These sections can be distinguished by the headings in column 1 and different saturation of colour, with the SHE sections being lighter in tone and the SU sections being darker in tone.

The 'Red SHE' section
The section in Red is applicable for any year level and highlights important aspects of scientist's work, but do not necessarily align with a specific curriculum descriptor. These characteristics include the nature of workplace hierarchy within research groups, mentoring, career progression, job titles and pathways to becoming a scientist. The Red section also includes characteristics of scientist's work that are seldom spoken about, such as interest, passion, values, agency and the important role played by failure.

How to navigate the resource:

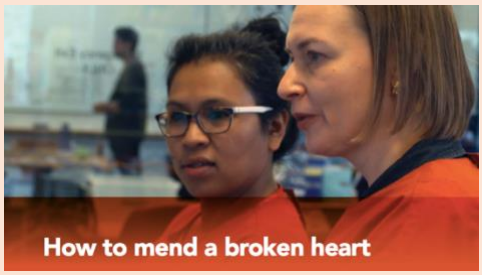
For ease of navigation, we recommend opening the Navigation Pane. This offers an overview of each of the Cases and can be used to quickly move throughout the resource and minimising scrolling. To open the Navigation Pane, select 'View' from the ribbon at the top and check the box next to 'Navigation Pane'.

1. The Heart

1.1 The Ramialison Group: How to mend a broken heart

Dr Mirana Ramialison and Dr Ekaterina Salimova
Australian Regenerative Medicine Institute

"Congenital heart disease affects 1 in 100 babies born in Australia. Babies with congenital heart disease are born with a heart defect." Dr Mirana Ramialison



"Congenital heart disease is the most common disorder that occurs at or before birth in newborns. The prevalence of congenital heart disease is understood to be approximately 8 – 10 cases per 1,000 live births. In Australia, there are approximately 300,000 registered births per year resulting 2,400 – 3,000 babies born each year with a form of congenital heart disease. Cumulatively, taking into consideration newborns through to adults living with congenital heart disease, this number could conceivably represent well over 65,000 Australians." https://www.heartkids.org.au/congenital-heart-disease

Accompanying Resources:
Refer to the Stem Cells Australia web page *'How to mend a broken heart,'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Ramialison Group research?

- The Ramialison Group are trying to understand how stem cells become particular cells. That is, what is the genomic (gene sequence on the DNA) 'message' (i.e. specific chemicals) that leads to the creation of specific stem cells?
- If the 'messages' that create specific cells are understood, a specific cell can be reverse engineered (i.e. to create a specific cell type in the laboratory).
- The Ramialison groups consists of biologists and computer engineers who are working to create custom designed software to produce a 3D map of every cell in the heart (this is called 3D Cardiomics). This map would provide genetic information about every different region of the adult heart and which genes are being expressed in each region.
- This group uses bioinformatics to better understand cardiac development and disease.

What is the science?

- Certain genes are responsible for creating cardiac cells in different regions of the heart. Due to the number of genes and the complexity of the heart as an organ, this knowledge is emerging.
- How are cardiac cell lines and tissues are created is not well understood.
- Some body tissues are regenerative (i.e. they can regenerate and repair) and some tissues are non-regenerative (i.e. cannot regenerate). Some cardiac cells/ tissues, such as the heart muscle is non-regenerative. It cannot self-repair after being damaged.

- Scientists use bioinformatics (complex and large biological data sets, such as genetic codes) to map cardiac development and disease.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Lab structure and pathways: Science laboratories consist of a diverse mix of people at different stages of their careers.
    - Nature of science: Science is interdisciplinary – in this case, biology and computer science.
    - Advances in scientific knowledge often rely on technological advances: In this case, the development of the program 3D Cardiomics.
    - Curiosity: Curiosity, fascination and dilemmas drive scientific endeavour. Ekaterina was fascinated that the heart has almost no regenerative capacity. That led her to think about how a broken heart can be mended. Mariana was curious about why some genes are only expressed in specific regions of the heart and not everywhere in the body. This curiosity led her to do a PhD.
    - Social, cultural and economic influences on scientific research and ethical aspects: in this case, babies born with congenital heart defects may not survive, or if they did survive, would require specialised care for the rest of their lives.
    - Models: The creation and use of models to simulate biological environments and processes (e.g. mapping the regions of the heart)
    - Opportunities exist for high school students to engage with work experience in research laboratories

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level /s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7-12	Structure of science laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, ECR, associate professor etc.)	• This video features Dr Mirana Ramialison and Dr Ekaterina Salimova. Dr Ramialison is Senior Research fellow at the Australian Regenerative Medicine Institute (ARMI). • The video also features Dr Ekaterina Salimova who is also a research fellow at ARMI. • In the Ramialison group there are biologists and computer scientists working together to create computerised models of the heart.	• Dr Ramialison is the 'head' of the Ramialison Lab – what might her role entail? • What is a 'research fellow'? You may like to refer to the Life as a Researcher Module on the Stem Cells Australia website. • What are some benefits of having biological scientists and computer scientists working in the same laboratory?
	7-12	Working like a scientist People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE136)	• Scientists often comment that they enjoy solving problems. Dr Ekaterina Salimova said that she was always fascinated by the heart as it has very little regenerative properties. From this curiosity she developed the question: "how can we mend a broken heart?"	• Dr Ekaterina Salimova talked about how the heart interested her because it cannot regenerate itself, yet other parts of the body (such as the skin) can. What fascinates you about the human body? Make a list of things about the human body which you find curious. Similar to Ekaterina, create 2 questions about the human body you would like to know more about. • Dr Mirana Ramialison spoke about doing a PhD. What is a PhD? What does it stand for? What might it involve? You may like to refer to the Life as a Researcher Module on the Stem Cells Australia website.

			• Dr Mirana Ramialison was fascinated by why some genes are expressed only in certain areas of the heart. This led her to undertake a PhD.	
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226 AND Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135)	• The Ramialison lab has developed the computer software called 3D Cardiomics. This software enables other scientists to view how genes are expressed in the heart. • The 3D Cardiomics website uses a computer-based model to make a representation of the heart. Models are used in science to help visualise something in a way that makes it easier to understand. Scientists benefit from the 3D model as it can help them understand the role of different genes in different areas of the heart. This knowledge would influence and guide the research of other scientists. Scientists share and use the knowledge generated by each other to build on, rather than 'reinventing the wheel'. • This video offers a springboard to talk about how genes and genetic conditions are officially named to ensure scientists from around the globe can benefit	• Go to the 3D Cardiomics website. • Although this website may be seem complicated for students in years 7 and 8, the nature of the model is worth exploring. • Just under the heading on the loading page, enter the gene "Myh7" into the search bar (located to the left of the "Expand" and "Reset" buttons) • The model of the heart will change to multiple colours. • Click on the rainbow button at the top left to show the colour key (i.e. blue represents low gene expression in that area of the heart to red which represents high gene expression in that region). For students who might be colour blind, click the key with the eye (beside the rainbow key) to change to a narrower range of colours. • On the right side of the screen, a list of similar genes will appear. Students can click on these genes to see where in the heart the gene is expressed. • This is an opportunity to highlight to students in years 7 and 8 that our cells contain our genetic information in the form of DNA. Sections of DNA code for genes, which are responsible for various essential bodily functions, such as making cells and making proteins. • The genes have what may seem to be unusual names – e.g. Myh7, Ulk3, Firre. The names of genes are purposeful and have some meaning related to that gene and what it does. Genetic conditions are also given official names by a committee. For more information see: • https://ghr.nlm.nih.gov/primer/mutationsanddisorders/naming

			from each other's' scientific research. Having multiple names for the same gene would cause confusion and slow down scientific progress. • Naming conventions in science: There is an opportunity to compare the naming of genes to the naming of living things or the naming of stars, for example. Creating commonly agreed names for things enables scientific advancement as it ensures people are talking about the same thing and can therefore share new knowledge, even if they speak different languages. • The Ramialison group work collaboratively with other scientists who are also interested in understanding the genes responsible for creating other stem cells and cell types around the body. This sharing of expertise is an example of how scientists work across disciplines to share knowledge and expertise to advance scientific endeavour.	• HUGO Gene Nomenclature Committee (i.e. who determines the names for genes) (HGNC) https://www.genenames.org/ Naming conventions in science: • Developing universal names for genes means that scientists can be sure they are talking about the same genes when communicating and planning their research. • This type of nomenclature can be compared to: Binomial nomenclature (in botany) or binomial nomenclature (in zoology). Carl Linnaeus (1707-1778) first suggested the binomial naming system for living things (i.e. the scientific name of living things has a common format - Genus name and species name, e.g. *Macropus rufus* or red kangaroo). From the early 19th century, the naming of species was more closely governed and has moved to nomenclature codes (e.g. ICZN). See for example animal nomenclature https://www.iczn.org/the-code/the-international-code-of-zoological-nomenclature/the-code-online/ or algae, fungi and plan nomenclature: https://www.iapt-taxon.org/nomen/main.php • The naming of celestial bodies is governed by the International Astronomical Union (IAU) (Est in 1919) see: https://www.iau.org/ • Use a Venn diagram or other graphic organisers to compare different types of naming conventions – e.g. naming genes, naming living things, naming stars or celestial bodies etc. • How might the work of the Ramialison group be of benefit to other scientists? • Which other areas of science might benefit from the work of the Ramialison group?

	9	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157) Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158)	• The 3D Cardiomics website uses a computer-based model to make a representation of the heart. Models are used in science to help visualise something abstract, like gene expression. • Combining biology and computer science to create the 3D Cardiomics software is an example of bioinformatics. • There is an opportunity here to draw attention to the naming of genes and genetic disorders.	• Go to the 3D Cardiomics website. • See section above about navigating the 3D Cardiomics website. • What is bioinformatics? How is 3D Cardiomics an example of this? • To explore more cardiac specific genes and proteins see the Human Protein Atlas, heart specific proteome: https://www.proteinatlas.org/humanproteome/tissue/heart • Enter a sample of these genes into the 3D Cardiomics website and see where these genes are expressed in the heart. • Scientific naming conventions: see section above relating to the naming of genes and comparison to the naming of living things and the naming of celestial bodies. Create a Venn diagram to compare the naming conventions of living things, genes and/or celestial bodies. Explain some of the similarities and differences between the different naming systems.
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research (ACSHE228)	• "In Australia, there are approximately 300,000 registered births per year resulting 2,400 – 3,000 babies born each year with a form of congenital heart disease. Cumulatively, taking into consideration newborns through to adults living with congenital heart disease, this number could conceivably represent well over 65,000 Australians." (HeartKids)	• The HeartKids organisation raises money to support research into causes, treatment and management of congenital heart disease. See https://www.heartkids.org.au/congenital-heart-disease • How many people are impacted by congenital heart disease in Australia? • What impact can congenital heart disease have on people's everyday lives? • How might you raise public awareness of congenital heart disease? What elements of the disease would you pay attention to and why? • The HeartKids organisation is interested in raising money for research into congenital heart disease. Outline two areas of research and how it will support people in the community.
Australian Curriculum:	8	Multi-cellular organisms contain systems of organs carrying out	• The heart consists of different groups of cells organised into tissues.	• What is the difference between regenerative and non-regenerative tissue?

Science – Science understanding (SU)		specialised functions that enable them to survive and reproduce (ACSSU150)	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged.	• There are many different kinds of congenital heart abnormalities. Pick one example and find out more about it: https://www.heartkids.org.au/congenital-heart-disease • What are the short- and long-term impacts for people living with the heart abnormality you selected?
	10	Transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)	• Genes determine which stem cell a cell will become. The Ramialison lab are trying to find out which genes are responsible for creating which stem cells. If this is understood, they can reverse engineer cells to become other types of cardiac cells with a view to repair damaged heart tissue.	• Why might the scientists in the Ramialison lab be focusing on gene expression in the heart? Explain your answer in relation to congenital heart disease. • What might 'reverse engineering' mean? How would reverse engineering stem cells be of interest to the Ramialison group?
Australian Curriculum: Senior Biology – Science as a Human Endeavour (SHE)	Units 1-4	Working like a scientist	• See section above	• See section above
		Structure of science laboratories and staff	• See section above	• See section above
	Unit 2, year 11 AND Unit 3 and 4	The role of models and modelling in science: Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038) Scientific knowledge can enable scientists to offer reliable explanations and make	• The new 3D Cardiomics website offers a **model** for visualising gene expression in the heart. • The 3D Cardiomics website is freely available to benefit scientific advancement. • Creation of the website was a collaboration between many scientists from the Monash University Biomedicine Discovery Institute and the Australian Regenerative Medicine Institute. Their names and the links to the	• See sections above related to the 3D Cardiomics website. • Extend on these by finding out more about the genes and their functions by navigating to the Uniprot website: https://www.uniprot.org/ • In the search bar at the top, type in the gene name (e.g. MYH7, XPO6, UBA7. If multiple results for the searched gene are listed, pick the human option by clicking on 'Human' under Popular Organisms in the sidebar). • NB the information listed on this website can be quite complex. The point of this exercise is to help senior biology students realise the complexity of the genes, the specificity of the gene functions, to appreciate that the gene product (i.e. protein) may be part of a complex pathway and the chromosomal location of the gene. They do not need to understand all the information on the site, but they may see words they are familiar with (such as

		reliable predictions (ACSBL042) ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068) International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)	organisations are located on the website.	enzyme, protein, pathway, ATP, AMP, cardiac, taxonomic lineage etc). Ask students to identify words they might know and what the information might mean. • Another feature of the Uniport is the section "subcellular location". Scroll down to this section which has an image of where the gene is most active in the cell.
		Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL037)	• Peer review: The Uniprot website highlight peer-reviewed citations alongside most of the information on the site. This highlights the importance of peer review for the scientific community and highlights the prevalence of the peer review process for scientific advancement. (See above.)	• Continued from above - on the Uniprot website there are yellow and blue call out icons which highlight publications and sources for information included on each page. This is a kind of referencing convention. Why are these citations important? Hover over several yellow citations. What do you notice about the citations? List some similarities and differences. What elements of science as a human endeavour are apparent: in the citations? On this site more generally?

			• The citations are either externally peer reviewed publications or electronic links. The peer-reviewed sources often have complex and long titles and a number of authors. This is a great opportunity to highlight the collaborative nature of scientific work and the specificity of the work; many groups of people working on highly specialised science, but all contributing to a shared knowledge bank.	• In the Unitprot website (see above) there are citations to publications. What are these citations? What do they refer to? What is the purpose of these citations? • The 3D Cardiomics software developed by the Ramialison group was developed by multiple scientists using funding from different sources. Navigate to the website and locate the names of the collaborators and the funding bodies. • The 3D Cardiomics website is publicly available to other scientists. What is the value in the group sharing this modelling software with others?
Senior Biology Australian Curriculum – Science Understanding content	Unit 2	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055) And In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged. • The heart consists of different groups of cells organised into tissues. • Specific genes give rise to stem cells which create specialised tissues in the heart. • Understanding how to make specific cardiac stem cells may enable reverse engineering of cells to repair cardiac cells and tissues. • If scientists are successful in developing this technology, there would be applications for the treatment of congenital	• What are pluripotent stem cells and how are they similar and different to tissue-specific stem cells? • See the Stem Cells Australia web page 'What are stem cells' for more information • Why is the Ramialison group interested in stem cells? • Draw a flow diagram or cartoon strip to explain how a cardiac cell might be reverse engineered into a stem cell to treat a heart tissue abnormality. • Use a Venn diagram to compare and contrast cardiac muscle tissue and leg muscle tissue. • Use your knowledge of the heart to explain at least 3 different kinds of heart abnormalities that would impact on the heart functioning normally.

		levels (for example, the structure and function of capillaries) (ACSBL058)	heart defects and heart attack damage.	
	Unit 3	Unit 3 Example in context: Bioinformatics	• The 3D Cardiomics software is an example of bioinformatics	• What is bioinformatics? How is the 3D Cardiomics website (see above) an example of this? • Examples of bioinformatics: Use the examples of activities related to the 3D Cardiomics website, and related websites, from above (e.g. Human protein atlas). See also more advanced associated activities (i.e. Uniprot website add on below).
		Genes include 'coding' and 'non-coding' DNA, and many genes contain information for protein production (ACSBL078) The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment (ACSBL081) Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth (ACSBL083)	• Genes determine which cell a stem cell will become. The Ramialison lab are trying to find out which genes are responsible for creating heart stem cells. If this pathway is better understood, they can reverse engineer cells to become other types of cardiac cells with a view to repair damaged heart tissue.	• Why might the scientists in the Ramialison lab be focusing on gene expression in the heart? Explain your answer in relation to congenital heart disease. • What might 'reverse engineering' mean? How would reverse engineering stem cells be of interest to the Ramialison group?

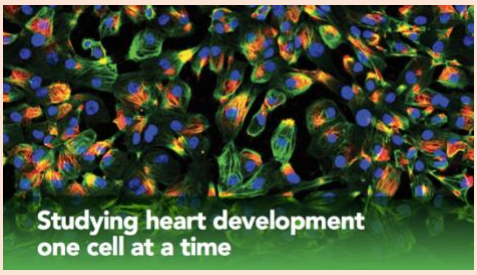
1.2 The Powell Group: Studying heart development one cell at a time

Associate Professor Joseph Powell and Dr Drew Neavin

Garvan-Weizmann Centre for Cellular Genomics and the University of New South Wales

Once an adult heart is damaged, it has no ability to heal itself. "We think the answers to heart repair are likely to lie in understanding heart development." Dr Nathan Palpant

"In the average lifespan of an individual will suffer on average from eight different diseases". Associate Professor Joseph Powell



Accompanying Resources:
Refer to the Stem Cells Australia web page *'Studying heart development once cell at a time,'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Powell Group research?

- Use of stem cells as a way of modelling complex diseases.
- Complex diseases have a large number of genetic factors that contribute to an individual's risk. The Powell Group is interested in knowing how genetic factors act in different cell types during different stages of cell development (i.e., from immature or pluripotent state to a mature state).
- The Powell group works very closely with the Palpant Group and the Pébay Group.
- Due to the increased chance of people developing an array of diseases over a life span, the Powell Group is motivated to understand gene expression in diseases to ultimately solve and cure different diseases.

What is the science?

- Complex diseases have a large number of genetic factors. Genes act differently in different cell types during different stages of cell development (i.e., from immature or pluripotent state to a mature state).
- Development of tissues and cell types can be mimicked and modelled using stem cells and stem cell technologies.
- The Garvan-Weizmann Centre houses a wide variety of technology that allows isolation, curation, culture and differentiation of stem cells and generate genomic profiles on tens of thousands of stem cells and differentiated cells.
- In 2018 the Palpant and Powell Groups found a gene (HOPX) which plays a crucial role in controlling heart growth.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Collaboration: Collaboration is essential for scientific endeavour and advancement. The Powell and Palpant groups collaborate closely. Palpant's lab focuses on cardiovascular disease while Powell's group works on statistical genetics and single-gene sequencing. The research would not be possible if the two labs did not work together.
    - Scientific endeavour takes time and involves the work of many people: Scientists use knowledge created by scientists in the past and build on that knowledge over time. Often, previous understandings are refined and changed as new evidence arises.
    - Nature of science: Discoveries and breakthroughs in science create new knowledge. Scientific knowledge is tentative, yet durable.
    - Interdisciplinary nature of scientific endeavour: The Powell lab can be defined as a single cell and computational genomics lab. They work with large data sets. This is called bioinformatics.
    - Advances in scientific knowledge often rely on technological advances: Advances in one field can influence other areas of science, technology and engineering.
    - Social, cultural and economic influences on scientific research and ethical aspects: In this case, the moral imperative of better understanding the nature of gene expression and understanding how individual cells work within a body system to better understand how to treat diseases.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Working like a scientist involves asking questions.	• Being a scientist involves asking questions, collaborating, and being enthusiastic and passionate about what you do. • Science involves working collaboratively with others, engaging with intellectual challenges and thinking about the application of research findings. • Scientific research usually starts with an issue that requires the generation of new knowledge. Scientific research is often a long-term endeavour, which requires collaboration between many people and funding. • This video and others in the series offer the opportunity to explore the complexities of scientific endeavour, such as starting with an issue, identifying the existing knowledge to guide generation of new knowledge and the application of new findings. NB The Powell Group and Palpant group resources are closely linked.	• In the video, Associate Professor Joseph Powell said; “We were always looking out for, and I think as a community wanting to engage with people who are enthusiastic and passionate about not only the intellectual challenges but also the application of what they can achieve with research and through thinking deeply about a problem and working to solve that problem.” • What does Joseph mean by this statement? • What does this statement say about the value of collaboration in science? What are important aspects of collaborative partnerships? • How might problems for research be identified? • In the Palpant Group, Dr Nathan Palpant talks about the importance of questioning. How might questioning fit into Joseph’s statement above? • How long do you think it might it take to ‘solve a problem’ in scientific research? Do you think it would be a short term (days to weeks) or long-term endeavour? Do you think it would be straightforward? What might be some complexities of scientific research?
	8	Scientific knowledge has changed peoples’	• In the past, little was known about how the heart developed in an embryo - from a	• The Palpant and Powell groups defined a new gene, HOPX.

Australian Curriculum: Science - Science as a Human endeavour (SHE)		understanding of the world and is refined as new evidence becomes available ACSHE134	single cell to a functioning organ. As the heart muscle consists of non-regenerative cells, heart tissue is unable to be repaired after injury. This has led scientists to investigate ways of helping people who have suffered a heart attack or heart tissue damage. • The Powell and Palpant teams defined a new gene - HOPX. This is an opportunity to discuss how new genes are defined and named AND how new knowledge develops through the work of many groups over time. Today's scientists are using the work of yesterday's scientists to expand understandings and develop new technologies. As a consequence of this process, knowledge and technology advances, which changes our understandings as new evidence becomes available. • NB – scientific knowledge does not already exist and therefore cannot be 'discovered'. Humans develop scientific understandings about the world using man-made conventions, vocabulary and technology. Therefore, when talking about new 'discoveries' or breakthroughs, it is helpful to remind students that this is new knowledge that scientists have developed and that it could be refined and change as new evidence becomes available in the future.	• This is an opportunity to highlight to students in year 7 and 8 that our cells contain our genetic information in the form of DNA. Sections of DNA code for genes, which are responsible for various essential bodily functions, such as making cells and making proteins. • Genes have unusual names. Explore how genes are named when scientists locate them, sequence them and learn more about how the gene functions and what role it plays in development. • HUGO Gene Nomenclature Committee (i.e. who determines the names for genes) (HGNC) https://www.genenames.org/ • Developing universal names for genes means that scientists can be sure they are talking about the same genes when communicating and planning their research. • In the article 'Studying heart development one cell at a time', what are two new understandings the Palpant and Powell groups have made? Why are these new understandings valuable? • Compare the new discoveries made by the Powell and Palpant Groups to the Porrello Group and the Harvey Group. What new discoveries have the teams made and how did they advance knowledge of stem cells or of the heart?
		Scientific knowledge can develop through	• The Palpant and Powell groups work closely together. Each group has particular	• Referring to the video and the article 'Studying heart development one cell at a time', what kinds of collaborations

		collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226	expertise and knowledge. By combining these skills and knowledge, the two groups can conduct scientific research that is more complex than they could otherwise have done alone. This is a benefit of working collaboratively in science.	has Associate Professor Powell developed and why have these connections been important? • How might you apply these characteristics the next time you have to work collaboratively with your peers?
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	• The Powell group is taking advantage of some recent advances in technology, in particular the capacity to generate genetic information for individual cells to large numbers of cells. • They are also using technology which makes their work with stem cells more efficient. They are able to isolate, grow and differentiate stem cells and create genetic profiles of these cells, then use supercomputers to analyse large data sets of genetic information. • Although the science of genetics is advanced for the year 8 level, the development of technology is a feature here. The development of equipment, such as machines which can generate genetic information, has application to a number of areas within scientific research and in a clinical setting. It is not restricted to research on heart tissue. The capacity to generate large genetic data sets in a short space of time has applications for areas such as clinical genetic screening and forensics. This is a great opportunity to show how technology can impact other areas.	• In the video, Joseph says "There's been some really phenomenal breakthroughs in technology in the last few years - so being able to generate genetic or genomic information for an individual cell then to do that for very large numbers of cells at the same time. And so, the Garvan-Weizmann Centre houses a wide variety of technology that allows us to isolate, curate, culture and differentiate stem cells, generate these genomic profiles on tens of thousands of stem cells and differentiated cells at the same time, take that digital readout and then feed it into supercomputers and allow analysts like myself and my team members to ask key critical questions with that type of data." • Based on what Joseph has said, how have new advances in technology assisted his research? • Explore some of the landmark advances in the field of genetic testing. Navigate to the following site (NB the main aspect of interest is Figure 1 – the rest of the article is quite heavy for year 7 and 8) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4385642/ There may be some terms that need further investigation.

	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192 See also ACSHE135 – advances may impact on other areas of society and may involve ethical considerations.	• See ACSHE135 above – in year 9 and 10, the situation of genetic testing can be used as a rich context from which to explore the nature of genetic data and why the data sets would be so large. • Also, there is impact from advances in genetic testing on society, in particular the speed, efficiency and cost effectiveness of new technologies. There are benefits for faster and more efficient testing techniques, but there are also issues and challenges, such as equity of access, patenting, management and analyse large data sets, digital computing capacity not keeping up, data storage, privacy of genetic/health information, access to genetic information, etc. • Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life. Use the context of the team developing the only lab in Australia with a single-gene sequencing machine in terms of the value of this machine for the Palpant and Powell groups' research.	• "When we began this project in 2016, we were the only lab in Australia, and the third in the world, to have a high-throughput single-cell sequencing machine," says Joseph • Use this context to explore what a single-cell sequencing machine is – in conjunction with ACSSU184 below. • Evolution of genetic testing - "Evolution of Genetic Techniques: Past, Present, and Beyond" https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4385642/ • Choose three big advances in the understanding of genetic testing. Explain what the advance was and why it was significant. How did other scientists later build on that new discovery/ technology? What new advances did this discovery pave the way for? • More on genetic testing in clinical settings - What are the different modes of genetic testing available. How do they work? What information do the tests yield? For assistance, see: https://ghr.nlm.nih.gov/primer/testing/uses • How has the nature of genetic testing changed in the last 50 years? • The rise in genetic testing has led to rapid advances in speed and efficient with a reduction in cost. Read the following article "The Past, Present and Future of Genome Sequencing": https://www.labiotech.eu/features/genome-sequencing-review-projects/ • Explore the cultural and social impact of such rapid advancement. Consider, for example, privacy of data, funding and sharing of genetic data. • Explore some of the different issues, for example: What might be some benefits and limitations of government funded projects and privately funded projects? How should we pay for genetic testing? Who owns the genetic materials

				once it has been collected? How is the genetic data being used? Are there cultural biases? Is it possible to sell genome data? What are the implications of this? How can this be monitored?
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research AC SHE230	• "Cardiovascular diseases (CVD) are the number 1 cause of death globally: more people die annually from CVD than from any other cause. • An estimated 17.9 million people died from CVD in 2016, representing 31% of all global deaths. Of these deaths, 85% are due to heart attack and stroke." • Use the context of CVD to simulate discussion about how values and needs of society influence the focus of research. Consider the role of the World Health Organisation (WHO) to see how nations collaborate to share knowledge and resources to improve the health of people globally, especially in nations experiencing disadvantage. Compare how fortunate we are in Australia to have a robust health care system. • Consider the role of the NHMRC (National Health and Medical Research Council), a major research funding body in Australia. Exploring the amount of research being funded in different areas can give an indication of value and need. Students can consider that different parties have different values and different vested interests. This can influence how people	• Find out more about CVD and why it is the leading cause of death globally. Navigate to the WHO website. This global organisation advocates for "better, healthier people all over the world". The core function of WHO is to "direct and coordinate international health through collaboration". The WHO has more than 7000 people working in 150 county offices around the world. • Looking at the factsheet: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) • What do you notice about the incidence of CVD around the world? Which countries or cultures are at higher risk than others? Why might this be the case? • The NHMRC governs the allocation of research funding in Australia. Other countries have similar funding bodies. Explore the distribution of funding over the last 10 years https://www.nhmrc.gov.au/funding/data-research/research-funding-statistics-and-data#download • What do you notice? • Which areas of research tend to be funded more than others? Why might this be the case? What might this say about what is valued? • How does CVD funding compare to funding in other areas?

			work and where money is spent. Science is very much value laden and is influenced by the needs and values of society.	
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149)	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. • Damage due to heart attack or stroke can damage the heart tissue permanently, making the muscle less flexible and strong. • The heart consists of different groups of cells organised into tissues. • Heart disease can impact people's health and cause short- and long-term health issues.	• What is the difference between regenerative and non-regenerative tissue? • There are many different kinds of congenital heart abnormalities. Pick one example and find out more about it: https://www.heartkids.org.au/congenital-heart-disease • What are the short- and long-term impacts for people living with the heart abnormality you selected?
	9 & 10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment ACSSU175 And Transmission of heritable characteristics from one generation to the next involves DNA and genes ACSSU184	• This video offers the opportunity to consider the nature of the heart in terms of specialised tissue (which is part of a complex body system) and the role genes play in developing that tissue. These two science understanding (SU) objectives can be explored together. • The heart consists of different groups of cells organised into tissues. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. That energy comes from cellular respiration in the mitochondria. Without this energy the heart muscle cells would not contract. • Heart tissue consists of non-regenerative cells. That is, once created, the cells do not	• Drawing on the article 'Studying heart development one cell at a time', explain broadly how heart muscle is formed. • What role do genes play in this process? • Why is the Palpant Group focusing on gene expression in the heart? Explain your answer in relation to congenital heart disease. • "In 2018 the pair found that a gene called HOPX plays a crucial role in controlling heart growth." Find out more about the gene HOPX and what it does (see below). • Why might this genetic discovery be important for the work of the Palpant and Powell labs? • What might be the long-term benefits of the work of these labs? • See also ACSHE158/192 above – in the context of the video and using your knowledge of genetics, explain why a single gene sequencing machine might be a useful technology.

			regenerate if damaged during heart attack or stroke. • In the video, Dr Neavin said the lab was "interested in how genetics interfaces with complex disease and trying to understand how genetics relates to health and disease." The body is made of millions of cells. Different cell types play different roles within the body. The Powell lab is interested in understanding how a single cell works within a larger system, to better understand how disease might interfere with the function of the system.	• Why might genetic data sets be so large? What do the data sets consist of? • Use the NCBI website to find out more about the HOPX gene - https://www.ncbi.nlm.nih.gov/gene/84525 • On which chromosome is HOPX located? • The information on the page is complex and can seem confusing, but it provides a wealth of different information for scientists. When you are navigating around the NCBI page for the HOPX gene, can you identify any words you have heard or know? • What do you think the information might relate to?
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	Unit 2	Working like a scientist	• Resources from the Red section above and other videos can be used to highlight the nature of how scientists work, such as a desire to know more about disease to help people, passion and enthusiasm for the work or the role of collaborating and questioning in science. In investigative science (i.e. where scientists plan experiments) questioning occurs at the beginning, during and end of the process. As scientific investigation occurs, more questions are raised. • In non-experimental knowledge development, questioning might come after an event or stimulus – such as Alexander Fleming questioning why the bacteria on his discarded agar plates was receding in certain sections.	• See resources in the section above to discuss what is involved in working as a scientist, in particular the role of empathy, collaboration and asking questions. • In the video, Joseph says; "We were always looking out for and I think as a community wanting to engage with people are enthusiastic and passionate about not only the intellectual challenges but also the application of what they can achieve with research and through thinking deeply about a problem and working to solve that problem." What does he mean by this statement? What does he imply about the nature of scientific endeavour? • Contrast the role of questions in scientific endeavour with the other ways scientific knowledge is generated, such as the role of creativity and imagination, (see the Parish Group) or the important role of failure (see the Merson Group).
	Unit 2	Development of complex models	• Use the context of the video to explore how the group is using stem cells to model	• In the video Joseph says "We don't know how they act in different cell types and we don't know how they act as cells

		and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	complex disease. These diseases are described as 'complex' because a number of genetic factors are involved. • Genes are large sections of DNA which consist of different combinations and lengths of base pairs (i.e. A, T, C, G). • How genes are expressed in different stages of development is not well understood. The genome in cells of the same organism is the same, but the expression can be different. Models can be used to better understand gene expression at a cellular level across different times and stages of cell development and how genes might vary. • Stem cells can enable controlled tissue mimicry in a lab environment to create model tissues for exploration.	develop from immature or pluripotent state to a mature state. And so, the kind of key questions that we're interested in is identifying those genetic variants and how they act at a cellular level across cell development time courses. So, to do this in you know in a human system would be extremely difficult because you know for obvious reasons. But we can really mimic and model the development of tissues and cell types using stem cells and stem cell technologies." • What does Joseph mean by the human system being extremely difficult? • What does he mean by 'mimic'? • How are pluripotent and mature cells similar and different? How might the genome be different? How might gene expression be different in these two types of cells? • How could stem cells support the Powell Group research?
	Unit 3	ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068) AND International collaboration is often required when	• The Powell Group work with very large genetic data sets (i.e. statistical genomics). The Powell Group works closely with the Palpant Group (who are cell biologists who specialise in cardiovascular disease). The collaboration could be considered interdisciplinary as the respective groups have specific expertise. (See also unit 3 SU below) • The collaboration with the Palpant Group offers the context through which the Powell Group can focus their genetic modelling. Working together, the labs can learn more about the nature of the genome during specific diseases.	• Joseph says "Probably one of the most rewarding areas of research for me since starting a lab is building strong collaborations with molecular stem cell labs and that's allowed us to address questions that would ordinarily be impossible for us to consider. And similarly for those labs, we arm them with the mathematical and computational tools to be able to drive our research forward." • The Powell Group work with large genomic data sets. They work closely with the Palpant Group who are cell biologists and specialise in stem cell differentiation. The work is very interdisciplinary. What qualities and skills might each of these discipline experts bring to the work of the Palpant and Powell groups? • Examine your list and consider if there are some generic skills which are associated with each group? Where might there be

		investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)		an opportunity for you to develop those kinds of skills in your schooling environment?
Senior Biology Australian Curriculum – Science Understanding (SU)	Unit 3	Genes include 'coding' and 'non-coding' DNA, and many genes contain information for protein production (ACSBL078) And DNA sequencing enables mapping of species genomes; DNA profiling identifies the unique genetic makeup of individuals (ACSBL086)	• Use this video and article as a context to explore the use of bioinformatics and use the HPOX gene as a context for exploring the nature of genes. • The Powell lab works with large genetic data sets. The HOPX gene is present in all cells. What role might this gene play in the heart specifically?	• Role of genes: Drawing on the article 'Studying heart development one cell at a time', explain broadly how heart muscle is formed. • What role do genes play in this process of heart tissue development? • Dr Drew Neavin says "we're really interested in how genetics interfaces with complex disease and trying to understand how genetics relates to health and disease." What does she mean by this statement? How might disease influence the genome? Use the video transcript to assist you. • In the video Joseph says "And so the Garvan-Weizmann Centre houses a wide variety of technology that allows us to isolate, curate, culture and differentiate stem cells, generate these genomic profiles on tens of thousands of stem cells and differentiated cells at the same time, take that digital readout and then feed it into supercomputers and allow analysts like myself and my team members to ask key critical questions with that type of data." • What is a genetic profile? • What kinds of information might the bioinformaticians be looking for? • What would the data sets consist of? • What kinds of questions might they be able to ask? • Explore the nature of the gene the group discovered (HOPX) via the Uniprot website: https://www.uniprot.org/ Where else in the body is HOPX expressed?

				• NB the information listed on this website can be quite complex. The point of this exercise is to help senior biology students realise the complexity of the genes, the specificity of the gene functions, to appreciate that the gene product (i.e. protein) may be part of a complex pathway and the chromosomal location of the gene. They do not need to understand all the information on the site, but they may see words they are familiar with (such as enzyme, protein, pathway, ATP, AMP, cardiac, taxonomic lineage etc). Ask students to identify words they might know and what the information might mean. • Another feature of the Uniport is the section “subcellular location”. Scroll down to this section which has an image of where the gene is most active in the cell. • On the Uniprot website there are yellow and blue call out icons which highlight publications and sources for information included on each page. This is a kind of referencing convention. Why are these citations important? Hover over several yellow citations. What do you notice about the citations? List some similarities and differences. What elements of science as a human endeavour are apparent: in the citations on this site more generally?

1.3 The Porrello Group: Fixing hearts by finding out what makes them tick

Associate Professor Enzo Porrello

Murdoch Children's Research Institute

Heart disease is Australia's leading cause of death. Each year, about 54,000 Australians suffer a heart attack, with an average of 23 deaths per day.

"We're trying to understand how the heart works in order to fix it, the same way a car mechanic needs to understand how a car engine works in order to fix it." Associate Professor James Hudson

Accompanying Resources:
Refer to the Stem Cells Australia web page *'Fixing hearts by finding out what makes them tick'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Porrello Group research?

- Heart tissue injury and damage is permanent. The Porrello Group is interested engineering better heart tissue and developing better therapeutic drugs for heart failure and regeneration.
- The lab also makes tissues for drug screening, 'artificial pumps' for children with congenital heart conditions, and develops drugs to simulate heart repair or improve function and broadly improve our understanding of the heart and how it works.

What is the science?

- Beating human heart tissue can be grown in a lab.
- Stem cells could be bioengineered into heart tissue for repair of heart defects in children.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Collaboration: Collaboration is essential for scientific endeavour and advancement – the Porrello Group works closely with Associate Professor James Hudson who works at QIMR Berghofer. Porrello's lab focuses on cardiac physiology and regenerative therapies for children and adults with heart disease while Hudson's group specialises in bioengineering. The research breakthroughs the teams have made would not be possible if the two labs did not work together.
    - Nature of science: Science involves asking questions and the need to work with other people to stimulate the formation of new questions and lines of research.

- Scientific knowledge is tentative, yet durable. Knowledge changes as new evidence becomes available. In this case, new evidence that heart tissue might recover from heart attack in newborns.
- Advances in scientific knowledge often rely on technological advances. Advances in one field can influence other areas of science, technology and engineering. In this case, the future prospect of bioengineering cells and tissues for injury repair.
- Values: Values influence scientific research. Heart disease is Australia's leading cause of death, thus the research group aims to find new ways to develop treatments and improve drug screening.
- Social, cultural and economic influences on scientific research and ethical aspects: In this case, the moral imperative of better understanding the nature of cardiovascular disease, especially in children, in order to learn how to 'mend a broken heart'.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 - 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7-12	Working like a scientist involves asking questions, working as a team and collaborating with other people.	• In the Video Associate Professor Enzo Porrello highlights that being a scientist involves working in an environment that is inclusive, nurtures discussion to progress the work is, and open to sharing information and collaboration. • Enzo also emphasises the role of asking interesting questions – which happens when you work with other people.	• In the video, Associate Professor Enzo Porrello says "We're a highly collaborative lab both within the lab, we really try and foster an environment that's very open and where postdocs and students are working hand in hand and sharing information and talking to each other to try and progress their work. We also collaborate outside of our lab. What do you know about the pathway to a career in researcher? What is a postdoc? You may like to refer to the Life as a Researcher Module on the Stem Cells Australia website. • Many of the scientists in this video series have highlighted the value of having students (i.e. Honours, Masters and PhD students) as part of the lab team. List some qualities you think students would bring to the team.
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• "There are a small number of case reports of human newborns recovering from heart attacks, which is very intriguing," says Enzo. • The article features Enzo talking about new knowledge which has resulted from research on newborn heart tissue. New evidence has become available related to the ways in which newborn's hearts recover from heart attacks. This new evidence will influence the current understanding about the resilience of newborn heart tissue.	• On the web page article 'Fixing hearts by finding out what makes them tick' - What is a new breakthrough that Enzo talks about? Why is this a new finding? How is it different to the previous understanding? • This is an example of how scientific knowledge can change when new evidence becomes available. • Were the previous scientists who suggested that *heart tissue cannot recover from damage* 'wrong'? Is there a better way to explain what has happened rather than saying they were 'wrong'? What words might be more suitable? Do you think this is an isolated case, or does scientific knowledge change?

		Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures (ACSHE223/226)	• Associate Professor Enzo Porrello and Associate Professor James Hudson worked together to "create beating human heart tissue for cardiac research in the lab and developed patented technology to do it at scale". • Enzo and James have knowledge and skills which is unique but complimentary. This is an opportunity to illustrate how collaboration often involves people coming together to share expertise and skills to advance a common interest or goal.	• Referring to the web page: *'Fixing hearts by finding out what makes them tick'* , Enzo describes a strong collaborative relationship with James Hudson. Why do you think this collaboration is so strong and successful? • Can you identify a strong collaborative relationship in your life? Is there someone you work really well with and can chat easily to? What does that feel like? Why do you think you get along so well? What are some characteristics of your behaviours that makes it an effective working relationship? • Compare the Porrello and Hudson collaboration to the collaboration between the Harvey and Graham labs (See the Harvey group), or the collaborations of the Palpant and Powell groups (see the Palpant Group). How are the collaborations similar or different? What are some common characteristics of collaborative relationships?
		Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120/135)	• Bioengineering involves the creation of body parts in a laboratory environment. This video offers an opportunity to explore this technology and the ethical considerations that it might arise. • The teams have been making bioengineered tissue from stem cells. There is an opportunity to compare this model to other forms of bioengineering.	• "There have been huge technological advances particularly in the last sort of five years or so." What are some of the advances to which Enzo is referring? Use the video and the article to assist you. How might technology and engineering play a role in these developments? • The article raises the concept of bioengineering. The term bioengineering consists of the words 'bio' and 'engineering'. What are the characteristics of each of these disciplines? What does each discipline bring to this research? • In this context, what might Enzo mean by bioengineering heart tissue? • Find out more about other kinds of bioengineering: https://www.pbslearningmedia.org/resource/nsn11.sci.life.stru.bodyparts/bioengineering-body-parts/ • Create a PMI (Plus, minus, interesting) chart to consider the benefits and limitations of bioengineering heart tissue.
	9 & 10	Advances in scientific understanding often rely on technological	• Advances in technology and science have led to greater understanding of the heart, and how it develops.	• "There have been huge technological advances particularly in the last sort of five years or so." What are some of the advances to which Enzo is referring? Use the video and the

		advances and are often linked to scientific discoveries (ACSHE158/192)	• Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life.	article to assist you. How might technology and engineering play a role in these developments? • Explain how bioengineering heart tissue might offer hope for people with heart disease or damage?
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research (ACSHE228/230)	• Congenital heart disease is the most common congenital disorder in newborns. Students can explore the nature of the different types of heart diseases. • To apply understanding of different values and perspectives, students can construct arguments for why research may or may not (should or should not be) be invested into congenital heart disease.	• "Congenital heart disease is the most common congenital disorder in newborns. The birth rate prevalence of congenital heart disease is understood to be approximately 8 – 10 cases per 1,000 live births." https://www.heartkids.org.au/congenital-heart-disease • How is Heart Kids trying to raise awareness of congenital heart disease in newborns? What kind of impact do you think this might be having? • Find out more about cardiovascular disease and why it is the leading cause of death globally. Navigate to the World Health Organization (WHO) website. This global organisation advocates for "better, healthier people all over the world". https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) • What do you notice about the incidence of CVDs around the world? Which countries or cultures are at higher risk than others? Why might this be the case?
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. • Damage due to heart attack or stroke can damage the heart tissue permanently, making the muscle less flexible and strong. •	• What is the difference between regenerative and non-regenerative tissue? • There are many kinds of congenital heart abnormalities in newborn babies. Pick one example and find out more about it: https://www.heartkids.org.au/congenital-heart-disease • What are the short- and long-term impacts for people living with the heart abnormality you selected?

		systems of organs carrying out specialised functions that enable them to survive and reproduce (ACSSU150	• The heart consists of different groups of cells organised into tissues. • Heart disease can impact people's health and cause short- and long-term health issues.	
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of the heart in terms of the specialised tissue (which is part of a complex body system). • The heart consists of different groups of cells organised into tissues. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. That energy comes from cellular respiration in the mitochondria. Without this energy the heart muscle cells would not contract. • Heart tissue consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged during heart attack or stroke.	• Referring to the web page: 'Fixing hearts by finding out what makes them tick' Enzo and James are trying to make heart tissue in the 'right ratio' of muscle and supporting cells. What might be the difference between these different tissue/cell types? What role might they play? • Create a list of body tissues which are regenerative and non-regenerative. Which systems do these tissues belong to and what are the consequences if these tissues are damaged? • Support resource: Can stem cells help me? Heart Disease: https://stemcellsaustralia.edu.au/conditions/explore/heart-disease/
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	Unit 2	Working like a scientist	• Resources from the Red section above and other videos can be used to highlight the nature of how scientists work, such as the role of diversity and collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • Working in an environment with open communication and sharing of knowledge	• See resources in the section above to discuss what is involved in working as a scientist, in particular the role of diversity and collaboration.

			can lead to the questioning and advancement of knowledge.	
	Unit 2	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) And The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)	• Beating heart tissue can be grown from stem cells in the laboratory.	• Learn about how scientists have been growing cardiac cells from stem cells in the laboratory: • Researchers Grow Tiny Beating Human Hearts from Stem Cells https://www.popsci.com/researchers-grow-first-ever-beating-hearts-stem-cells/ • Learning to build a heart from the cells up https://www.eurostemcell.org/learning-build-heart-cells • Eight tiny organs grown by scientists https://www.eurostemcell.org/eight-tiny-organs-grown-scientists
	Unit 3	ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068) And International collaboration is often required when	• Use the context of the video to explore how the group is using stem cells to bioengineer heart tissue. • Enzo and James have knowledge and skills which are unique but complimentary. This is an opportunity to illustrate how collaboration often involves people coming together to share expertise and skills to advance a common interest or goal.	• Find out more about other kinds of bioengineering: https://www.pbslearningmedia.org/resource/nsn11.sci.life.stru.bodyparts/bioengineering-body-parts/ • Create a PMI (Plus, minus, interesting) chart to consider the benefits and limitations of bioengineering heart tissue • Use in conjunction with ACSBL055 below • Collaboration – scientists collaborate within labs, locally, nationally and internationally. Enzo said, “That sort of partnership and interaction between scientists from different disciplines is an example of how collaboration can really lead to new discoveries and new fields of research.” Explain why collaboration is important for science. • Create an explanation about the role and value of collaboration for scientific endeavour that would be

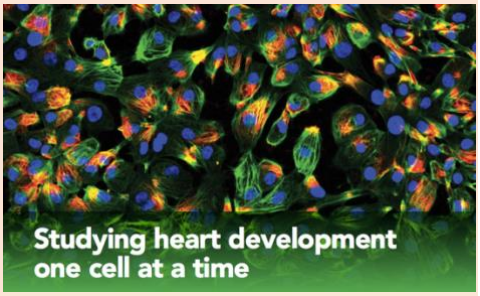
		investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)		appropriate for a primary school student (e.g. grade 3) or a year 7 student.
Senior Biology Australian Curriculum – Science Understanding (SU)	Unit 2	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055) And In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of capillaries) (ACSBL058)	• See resources above related to heart cell development. Research related to cardiac tissue has focused on ways to regenerate heart tissue for injury repair and the use of stem cells to develop models for testing and modelling. Students can use these contexts as a way of learning more about the nature of cells and how cells develop into tissues and organs. • Bioengineering is the amalgamation of knowledge, skills and characteristics from biology and engineering, working together to find a solution to the problem. Developing new technologies also requires creativity and imagination to advance our knowledge.	• Bioengineering: (See also above) The Porrello group is using stem cells to bioengineer heart tissue. Which kind of stem cell would work best for the Porrello group? Explain your reasons. (Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/#pluripotent-stem-cells) • Bioengineering may support stem cell therapies for the treatment of heart tissue damage. These advances rely on a number of disciplines, working together. It also requires imagination and creativity to think of novel ways to tackle treatment of the disease. Compare the bioengineering here to that of the Parish group (see the web page article *'Towards stem cell therapies for Parkinson's'*) • Compare how the Porrello and Parish Groups are using bioengineering technology? • Using your knowledge of cell and tissue growth and development, how would a bio-scaffold in the heart work? Why might it be important in the case of stem cell therapies? • How are stem cells being used for cardiovascular research in Australia and worldwide? What possibilities might stem cells offer patients in the future? Explore some article below: • https://www.eurostemcell.org/video-stem-cells-myths-truths-and-possibilities •

1.4 The Palpant Group: Studying heart development one cell at a time

Dr Nathan Palpant and Enakshi Sinniah

Institute for Molecular Bioscience at the University of Queensland

"Cardiovascular diseases (CVD) are the number 1 cause of death globally: more people die annually from CVDs than from any other cause." World Health Organization



Accompanying Resources:
Refer to the Stem Cells Australia web page *'Studying heart development once cell at a time,'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Palpant Group research?

- Examining how individual heart cells develop reveals how these cells 'make decisions' to form a working heart.
- Heart tissue injury and damage is permanent. The Palpant group is interested in exploring how heart tissue develops, with a view of generating knowledge about how heart tissue might be repaired or regenerated.
- The Palpant group works very closely with the Powell Group.

What is the science?

- Heart development is a complicated process.
- If the cellular changes during heart development are better understood, scientists might better understand what happens in conditions like heart disease.
- Heart cells and tissue are unable to regenerate. Once an adult heart is damaged, it has no ability to heal itself.
- Single cell sequencing can provide information about how genes function in individual cells (i.e. which genes switch on and off).
- In 2018 the Palpant and Powell groups found a gene (HOPX) which plays a crucial role in controlling heart growth.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Collaboration: Collaboration and the interdisciplinary nature of scientific endeavour – the Palpant Group works closely with Associate Professor Joseph Powell at the Garvan Institute. Palpant's lab focuses on cardiovascular disease while Powell's group works on statistical genetics and single-gene sequencing. The research would not be possible if the two labs did not work together.
    - People from different disciplines (e.g. biologists and bioinformaticians) work together to create new insights, new questions and new possibilities.
    - Interest: Science involves being curious and asking questions.

- Nature of science: Advances in scientific understanding relay on advances in technology. In this case, the development of a single-cell sequencing machine has enabled the Palpant and Powell groups to create new knowledge about the heart and how it develops.
- Social, cultural and economic influence scientific research and ethical aspects – in this case, the moral imperative of better understanding the nature of cardiovascular disease and how to mend a 'broken' heart.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/ s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7-12	Working like a scientist involves asking questions. E.g. People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE136	Being a scientist involves creating new knowledge which comes about by asking questions and being curious. NB The Palpant and Powell Group resources are closely linked.	• In the video, Dr Nathan Palpant said "I would never have imagined that I would be doing this kind of research even five years ago. I would never have imagined it. Making use of key collaborations, building those networks and figuring out what are the biggest questions we can ask and taking opportunities where they come. And so that's where it's been an exciting journey. And honestly, I don't know that I would have been able to do this anywhere else in the world." • What does Nathan mean by asking 'big questions'? • Why are questions important in investigative science endeavour? • It may appear that science happens in an ordered fashion - such as starting with a question, designing an experiment, gathering data, analysing results and communicating findings. However, new scientific knowledge does not always arise in this way. Can you find an everyday example when a person has made a discovery, rather than starting with an experiment design?
Australian Curriculum: Science - Science as a Human	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as	• In the past, little was known about how the heart developed in an embryo - from a single cell to a functioning organ. As the heart muscle consists of non-regenerative cells, heart tissue is unable to be repaired after injury. This has led scientists to investigate	• The Palpant and Powell groups defined a new gene, HOPX. • This is an opportunity to highlight to students in year 7 and 8 that our cells contain our genetic information in the form of DNA. Sections of DNA code for genes, which are responsible for various essential bodily functions, such as making cells and making proteins.

endeavour (SHE)		new evidence becomes available ACSHE134	ways of helping people who have suffered a heart attack or heart tissue damage. • The Palpant and Powell teams defined a new gene. This is an opportunity to discuss how new genes are defined and named AND how new knowledge develops through the work of many groups over time. Today's scientists are using the work of yesterday's scientists to expand our understandings and develop new technologies. As a consequence of this process, knowledge and technology advances and our understandings change as new evidence becomes available. • NB – scientific knowledge does not already exist and therefore cannot be 'discovered'. Humans develop scientific understandings about the world using man-made conventions, vocabulary and technology. Therefore, when talking about new 'discoveries or breakthroughs, it is helpful to remind students that this is new knowledge that scientists have developed and that it could be refined and change as new evidence becomes available in the future.	• Genes have unusual names. Explore how genes are named when scientists locate them, sequence them and learn more about how the gene functions and what role it plays in development. • HUGO Gene Nomenclature Committee (i.e. who determines the names for genes) (HGNC) https://www.genenames.org/ • Developing universal names for genes means that scientists can be sure they are talking about the same genes when communicating and planning their research. • In the article *'Studying heart development one cell at a time'*, what are two new understandings the Palpant and Powell groups have made? Why are these new understandings valuable? • Compare the new discoveries made by the Palpant group, the Porrello Group and the Harvey Group.
		Scientific knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures (ACSHE223/226)	• The Palpant and Powell groups work closely together. Each group has particular expertise and knowledge. By combining these skills and knowledge, the two groups have been able to conduct scientific research more complex than they could have conducted alone.	• Referring to the video and the article *'Studying heart development once cell at a time,'* what kinds of collaborations has Dr Palpant created and why have these connections been important? • Compare the Palpant and Powell collaboration to the Porrello and Hudson collaboration (See the Porrello Group). How are the collaborations similar or different? What are some common characteristics of collaborative relationships?

	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158/192)	• Advances in technology and science have led to greater understanding of the heart and how it develops. • Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life. Use the context of the team developing the only lab in Australia with a single-gene sequencing machine in terms of the value of this machine for the Palpant and Powell groups' research.	• "When we began this project in 2016, we were the only lab in Australia, and the third in the world, to have a high-throughput single-cell sequencing machine," says Joseph. Why might a single-cell sequencing machine be useful? What do you think might be the purpose of a single cell sequencing machine? • Use in conjunction with ACSSU184 below.
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research (ACSHE230)	• "Cardiovascular disease (CVD) is the number 1 cause of death globally: more people die annually from CVDs than from any other cause. • An estimated 17.9 million people died from CVDs in 2016, representing 31% of all global deaths. Of these deaths, 85% are due to heart attack and stroke." https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) • Use the context of CVD to simulate discussion about how values and needs of society influence the focus of research. Consider the role of the World Health organisation to see how nations collaborated to share knowledge and resources to improve the health of people globally, especially in nations experiencing disadvantage. Compare how fortunate we are in Australia to have a robust health care system.	• In the video, Joseph says "In the average lifespan of an individual will suffer on average from eight different diseases. These could be cardiovascular diseases, cancers, neurological conditions, autoimmune diseases. So one of the things that we're really motivated by is trying to ultimately solve and cure those diseases, although I think that's a grand statement, but really is to try to mitigate and reduce its disease severity within society and using stem cells as a way to model these myriad of different tissues and different cell types and different organs and different diseases creates essentially a unified platform to be able to address a huge range of different diseases and critical problems in a really rapid and transformative manner." • What does Joseph value? How might these values influence his research? • Find out more about cardiovascular disease and why it is the leading cause of death globally. Navigate to the World Health Organization (WHO) website. This global organisation advocates for "better, healthier people all over the world".

			• Consider the role of the NHMRC (National Health and Medical Research Council), a major research funding body in Australia. Exploring the amount of research being funded in different areas can give an indication of value and need. Students can consider that different parties have different values and different vested interests. This can influence how people work and where money is spent. Science is very much value laden and is influenced by the needs and values of society.	The core function of WHO is to "direct and coordinate international health through collaboration". The WHO has more than 7000 people working in 150 county offices around the world. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) • What do you notice about the incidence of CVD's around the world? Which countries or cultrues are at higher risk than others? Why might this be the case? • The NHMRC governs the allocation of research funding in Australia. Other countries have similar funding bodies. Explore the distribution of funding over the last 10 years https://www.nhmrc.gov.au/funding/data-research/research-funding-statistics-and-data#download • What do you notice? • Which areas of research tend to be funded more than others? Why might this be the case? What might this say about what is valued? • How does cardiovascular funding compare to funding in other areas?
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149)	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. • Damage due to heart attack or stroke can damage the heart tissue permanently, making the muscle less flexible and strong. • The heart consists of different groups of cells organised into tissues. • Heart disease can impact people's health and cause short- and long-term health issues.	• What is the difference between regenerative and non-regenerative tissue? • There are many different kinds of congenital heart abnormalities. Pick one example and find out more about it: https://www.heartkids.org.au/congenital-heart-disease • What are some of the short and long-term impacts for people living with the heart abnormality you selected?

	9/10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175 AND Transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184	• This video offers the opportunity to consider the nature of the heart in terms of specialised tissue (which is part of a complex body system) and the role genes play in developing that tissue. These two SU objectives can be explored together. • The heart consists of different groups of cells organised into tissues. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. That energy comes from cellular respiration in the mitochondria. Without this energy the heart muscle cells would not contract. • Heart tissue consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged during heart attack or stroke. • Gene function determines how an undifferentiated cell becomes a specialised heart tissue cell. The Palpant and Powell labs are examining how genes influence the development of specialised cells. Which genes are switched on and off during cell development.	• Drawing on the article '*Studying heart development once cell at a time*,' explain broadly how heart muscle is formed. • What role do genes play in this process? • Why is the Palpant group focusing on gene expression in the heart? Explain your answer in relation to congenital heart disease. • "In 2018 the pair found that a gene called HOPX plays a crucial role in controlling heart growth." Find out more about the gene HOPX and what it does. • Navigate to the NCBI website: https://www.ncbi.nlm.nih.gov/gene/84525 • The NCBI website has a lot of information. Can you identify any familiar words? • On which chromosome is HOPX located? • Why might this genetic discovery be important for the work of the Palpant and Powell labs? • What might be some long-term benefits arising because of the work in the Palpant and Powell labs? • See also ACSHE158/192)above – in the context of the video and using your knowledge of genetics, explain why a single gene sequencing machine might be a useful technology.
Senior Biology Australian Curriculum – Science as a Human	Unit 2	Working like a scientist	• Resources from above and other videos can be used to highlight the nature of the way scientists work, such as the role of questioning in science. In investigative science (i.e. where scientists plan experiments) questioning occurs at the beginning, during and end of the process. As	• See resources in the section above to discuss some of the aspects of working as a scientist that are highlighted in this video. For example, the role of questioning in science. How are questions and questioning an essential element of scientific endeavour? • Contrast the role of questions in scientific endeavour with the other ways scientific knowledge is generated, such as the

Endeavour (SHE)			scientific investigation occurs, more questions are raised. • In non-experimental knowledge development, questioning might come after an event or stimulus – such as Alexander Fleming questioning why the bacteria on his discarded agar plates was receding in certain sections.	role of creativity and imagination (See the Parish Group) or the important role of failure (See the Merson Group).
	Unit 2	Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	• Use the context of the video to explore how the group is using stem cells to create a model of heart development.	• "Heart development is a difficult and complicated process, but we think the answers to heart repair are likely to lie in understanding heart development," Nathan says. "So, we are using stem cells to model development as it occurs in our bodies." • Explain why stem cells would be valuable for the Palpant group research. • Learning to build a heart from the cells up https://www.eurostemcell.org/learning-build-heart-cells • Using stem cells as models - use in conjunction with ACSBL055 below.
	Unit 3 (Year 12)	ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068) AND International collaboration is	• The Palpant group has partnered with bioinformaticians to work with large genomic data sets, cell biologists who specialise in stem cell differentiation and physiologists who can work with animals. The work is interdisciplinary. (See also unit 3 SU below). • The collaboration with computer analysists enables the Palpant group scientists to look at the genomic data of a single cell to learn more about the nature of the genome. • The group is also working with a team who are exploring the health benefits of spider venom with a hope to find proteins in the venom which might advance understanding	• The Palpant group collaborate with bioinformaticians to work with large genomic data sets, cell biologists who specialise in stem cell differentiation and physiologists who can work with animals. The work is very interdisciplinary. What qualities and skills might each of these discipline experts bring to the work of the Palpant and Powell groups? • Examine your list and consider if there are some generic skills which are associated with each group? Where might there be an opportunity for you to develop those kinds of skills in your schooling environment?

		often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)	about how heart tissue could be protected after injury by minimising tissue damage.	
Senior Biology Australian Curriculum – Science Understanding (SU)	Unit 2	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055) And In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of	• See resources above related to heart cell development. Research related to cardiac tissue has focused on ways to regenerate heart tissue for injury repair and the use of stem cells to develop models for testing and modelling. Students can use these contexts as a way of learning more about the nature of cells and how cells develop into tissues and organs. • The article and video highlight that the Palpant Group works with stem cells. Pluripotent stem cells can grow into any cell type in the body under the right conditions. • Cell potency refers to the varying ability for stem cells to differentiate into specialised cell types. Cells with the greatest potency can differentiate into more cell types than those with lower potency. • Multipotent cells can differentiate into a limited number of cell types of a particular lineage. For example, a stem cell that is able to make blood cells (a haematopoietic SC) is multipotent, as it can differentiate into multiple cell types, however only cells that are within the blood cell lineage.	• Cellular processes: "When a person has a heart attack, their heart loses billions of cells just within the process of losing blood flow to the heart that causes an injury that ultimately results in heart failure." In the video, Dr Palpant talks about reducing heart tissue stress during injury. How might proteins in spider venom be useful for preventing damage to injured heart muscle? See for example: https://www.abc.net.au/radionational/programs/healthreport/unlocking-the-secrets-of-venom/9735458 • Modelling heart development: (see also above) the Palpant group is using stem cells to model heart development. • Which kind of stem cell would work best for the Palpant group? Explain your reasoning (Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/#pluripotent-stem-cells). • How are stem cells being used for cardiovascular research in Australia and worldwide? What possibilities might stem cells offer patients in the future? Explore some articles below: https://www.eurostemcell.org/video-stem-cells-myths-truths-and-possibilities • Scientists are able to grow organs in the lab using stem cell technologies. Explore some of these advances: https://www.eurostemcell.org/eight-tiny-organs-grown-scientists https://www.eurostemcell.org/mini-lab-grown-organs-good-bad-and-mucousy

		capillaries) (ACSBL058)	• Pluripotent cells can differentiate into any cell type, however, cannot make embryonic cells. This means that you cannot create an entire animal from pluripotent cells. • Totipotent cells can differentiate into any cell type including placenta cells. This means you could potentially create an animal from these cells.	• How might these new understandings be applied in the future?
	Unit 3	Genes include 'coding' and 'non-coding' DNA, and many genes contain information for protein production (ACSBL078) And DNA sequencing enables mapping of species genomes; DNA profiling identifies the unique genetic makeup of individuals (ACSBL086)	• Use this video and article as a context to explore the use of bioinformatics and use the HPOX gene as a context for exploring the nature of genes. • The Palpant lab works with bioinformatics experts on large genetic data sets. • The HOPX gene is present in all cells. What role might this gene play in the heart specifically?	• Role of genes: Drawing on the article *'Studying heart development once cell at a time,'* explain broadly how heart muscle is formed. • What role do genes play in this process of heart tissue development? • Bioinformatics: In the video, Enakshi says "So we're looking at a lot of big data - data where we're looking at genomic wide information at the level of a single cell. So we're taking that data and actually trying to identify what defines the genetic soul of a cell." • What might Enakshi mean by the 'genetic soul' of the cell? Using this context, explain what bioinformatics is. • What kinds of information might the bioinformaticians be looking for? • What would the data sets consist of? • Explore the nature of the gene the group discovered (HOPX) via the Uniprot website: https://www.uniprot.org/ • Where else in the body is HOPX expressed? • NB the information listed on this website can be quite complex. The point of this exercise is to help senior biology students realise the complexity of the genome, the location of the gene, the specificity of the gene functions and to appreciate that the gene product (i.e. protein) may be part of

				a complex pathway. They do not need to understand all the information on the site, but they may see words they are familiar with (such as enzyme, protein, pathway, ATP, AMP, cardiac, taxonomic lineage etc). Ask students to identify words they might know and what the information might mean. • Another feature of the Uniport is the section “subcellular location”. Scroll down to this section which has an image of where the gene is most active in the cell. Compare different genes to see where they are most active. • On the Uniprot website there are yellow and blue call out icons which highlight publications and sources for information included on each page. This is a kind of referencing convention. Why are these citations important? Hover over several yellow citations. What do you notice about the citations? (i.e. how many authors, title, journal, specificity of the article aims etc.) List some similarities and differences. • What elements of Science as a Human Endeavour (SHE) are apparent: in the citations? On this site more generally? (Hint: Think about aspects like collaboration, values, breakthroughs, building on previous knowledge, values etc).

1.5 The Harvey Group: Pathways to heart repair

Professor Richard Harvey and Dr Aude Dorison

Victor Chang Cardiac Research Institute and the University of New South Wales

Heart trauma and disease are a leading cause of disability and death in children and adults, affecting one in every six Australians. Next to cancer, it has the highest burden in terms of treatment cost and lost income to patients and their families and caregivers.

Professor Robert Graham

Accompanying Resources:
Refer to the Stem Cells Australia web page *'Pathways to heart repair,'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Harvey Group research?

- The Harvey group focuses on developmental biology of the heart.
- Adult stem cells and their potential as therapeutics and models for disease
- The lab is studying one of the most severe congenital heart diseases called hypoplastic left heart (a congenital heart defect in newborns).

What is the science?

- Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions.
- After a heart attack, the heart muscle tissue can scar, which can impede heart function.
- Heart tissue is non-regenerative and cannot be repaired after injury.
- Stem cells have the potential to help repair damaged heart tissue (in the future). There may be a lack of awareness about the current state of stem cell use in therapeutic medicine (see also the Professor Munsie video).
- NKX2-5 is a master-regulator gene of heart development.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Collaboration: Collaboration is essential for scientific endeavour and advancement. Science laboratories consist of a diverse mix of people at different stages of their careers.
    - People from different disciplines (e.g. biologists and bioinformaticians) work together to create new insights, new questions and new possibilities.
    - Nature of science: Discoveries and breakthroughs in science create new knowledge. Scientific knowledge is tentative, yet durable. Knowledge changes as new evidence becomes available. In this case, overturning the belief that heart cells do not divide after birth.
    - Advances in scientific knowledge often rely on technological advances: Advances in one field can influence other areas of science, technology and engineering.

- Social, cultural and economic influence scientific research and ethical aspects: in this case, the moral imperative of developing better treatments for heart injury and disease to enhance survival.
- Some scientific research involves the use of animals: There are ethical implications associated with research practices involving animals. You may like to refer to the companion module Ethics and Stem Cells

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7-12	Structure of scientific laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, associate professor etc.)	• This video features Professor Richard Harvey and Dr Aude Dorison. • Research laboratories consist of a range of people (younger and more senior) from a variety of career stages (beginning students to experienced researchers). • Scientific laboratories, like other workplaces, conduct the 'serious business' of research but are also places of fun and collegiality.	• In the video Professor Richard Harvey says "Science is done in teams. I think that's one of the great parts about it. And there are young people and more senior people, there are people from all different nationalities. What you try and do is create an environment that, you know, encompasses the serious business of doing science and the competitive edge that that entails but also to make it fun and to carry your people along with you in a training exercise that prepares them for their next part of their journey." • 'Science is done' in teams. What are the benefits of working as a team? • Many of the scientists in this video series have highlighted the value of having both experienced and beginning scientists (i.e. Honours, Masters and PhD students) as part of the lab team. List some qualities you think students would bring to the team.
Australian Curriculum: Science - Science as a Human endeavour **(SHE)**	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• In the article *'Pathways to heart repair,'* there is a quote: "In 2014, Graham's research team overturned a long-standing belief that heart cells do not divide after birth." • This quote highlights the nature of scientific knowledge development. New evidence influences the scientific discourse. As new evidence becomes available (through new research and changes in technology), new	• Use in conjunction with ACSSU150 below • In the video Richard mentions a disorder called hypoplastic left heart, which is a congenital heart defect in newborn babies. • Find out more about hypoplastic left heart. See for example: https://www.stanfordchildrens.org/en/topic/default?id=hypoplastic-left-heart-syndrome-90-P01798 • What is hypoplastic left heart?

			insights are offered, which changes the scientific discourse. This leads to changes in currently held scientific conceptions. It does not imply that previous scientific knowledge was 'wrong'. The previous explanation was the most suitable explanation for that phenomenon, at that time, with that level of discourse and technology. Changes in scientific knowledge can cause people to doubt the validity of science. Highlighting this aspect of knowledge development and change is a way of illustrating the tentative yet durable nature of scientific knowledge. • There is also an opportunity to make a distinction between alternate conceptions (also referred to as misconceptions), where students hold a naïve or inaccurate understanding of a scientific concept (i.e. the moon being made of cheese) and changes in scientific concepts and knowledge due to advancements in the scientific discourse, technology and new evidence. Being aware of this distinction can lead to better understanding how scientific advancement occurs.	• What region of the heart does it affect? How does this influence the routine function of the heart? • What are the causes? • What are the symptoms? • How can it be treated? • What are the long-term implications for living with this condition? • Why might the Harvey group be conducting research on this disorder? • Read the article *'Pathways to heart repair,'* • Explain what is meant by heart cells not diving after birth. What would be the implications of heart cells not dividing? • Find out more about the previous notion that heart cells do not divide after birth. • How has this knowledge changed and why might it have changed? What evidence did Harvey's lab gather and why did it challenge the idea that heart cells don't divide? • Can you find an example of where a currently held scientific concept has changed as new evidence became available? • Explain why this is an example of scientific knowledge being tentative yet durable. What do these terms mean?
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226	• In the video Professor Harvey talks about the laboratory being a place of diversity and collaboration. This is an opportunity to showcase the diversity of workplaces and the nature of starting as a new member of a team and working to develop experience and expertise. • Professor Harvey notes that young people are important in the lab as they bring	• In the video, Professor Harvey talks about the diversity of the laboratory workplace. List the variety of people who work in the lab. What are the benefits of this diversity? What are some characteristics Professor Harvey attributes to young people? How might these characteristics be valuable in scientific research? • In the video Professor Harvey also talks about working with a bioinformatician. What do you think a bioinformatician does?

			freshness and curiosity. Diversity also facilitates collaboration due to the sharing of diverse ideas and perspectives. This enables issues and problems to be viewed in a number of different ways, which can lead to more effective problem solving. • In the article *'Pathways to heart repair,'* Professor Harvey's team has been collaborating with Professor Robert Graham and his team. • These are examples of how scientists work collaboratively, usually across disciplines to share knowledge and expertise to advance scientific endeavour.	What skills might the scientists and bioinformatician bring to the collaboration? Create a list. • How does this interdisciplinary relationship compare to the Ramialison Group? What are some characteristics of working with people from different disciplines? • Read the article *'Pathways to heart repair,'* How have the Harvey and Graham labs been collaborating? What new knowledge have they contributed to our understanding of heart function and repair? • Compare the collaboration of the Harvey and Graham labs to the collaboration of the Porrello and Hudson (see the Porrello group) or the collaborations of the Palpant and Powell groups (see the Palpant Group). How are the collaborations similar or different? What are some common characteristics of collaborative relationships?
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE 135	• In science research, models are used to test hypotheses and run investigations to test new ideas. These can include non-human models (such as rodents, insects and non-human primates), computer modelling and new advances in stem cell research. • Use of human and non-human models has ethical implications as non-human animals are unable to grant consent. How might ethical animal testing be regulated? Who decides what is appropriate and not appropriate for animal handling and use in research? How might these decisions be made? This is an opportunity to consider the creation of international bodies and committees to discuss these questions and formulate guidelines for practice.	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn diagram to compare and contrast the benefits and limitations of these different models. • In the Harvey group, Aude says "Every work we do on animals is really needs to be approved by an independent committee before we do it and we make sure that no matter what we do, we respect the animals and we use as little amount as we can." How might the scientists treat the animals with respect? Create a list of ideas. • Scientists are encouraged to reduce research on animals. This is where stem cell research offers another option to animal research. Why might this Harvey lab research benefit

				from using an animal model rather than a single cell tissue culture in the lab? • There are a number of ethical considerations around using non-human primates or any animals in scientific research. • The following link is a video which highlights some of the different models that scientists use. The video also covers ethical implications in the use of animals in research: https://www.brainfacts.org/in-the-lab/animals-in-research/2013/understanding-animal-research • Why are some groups calling for a reduction in the use of animals in research? • Create a Plus, Minus, Interesting chart to create arguments for the benefits and limitations of using animals in science research. The idea here is to be able to recognise and pose an argument, without necessarily agreeing. This is an example of critical thinking – being able to explain another person's argument for something without necessarily agreeing with it. • How might scientists reduce the use of animals in research? • You may like to refer to the companion module Ethics and Stem Cells.
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192	• Advances in technology and science have led to greater understanding of the heart – how it develops. (See ACSHE 134 above) • Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life.	• See also section above - ACSHE134 above related to change in scientific knowledge • Read the article *'Pathways to heart repair*,' What are two discoveries the Harvey group has made in relation to our understanding of the heart? Why might these advances be significant? How do advances in technology support these discoveries? • See ACSHE226 above related to the collaboration between Professor Harvey and a bioinformatician. What is a

				bioinformatician? Why has Professor Harvey been working with an expert in bioinformatics? How might bioinformatics support the work of the Harvey group?
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE228/230	• The article '*Pathways to heart repair*,' states, "Heart trauma and disease are a leading cause of disability and death in children and adults, affecting one in every six Australians. Next to cancer, it has the highest burden in terms of treatment cost and lost income to patients and their families and caregivers." • The Harvey Group case offers an opportunity to explore how values guide research. The article opens with a statement of a large issue – heart trauma and disease and the impact it has on every one-in-six Australians. • To apply understanding of different values and perspectives, students can construct arguments for why research may or may not (should or should not be) be invested into heart attack prevention and recovery.	• In the video Professor Harvey says "And again, I think we would like to be part of the movement, the optimistic movement, that believes we can regenerate human hearts after injury. That's our goal in that area." What does Professor Harvey mean by this statement? What does it say about what he values? • Use the article '*Pathways to heart repair*,' to highlight how Professor Harvey's team's research reflects his values. • How might the Harvey and Graham groups be using research to create social impact? (i.e. think about what advances might cause long term changes to people's health and changes which might impact the health system)?
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain systems of organs	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. • Damage due to heart attack or stroke can damage the heart tissue permanently, making the muscle less flexible and strong.	• What is the difference between regenerative and non-regenerative tissue? • Heart tissue is non-regenerative. What happens to the heart cells after a heart attack? • Use in conjunction with ACSHE134 above • The heart is an organ in the circulatory system. In a child with hypoplastic left heart, the heart is damaged and does not work properly. Create (or download) a diagram of the human heart. Explain what each part of the heart does using one

		carrying out specialised functions that enable them to survive and reproduce (ACSSU150	• The heart consists of different groups of cells organised into tissues. • Heart disease can impact people's health and cause short- and long-term health issues. • See the section about (ACSHE134) on hypoplastic left heart. Use this condition as a context for teaching about the heart and what happens when it does not work properly.	colour. Going back to each part you labelled, using a different colour, explain what could happen (or not happen) in each part of the heart you have labelled in a child with hypoplastic left heart. Use the following website to help you: https://www.stanfordchildrens.org/en/topic/default?id=hypoplastic-left-heart-syndrome-90-P01798 • In the video Dr Dorison says, "And after a heart attack you have a thick scar that does not contract with the rest of the heart." Using your knowledge of the heart, explain why a thick scar would be detrimental to heart function.
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of the heart in terms of the specialised tissue (which is part of a complex body system), in particular cells called cardiomyocytes, which make up heart tissue. • The heart consists of different groups of cells organised into tissues. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. That energy comes from cellular respiration in the mitochondria. Without this energy the heart muscle cells would not contract. • Defects in the heart muscle can disrupt heart function. In the case of infants with hypoplastic left heart, various abnormalities with the mitral valve, left ventricle, aortic valve and aorta. See https://www.stanfordchildrens.org/en/topic/default?id=hypoplastic-left-heart-syndrome-90-P01798	• See ACSSU150 above about using hypoplastic left heart as a context for students explaining the different parts of the heart and what happens when they are not working. • Referring to the video and the article '*Pathways to heart repair*,' • What are induced pluripotent stem cells? (Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/#pluripotent-stem-cells) • Why would these cells be beneficial for growing cardiomyocyte cells? • Professor Harvey suggests that induced pluripotent stem cells be useful as a model. What does he mean by a 'model'? • How might a stem cell model be useful for research on hypoplastic left heart?

			• Use the context of hypoplastic left heart to have students explain how the heart would function differently if each of these areas were not working. • As heart tissue consists of non-regenerative cells, once created, the cells do not regenerate or repair if damaged. New regenerative medicine approaches may offer hope in the future through heart therapies. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions.	
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	11 (Unit 2)	Working like a scientist AND Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to aspects of working as a scientist, such as working with experts from other disciplines. In the video Professor Harvey talks about working with a bioinformatician. This interdisciplinary nature of science is valuable for advancing scientific knowledge.	• See the SHE (red) section above related to collaboration and lab structure for resources. • What might a bioinformatician do? Compare this to the Ramialison group who also works with large data sets • How might the computer program developed by the Ramialison group be of value to the research of the Harvey group (see the article *'Pathways to heart repair,'*)
	Unit 2 & 3	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) AND	• In the article *'Pathways to heart repair'* (page 8-9 of At the frontier of tomorrow's medicine), there is a quote: "In 2014, Graham's research team overturned a long-standing belief that heart cells do not divide after birth." This quote highlights the nature of scientific knowledge development. New evidence influences the scientific discourse. As new evidence becomes available (through	• Read the article *'Pathways to heart repair,'* • What are two advances the Harvey group has made in relation to our understanding of the heart? Why might these advances be significant? • See sections related to advances in knowledge above (e.g. ACSHE134 and ACSHE158/192)

		The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041) SEE also Unit 3 – Protein structure and function (ACSBL080)	new research and changes in technology), new insights are offered which changes the scientific discourse. This leads to changes in currently held scientific conceptions. • Use in conjunction with ACSBL055 below – see discussion about the current state of use of stem cells in mainstream medicine. This also links well to Stem Cell Tourism (see video with Professor Megan Munsie).	• UNIT 3 - In the video Sujitha says "novel therapies and in particular we were looking at the effect of recombinant human PDGF-AB which is a protein as a potential therapy for patients after a heart attack." Use your knowledge of signalling molecules to explain the role this protein might play after a heart attack. • See section below – current use of stem cells in mainstream medicine.
	Unit 2	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL043)	• Use of animals in scientific research has many ethical, social and cultural implications. • Use of human and non-human models has ethical implications as non-human animals are unable to grant consent. • How might ethical animal testing be regulated? Who decides what is appropriate and not appropriate for animal handling and use in research? How might these decisions be made? • This is an opportunity to consider the creation of international bodies and committees to discuss these questions and formulate guidelines for practice.	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn diagram to compare and contrast the benefits and limitations of the different models. • How is the Harvey group using a non-human animal model? Why might this model be useful for the group? • There are a number of ethical considerations around using non-human primates or any animals in scientific research. • The video covers ethical implications in the use of animals in research: https://www.brainfacts.org/in-the-lab/animals-in-research/2013/understanding-animal-research • You may like to refer to the companion module Ethics and Stem Cells • Create a two-column table to compare the strengths and weaknesses of using a non-human based models (i.e. animal testing) to conduct research into heart injury treatment options. The idea here is to be able to recognise and pose an argument, without necessarily agreeing. This is an example of critical thinking – being able to explain another person's argument for something without necessarily agreeing with it.

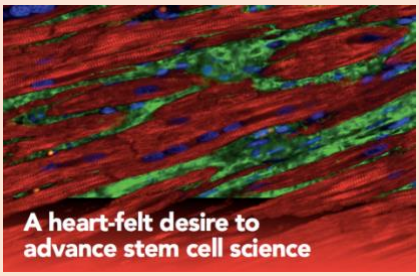
				• Read the article *'Pathways to heart repair,'* • What is the main aim of the Harvey research group? How might they be using research to create social impact? In what ways might their research be geared towards enhancing sustainability (i.e. think about what advances might cause long term changes to people's health and changes which might impact the health system)?
Senior Biology Australian Curriculum – Science Understanding (SU)	11 (Unit 2)	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055) AND In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of capillaries) (ACSBL058)	• Stem cell research related to cardiac tissue has focused on ways to regenerate heart tissue for injury repair and the use of stem cells to develop models for testing drugs. • Students can use these contexts as a way of learning more about the nature of cells and how cells develop into tissues and organs. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	• Induced pluripotent stem cells can grow into any cell type in the body under the right conditions. Find out what these cells are why they might be beneficial for the Harvey group. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • See ACSSU150 and ACSSU175 above about using hypoplastic left heart as a context for students explaining the different parts of the heart and what happens when they are not working. • In the video Dr Dorison says, "And after a heart attack you have a thick scar that does not contract with the rest of the heart." Using your knowledge of the heart, explain why a thick scar would be detrimental for heart function. • Consider the current issues related to heart injury and repair. Explain what the Harvey group hopes will be possible in the future and how might stem cells help them achieve their goals?

	Unit 3, year 12	The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment (ACSBL081)	• NKX2-5 is a master-regulator gene of heart development. Harvey and his team have identified a network of proteins that interact with NKX2-5. Congenital heart disease occurs when this network of iterations goes awry. • This video provides a context for discussing the role of transcription factors for protein production and considers the role of cellular pathways and signals for heart tissue development.	• "This gene encodes a homeobox-containing transcription factor. This transcription factor functions in heart formation and development. Mutations in this gene cause atrial septal defect with atrioventricular conduction defect, and also tetralogy of Fallot, which are both heart malformation diseases." https://www.genecards.org/cgi-bin/carddisp.pl?gene=NKX2-5 • What is a transcription factor? • Read the article *'Pathways to heart repair*,' • Using your knowledge of signalling molecules, explain the following excerpt: "a single protein that binds the hormone neuregulin could supercharge the repair pathways of the adult heart, causing a ~5-fold increase in cardiomyocyte division." • Explain the following excerpt: "identified a new network of proteins that interact with the gene NKX2-5, one of the master-regulators of heart development. Through genome-wide and computational approaches, Harvey's team revealed how this network goes awry to cause congenital heart disease." • How are findings from the Harvey and Graham labs advancing knowledge about congenital heart disease? • The article mentions thyroid hormone. What is the thyroid? What role does it play in homeostasis? What hormones does it produce? What do these hormones do in the body? Why might the thyroid hormones be of interest to a group researching the heart?

1.6 The Chong Group: A heart-felt desire to advance stem cell science

Associate Professor James Chong and Dr Sujitha Thavapalachandran

Westmead Institute for Medical research at the University of Sydney



"As a cardiologist at Sydney's Westmead Hospital, I have seen first-hand the suffering of patients with cardiovascular disease and heart failure. In many cases our current treatment options are limited.

Although heart transplantation is a viable option for severe heart failure, there will never be enough donor organs to supply the increasing demand of our ageing nation. This motivated me to set up my research group at the University of Sydney/Westmead Institute for Medical Research focusing on developing novel therapies for cardiovascular diseases and heart regeneration". Associate Professor James Chong

Accompanying Resources:
Refer to the Stem Cells Australia web page *': 'A Heart felt desire to advance stem cell science'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Chong Group research?

- As a practicing cardiologist Associate Professor Chong understands the needs of patients with heart damage or disease. Professor Chong applies this knowledge to direct his research into repair and regeneration of injured heart tissue.
- Stem cell research is being directed towards growing heart tissue in the lab for potential heart repair and growing heart tissue for drug testing and discovery.
- Dr Sujitha Thavapalachandran is investigating potential treatment options for people who have suffered a heart attack. This research focuses on reducing cardiac death after a heart attack.

What is the science?

- The lab is able to change pluripotent stem cells into cardiomyocytes, a specific heart cell which makes up heart muscle. These cells can be seen beating (contracting) in a dish.
- Stem cells have the potential to help repair damaged heart tissue (in the future). There may be a lack of awareness about the current state of stem cell use in therapeutic medicine (see also the Professor Megan Munsie video).
- The team is looking at protein PDGF-AB, as a potential therapy for patents who have suffered a heart attack. The protein may help minimise heart tissue damage. This drug is currently being tested on animals with very positive progress so far.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:

- Collaboration: Collaboration is essential for scientific endeavour and advancement. As Associate Professor Chong is a practicing cardiologist, he can offer insights about heart disease which scientists in a lab may not be aware, as they do not work with patients. This greatly enhances the development of knowledge as he can apply understandings from his practice as a cardiologist to directly guide his research.
- Lab structure and pathways: Science laboratories consist of a diverse mix of people at different stages of their careers.
- Interest: Scientists use empathy, the ability to understand and share the feelings of another, to guide their research.
- Nature of science: Advances in scientific knowledge often rely on technological advances. Advances in one field can influence other areas of science, technology and engineering. Advances in stem cell research has opened the door to a multitude of possibilities for bioengineered solutions to address heart related problems in the future.
- Values: Scientists have values, and these values influence their work and behaviour. Values can include curiosity, open-mindedness, parsimony, creativity, rationale thinking, empiricism and scepticism.
- Social, cultural and economic influence scientific research and ethical aspects: In this case, the moral imperative of developing better treatments for heart injury and disease to enhance survival.
- The lab also uses large animals in research: This case offers an example of how non-human animals are used in research and the ethical implications associated with research practices.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 - 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7-12	Structure of scientific laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, associate professor etc.)	• This video features Associate Professor James Chong who is a clinician scientist. • Research laboratories consist of scientists at a variety of career stages. Post-doctoral researchers have completed a PhD and are able to design and conduct specific research projects. The lab also has students (e.g. Honours, Masters and/or PhD) who are learning how the lab works, and gaining new skills and practices which will aid them in becoming employed as post-doctoral researchers.	• Associate Professor James Chong is a clinician (practicing doctor) and a scientist. How might his experiences as a doctor and a scientist be mutually beneficial? How might this be limiting? Create a Plus, Minus, Interesting chart to represent your thinking. Refer to the video for clues about what else James said is involved with his different roles. • James is a medical doctor. What is the difference between a medical doctor and a person who has a PhD (and is also considered a doctor)? (Hint – this distinction was often made on the popular TV sitcom, The Big Bang Theory) • Dr Sujitha Thavapalachandran is a PhD student in the Chong lab. How long does a PhD take? Why do scientists undertake a PhD? What is a postdoc? You may like to refer to the companion Life as a Researcher module • Many of the scientists in this video series have highlighted the value of having students (i.e. Honours, Masters and PhD students) as part of the lab team. List some qualities you think students would bring to the team.
	7-12	Working like a scientist involves empathising with other people about an issue and using those feelings to	• In the article and video Associate Professor James Chong highlights his strong desire to apply what is being learned from stem cell research to mainstream cardiology practice to help people who have heart issues. • This is a great opportunity to highlight to students that most scientific research and	• In the video, Associate Professor James Chong says “I want to see my therapies or those developed by my colleagues giving options to patients that just simply don't have them at the moment.” • What does James mean by this?

		guide research and actions.	much of where people invest their energy and work, stems from empathy. Empathy can be defined as the ability to understand and share the feelings of another. The video and article demonstrate a strong sense of desire to help people, which probably stems from a sense of empathy. • Empathy is the foundation for the Stanford School Design Thinking process. For more information about this see: • Design thinking bootleg Deck (defines empathy): https://dschool.stanford.edu/resources/design-thinking-bootleg • Introduction to design thinking process guide: https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf •	• Find evidence in the article '*A Heart felt desire to advance stem cell science*' of what might drive James to do the work that he does. • Have you experienced empathy – the strong sense of desire to help people? Can you think of an example of when you have experienced empathy? Briefly summarise the example. How did it make you feel? How did it impact your actions? Have there been (or might there be) any long-term changes you have made because of this experience?
Australian Curriculum: Science - Science as a Human endeavour (SHE)	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• Heart attacks "claimed 7,813 lives in 2017, or on average, 21 each day. In the last 10 years (from 2008 to 2017), more than 92,000 Australians have lost their lives due to heart attack." https://www.heartfoundation.org.au/about-us/what-we-do/heart-disease-in-australia/heart-attack-fact-sheet • Use the video as a context to explore the nature of heart attack – what it is, what we know and what we don't know. Explore how understanding of heart attack has changed over time.	• In the video James mentions heart attack. Our knowledge of heart attack prevention and recover has changed as new knowledge has become available. • "Heart attack, also known as 'acute myocardial infarction', is a life-threatening event that occurs when a blood vessel supplying the heart itself is suddenly blocked completely, threatening to damage the heart muscle and its functions." https://www.heartfoundation.org.au/about-us/what-we-do/heart-disease-in-australia/heart-attack-fact-sheet • Find out more about heart attack – how many people are affected each week? Each year? • What happens to the heart during a heart attack? • What are the symptoms of a heart attack?

				• What have been some recent discoveries related to heart attack? How have these new findings changed prevention and treatment? • Explore the Heart Foundation website to find out more: https://www.heartfoundation.org.au/your-heart/heart-conditions/heart-attack •
		Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135	• In science research, models are used to test hypotheses and run investigations to test new ideas. These can include non-human models (such as rodents, insects and non-human primates), computer modelling and new advances in stem cell research. • Use of human and non-human models has ethical implications as non-human animals are unable to grant consent. This is an opportunity to consider the creation of international bodies and committees to discuss these questions and formulate guidelines for practice.	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn diagram to compare and contrast the benefits and limitations of different models. • In the Chong group, Sujitha talks about using large animals with a heart of similar size to humans. Which animals might fit these criteria? • Use of human and non-human models has ethical implications as non-human animals are unable to grant consent. How might ethical animal testing be regulated? Who decides what is appropriate and not appropriate for animal handling and use in research? How might these decisions be made? • There are a number of ethical considerations around using animals in scientific research. • You may like to refer to the companion module on Ethics and Stem Cells • Support video which highlights some of the different models that scientists use. The video also covers ethical implications in the use of animals in research: https://www.brainfacts.org/in-the-lab/animals-in-research/2013/understanding-animal-research
	9 & 10	Advances in scientific understanding often rely on technological	• Advances in technology and science have led to greater understanding of the heart – how it develops.	• See also section above (ACSHE120/135) • James speaks of a long-term goal of growing heart tissue in the lab and using it to directly repair damaged heart tissue.

		advances and are often linked to scientific discoveries ACSHE158/192	• See also ACSHE120/135 above. • Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life.	Create a PMI (Plus, Minus, Interesting) chart to consider the benefits and limitations of bioengineering heart tissue. Use the following resources to learn more about this process: https://www.eurostemcell.org/christine-mummery-physicists-take-stem-cell-biology • https://www.eurostemcell.org/learning-build-heart-cells • https://www.health.harvard.edu/heart-health/repairing-the-heart-with-stem-cells
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE228/230	• Heart attack "claimed 7,813 lives in 2017, or on average, 21 each day. In the last 10 years (from 2008 to 2017), more than 92,000 Australians have lost their lives due to heart attack." https://www.heartfoundation.org.au/about-us/what-we-do/heart-disease-in-australia/heart-attack-fact-sheet • When so many people in the population are affected, research tends to be focused in areas which may reduce such impact. • To apply understanding of different values and perspectives, students can construct arguments for why research may or may not (should or should not be) be invested into heart attack prevention and recovery.	• Find out more about heart attacks and why it is the leading cause of death globally. Navigate to the World Health Organization (WHO) website. This global organisation advocates for "better, healthier people all over the world". The core function of WHO is to "direct and coordinate international health through collaboration". WHO has more than 7000 people working in 150 county offices around the world. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) • What do you notice about the incidence of cardiovascular diseases (CVD's) around the world? How is the WHO trying to reduce the incidence of heart attacks? Are some countries or cultures at higher risk of heart attack than others? Why might this be the case?
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND	• The heart consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. • Damage due to heart attack or stroke can damage the heart tissue permanently, making the muscle less flexible and strong.	• What is the difference between regenerative and non-regenerative tissue? • Heart tissue is non-regenerative. What happens to the heart cells after a heart attack? • See ACSHE134 for links and resources • How might heart attack disrupt the function of the heart?

		Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce (ACSSU150	• The heart consists of different groups of cells organised into tissues. • Heart disease can impact people's health and cause short- and long-term health issues.	
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of the heart in terms of the specialised tissue (which is part of a complex body system), in particular cells called cardiomyocytes, which make up heart tissue. • The heart consists of different groups of cells organised into tissues. The Chong group is focusing on cardiomyocytes. • Heart muscle cells are responsible for providing energy for the heart to pump blood around the body. That energy comes from cellular respiration in the mitochondria. Without this energy the heart muscle cells would not contract. • Heart tissue consists of non-regenerative cells. That is, once created, the cells do not regenerate if damaged during heart attack or stroke.	• Referring to the video and the article '*A Heart felt desire to advance stem cell science*' • What are pluripotent stem cells? (Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/) • Why would these cells be beneficial for growing cardiomyocyte cells? • How might the lab be able to grow 'billions of cells' in a dish? • What are the benefits of having a stem cell culture of cardiomyocytes? How is the lab using these cells? • What are some other cells and tissue which make up the heart? • In the video James mentions heart attacks. What happens to the heart during a heart attack? • Explore the Heart Foundation website to find out more: https://www.heartfoundation.org.au/your-heart/heart-conditions/heart-attack • What are the symptoms of a heart attack?
Senior Biology Australian Curriculum – Science as a Human	Unit 2	Working like a scientist AND	• Resources from above and other videos can be used to highlight the nature of how scientists work, such as the role of empathy, which is a value laden emotion. Values such as curiosity, open-mindedness, and scepticism (to name a new) are just some of	• See resources in the section above to discuss the role of empathy in science. There are other values which influence scientific research. • Can you find examples, from this resource collection, in your textbook or other school readings or in the world around you where these values are obvious in science?

Endeavour (SHE)		Laboratory structure and staff	the values which influence scientists' work. A number of values are listed in the column to the right. Value statements are from Corrigan and Smith (2015). *The role of values in teaching and learning science. In Inclusive pedagogy across the curriculum*. • Empathy is the foundation for the Stanford School Design Thinking process. For more information about this model see: • Design thinking bootleg (defines empathy): https://dschool.stanford.edu/resources/design-thinking-bootleg • Introduction to design thinking process guide: https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf • Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to aspects of working as a scientist, such as Associate Professor James Chong who is a doctor and a research scientist. In terms of future careers, students can become aware of the interdisciplinary nature of some jobs. Real world science jobs can exist in silos, such as biology, chemistry etc. but can also straddle 'traditional' silos, such as research and medicine.	• Curiosity – questioning, wonder and mystery that is aroused when attempting to provide explanations for occurrences in the natural world • Parsimony – when there are competing explanations (i.e. hypotheses or models), the simplest explanation is accepted for use • Creativity – creative thinking is when there is little apparent link to other ideas. I.e. thinking outside the box, 'guesses', intuition. • Open-mindedness – being receptive to different ideas and opinions and looking at the same thing from different perspectives. • Rationale thinking – the process of reason – how one ideas links to another. • Empiricism – knowledge derived from using the senses (includes direct and indirect observations). • Scepticism - the general attitude of doubt or questioning knowledge, opinions, beliefs and items presented as 'fact'. • Why are these values important in scientific endeavour? How might these values influence how science is done? For each value, state a benefit and limitation. • When have you exercised these values? Which ones do you value more than others? Rank them from 1-7 where 1 is the most important and 7 the least. • In pairs, take turns listening and talking. The talking person justifies their list. The listening person asks 2 probing questions which aim to challenge any taken for granted assumptions. What new insights have you come to appreciate by doing this? Change roles and start the process again.

	Unit 2 and 3	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) AND The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041) SEE also Unit 3 – Protein structure and function (ACSBL080)	• Beating heart tissue can be grown from stem cells in the laboratory. This tissue can be used for drug testing and development. • This video provides a context for exploring the role of signalling molecules, in particular the protein PDGF-AB. • Use in conjunction with ACSBL055 below – see discussion about current of the use of state of stem cells in mainstream medicine. This also links well to Stem Cell Tourism (see video with Professor Megan Munsie).	• Learn about how scientists have been growing cardiac cells from stem cells in the laboratory: • Researchers Grow Tiny Beating Human Hearts From Stem Cells https://www.popsci.com/researchers-grow-first-ever-beating-hearts-stem-cells/ • Learning to build a heart from the cells up https://www.eurostemcell.org/learning-build-heart-cells • Eight tiny organs grown by scientists https://www.eurostemcell.org/eight-tiny-organs-grown-scientists • In the video Sujitha says "novel therapies and in particular we were looking at the effect of recombinant human PDGF-AB which is a protein as a potential therapy for patients after a heart attack." Using your knowledge of signalling molecules to explain the role this protein might play after a heart attack. • See section below – current use of stem cells in mainstream medicine.
	Unit 2	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL043)	• Use of animals in scientific research has many ethical, social and cultural implications. • Use of human and non-human models has ethical implications as non-human animals are unable to grant consent. How might ethical animal testing be regulated? Who decides what is appropriate and not appropriate for animal handling and use in research? How might these decisions be made? • This is an opportunity to consider the creation of international bodies and	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn diagram to compare and contrast the benefits and limitations of different models. • There are a number of ethical considerations around using animals in scientific research. • You may like to refer the companion module on Ethics and Stem Cells

			committees to discuss these questions and formulate guidelines for practice.	• The video covers ethical implications in the use of animals in research: https://www.brainfacts.org/in-the-lab/animals-in-research/2013/understanding-animal-research • Create a two-column table to compare the strengths and weakness of using a non-human based models (i.e. animal testing) to conduct research into heart injury treatment options.

Senior Biology Australian Curriculum – Science Understanding (SU)	11 (Unit 2)	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)
		
		AND
		
		In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of capillaries) (ACSBL058)
			• See resources above related to heart cell development.
			• Research related to cardiac tissue has focused on ways to regenerate heart tissue for injury repair AND the use of stem cells to develop models for testing drugs. Students can use these contexts as a way of learning more about the nature of cells and how cells develop into tissues and organs.
				• Associate Professor James Chong is very passionate about one day applying stem cell research and science into mainstream cardiology practice.
				• There is often uncertainty about what is currently being practiced and what is a developing technology. This can cause confusion for people, especially when they (or a loved one) have a cardiac issue and are looking for treatment options.
				• Explore how stem cells are currently being used for cardiovascular research in Australia and worldwide. What is currently happening and what is not? What possibilities might stem cells offer patients in the future? (See also Professor Munsie video)
				• Scientists are able to grow organs in the lab using stem cell technologies. Explore some advances below:
				  • https://www.eurostemcell.org/video-stem-cells-myths-truths-and-possibilities
				  • https://www.eurostemcell.org/mini-lab-grown-organs-good-bad-and-mucousy

2. The Neural System

2.1 The Bourne Group: Building tools for brain repair

Professor James Bourne and Dr Jihane Homman-Ludiye

Australian Regenerative Medicine Institute and Monash University

"Brain injury—particularly stroke—is a serious health issue. Some estimates suggest that an Australian has a stroke every ten minutes, and many thousands of people are left with some form of disability afterwards."
Professor James Bourne

Accompanying Resources:
Refer to the Stem Cells Australia web page *'Building tools for Brain repair'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Bourne Group research?

- The Bourne group is exploring ways to develop tools for brain repair. They are interested in learning more about brain diseases and disorders.
- The Bourne group uses non-human primates as model systems. There are ethical implications for using animal models for biomedical research.
- The Bourne group work is a prelude to direct stem cell research. The findings from this group can be used to further stem cell research.
- The Bourne group Understanding how nerve cells behave from in-vitro setting to the system setting

What is the science?

- The process and pathways from stem cell to differentiated nerve cells in the brain in not well understood.
- How to create the best environment for repair after brain injury?
- Stem cells cannot be directly applied to the injury site as injured brain cells release toxins and the area becomes inflamed.
- Potential stem cell therapies would work more effectively is there is less scarring. Infant's brains produce a molecule which can minimise scarring. This molecule is of interest to the Bourne group for creating optimum recovery environments from injured brain tissue.

Where is the Science as a Human Endeavour?

- The general nature of scientific endeavour, such as:
    - Lab structure and pathways: Early career researchers are integral for building a strong research laboratory. They can bring new ideas and a fresh perspective.
    - Women working in science have different needs in relation to workplace conditions (e.g. maternity leave)

- Values: ‘Who you are and what do you bring to the team of scientists’ is of importance when working in a lab
- Models: Using different living systems as models (e.g. primate system to act as a model for the human system)
- Social, cultural and economic influences on scientific research: In this case, acquired nerve damage and resources invested in the prevention and treatment of nerve injuries

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 - 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level /s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Structure of science laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, ECR, associate professor etc.) Science laboratories as a workplace.	• This video features Professor James Bourne and Dr Jihane Homman-Ludiye from the Australian Regenerative Medicine Institute (ARMI). • Professor James Bourne talks about the importance of Early Career Researchers (ECR's). • Dr Jihane Homman-Ludiye spoke about being the only female in her laboratory group. She also mentioned taking time off work for parental leave. • Many workplaces, like ARMI, are committed to supporting staff and promote equal opportunity and equity in employment. Staff are supported with parental leave (maternity and adoption), which can vary in length, but is commonly up to a year with some portion of that time being paid.	• Professor Bourne is the 'head' of the Bourne Lab – what might her role entail? • You might like to refer to the companion module Life as a Researcher • Dr Jihane Homman-Ludiye spoke about being the only female in her laboratory group. • Dr Jihane Homman-Ludiye also mentioned taking time off work to have a baby. This is referred to as parental leave and is available for women who give birth to babies and for other people who become parents. Jihane mentioned negotiating when she would return to work. She may also have negotiated a flexible work option (e.g. part time, if it was available under her workplace agreement). She would discuss all these options with her supervisor at work. • Women and people from minority groups have often been under-represented in science. In a research study conducted by David Chambers (between 1966 and 1977), primary school children were asked to draw a picture of a scientist. Of the 5000 drawings Chambers collected, only 28 were female (all of which were drawn by girls). The pictures

				depicted males in white lab coats, with eyeglasses, lab equipment and books. In more recent research, this trend appears to be shifting, with over 28% of children drawing female scientists (a trend that has occurred since the 1980's). Gender stereotypes of scientists influence people's perceptions of who can be a scientist and can therefore influence students' decision to pursue science as a career. (see for example https://www.theatlantic.com/science/archive/2018/03/what-we-learn-from-50-years-of-asking-children-to-draw-scientists/556025/ • Highlighting the role that women and people from diverse background play in scientific endeavour is important. • To showcase women in STEM, navigate to the STEM Women website and search the database for a female scientist who is doing research in an area of interest for you: https://www.stemwomen.org.au/ • You may want to reach out and contact the scientists and ask about their career journeys so far.
	7-12	Working like a scientist People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121/136)	• Dr Jihane Homman-Ludiye spoke about being the only female in the lab and that it was not what you are but who you are and what you bring that is important in a lab group. This highlights that workplaces are diverse.	• See above and women in STEM website.
	8	Scientific knowledge has changed peoples' understanding of the world and is refined as	• In the past, not much has been known about the way the brain recovers after stroke, trauma or disease.	• "Brain injury—particularly stroke—is a serious health issue. Some estimates suggest that an Australian has a stroke every ten minutes, and

		new evidence becomes available ACSHE134	• Brain injury affects many people around the world. • Our understanding of how the brain recovers has changed, as new evidence has become available. For example, the role that scarring plays on how well the brain can recover is a focus of the Bourne group. • Neurogenesis is the process of neural development and repair. • Our understanding of neurons and whether or not they can be repaired has also changed in recent years. Neuroplasticity describes the changes in neural connections. See here for example.	many thousands of people are left with some form of disability afterwards." Professor Bourne explains that injecting stem cells directly at the site of a brain injury would not aid healing. In your own words, explain why this is not the case. • Why might scarring cause issues for brain tissue repair? • Find out more about how a stroke might lead to brain injury: https://strokefoundation.org.au/About-Stroke • Explore the Stroke Foundation website and find two ways in which our understanding of stroke and stroke prevention might have changed over the last few decades.
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226	• The article 'Building tools for brain repair' suggests that if the Bourne group research is successful, the team will form a collaboration with the Parish Group at the Florey Institute of Neuroscience and Mental Health. Use this example as a way of highlighting how scientists work together.	• The article 'Building tools for brain repair' suggests that if the Bourne group research is successful, the team will form a collaboration with the Parish Group at the Florey Institute of Neuroscience and Mental Health. Explore the Parish Group resources and explain how the Parish group would benefit from the findings of the Bourne Group.
		Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	• In science research, models are used to test hypotheses and run investigations to test new ideas. These can include non-human models (such as rodents, insects and non-human primates), computer modelling and new advances in stem cell research. • Use of human and non-human models has ethical implications as non-human	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn diagram to compare and contrast the benefits and limitations of different models.

			animals are unable to grant consent. How might ethical animal testing be regulated? Who decides what is appropriate and not appropriate for animal handling and use in research? How might these decisions be made? This is an opportunity to consider the creation of international bodies and committees to discuss these questions and formulate guidelines for practice.	• There are a number of ethical considerations around using animal models in scientific research.
	9	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157	• This video is a good catalyst for exploring the pros and cons of using animal models in research. • The following resources may be helpful: • This article links to various articles. The article is useful for background and sections may be useful as an extension reading: https://www.cell.com/neuron/pdf/S0896-6273(16)30784-X.pdf • This website has information on different neurodegenerative diseases. Also see the tab 'in the lab' for information and interactive media related to animals in research and scientific tools and techniques: https://www.brainfacts.org/	• Create a two columns table to compare the strengths and weakness of using non-human based models (i.e. animal testing) to conduct research into brain injury. • There has been discussion and debate about the use of animal models for neuroscience research. Access the following article: https://www.ncbi.nlm.nih.gov/books/NBK100126/ **NB Encourage students to find information they need, rather than reading all of these articles as the language is inaccessible in multiple locations. However, the arguments are interesting. • Why have rodents and non-human primates been used for neuroscience research? Draw up a table to organise your thinking into benefits and limitations for each animal model. Consider biological and ethical considerations. Video about how and why scientists use animal research models: https://www.brainfacts.org/in-the-

				lab/animals-in-research/2013/understanding-animal-research
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE228/ 230	• Millions of people around the world are impacted by brain injuries brought about by stroke and trauma. • The values of society influence the direction of funding and research into better understanding the nature of brain injuries and stroke, as well as potential treatments and prevention of stroke, and treatment for acquired brain injuries (e.g. from accidents). • See for example: • https://strokefoundation.org.au/About-Stroke • https://brainfoundation.org.au/disorders/acquired-brain-injury/	• Find out more about stroke or acquired brain injury as a way of explaining why resources are invested into stroke and brain injury prevention and treatment. Use the following questions to guide your research: • What is a stroke/ acquired brain injury? • Which organs or tissues are impacted? • How many people does it affect (in Australia and worldwide?) • What are the current treatment options available? • What is known about prevention? Can it be avoided? • What are the symptoms? • Explain the nature of support networks for people who have had a stroke or who have an acquired brain injury. • What is one recent advance in science research related to stroke/ acquired brain injury? • What is currently not known about stroke/ acquired brain injury? • Where are scientists currently focusing their research? What are they hoping to achieve in the short term and long term? • Explain how groups are raising awareness of stroke / acquired brain injury (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop Adsel poster) to

				raise awareness and/or fundraising for stroke or brain injury awareness or research.
Australian Curriculum: Science understanding	8	Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce ACSSU150	• In the article 'Building tools for brain repair', Professor Bourne mentions that initially, damaged cells release toxins and swelling occurs. Long-term scarring also occurs, which can cause further damage. • The human body has processes which stimulate healing and repair of damaged tissue. This video offers a context for exploring the nervous system, in particular brain tissue and how body responds when this tissue is damaged. • Stem cells offer potential for brain injury repair. This context can also act as a springboard to consider spinal cord injuries and the ways in which stem cell research is seeking to find treatments for these kinds of injuries.	• "Brain injury—particularly stroke—is a serious health issue. Some estimates suggest that an Australian has a stroke every ten minutes, and many thousands of people are left with some form of disability afterwards." (Page 46) • Explore what a stroke is and how it might lead to brain injury: https://strokefoundation.org.au/About-Stroke • Professor Bourne explains that injecting stem cells directly at the site of a brain injury would not aid healing. In your own words, explain why this is not the case. • Why might scarring cause issues for brain tissue repair? • What implications might scarring have for the functioning of the nervous system in the brain? • The following resources explore how stem cells might benefit other injuries of the nervous system, such as spinal cord injuries: • https://www.eurostemcell.org/spinal-cord-injuries-how-could-stem-cells-help
	9 and 10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175) AND	• This video highlights research on the brain. The brain is part of the nervous system, which coordinates movement and helps the body respond to the environment. Use the context of brain injury (acquired through stroke or trauma) to unpack the	• Find out more about how stoke can lead to brain injury: https://strokefoundation.org.au/About-Stroke • Centre for neurotechnology lesson plans: http://csne-erc.org/content/lesson-plans

		An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by synapses (VCSSU118) NB This SU descriptor is from the Victorian Curriculum	role of different organs, tissues and cells of the nervous system. • NB Teachers can use the Bourne group video in conjunction with videos and resources from the Parish, Pouton and Merson groups to compare and contrast stem cell research related to the nervous system.	• https://thepsychologist.bps.org.uk/volume-29/august/why-research-using-animals-important-psychology
Senior Biology Australian Curriculum – Science as a Human Endeavour		• Structure of science laboratories and staff	• See SHE (red) section above to initiate conversations about the diversity of workplaces and the need to have flexible and inclusive structures to ensure people of different genders and cultures are able to thrive in the workplace. • This video offers the opportunity to raise awareness of the important work of women in STEM.	• See SHE (red) section above
	Units 1-4	• The role of models and modelling in science: Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038) • Design investigations, including the procedure/s to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and	• Animal ethics – using primate models to make predictions about human systems. Professor Bourne mentions that his lab conducts research on non-human primates. See resources above to consider the benefits and limitations of this kind of testing.	• See section above related to animal testing and use of non-human models. • Students can explore the pros and cons of using different kinds of models for testing, in particular animal testing and how this kind of testing can be reduced or replaced by other kinds of models.

		consider research ethics, including animal ethics (ACSBL062)		
		The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)	• See ACSHE135, ACSHE157 and (ACSHE230) above • This context provides an opportunity to discuss the values of science-based research, in particular disorders or conditions which have a higher prevalence in the population than others.	• Consider the role of values in scientific research – do some disorders or diseases get more funding or awareness than others? Are there stigmas and biases towards some conditions that others (e.g. acquired brain injury compared to mental health issues).
Senior Biology Australian Curriculum – Science Understanding content	Unit 2	Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs and systems (ACSBL054) The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• Use the context of brain injury to explore the structure of the nervous system and the structure of neurons.	• How is the nervous system impacted after brain tissue when it is injured through stroke or trauma? Consider structure of the nervous system and what is currently known about the structure of neurons. • See resources above.
	Unit 4	Homeostasis involves a stimulus-response model in which change in external or internal environmental conditions is detected and appropriate responses occur via negative feedback; in vertebrates, receptors and effectors are linked	• In the article, Professor Bourne says "After an injury, and stroke in particular, the environment in the brain is really harsh. A stroke is caused when brain tissue doesn't get enough blood and damage begins immediately. Injured brain cells release toxins and then inflammation, swelling and longer-term	• Use the article "Building tools for brain repair" as a stimulus to explore the body's response when neuron cells are injured through stroke or trauma. The process involves aspects such as consequences of a lack of blood, toxin release from injured cells, inflammation and swelling, and scarring. Draw concept map or flow chart to explain the mode of each

		via a control centre by nervous and/or hormonal pathways (ACSBL110) AND Neural pathways consist of cells that transport nerve impulses from sensory receptors to neurons and on to effectors; the passage of nerve impulses involves transmission of an action potential along a nerve axon and synaptic transmission by neurotransmitters and signal transduction (ACBL112)	scarring cause further damage. Simply adding stem cells into this environment might not do any good, because they are likely not to survive." • Unit 4 involves exploring how the body maintains an internal environment. Injuries to cells stimulate a response by the body. This video offers a context for exploring what happens to brain tissue when it is damaged and the associated cellular responses.	response, why each of these responses may occur and what happens at the cellular level to stimulate the response. • In the article, Dr Leon Teo mentions a molecule which is released from the brains of infants which can minimise scarring. Explain why the Bourne group is interested in this molecule. • Using information from the article, explain what stem cells might do for a person with a brain injury. (This question could be explored by drawing on resources from the Pouton Group (i.e. microglial cells) and Merson Group (i.e. myelin sheath)) • See also: • https://www.eurostemcell.org/image-blog-making-and-re-making-brain

2.2 The Pouton Group: Enlisting the brain's immune cells to fight MS

Professor Colin Pouton and Dr John Haynes

Monash Institute of Pharmacological Sciences

"Only 10% of all drugs developed make it to the chemist shelves." Professor Colin Pouton

Accompanying Resources:
Refer to the Stem Cells Australia web page *'Enlisting the brain's immune cells to fight MS'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Pouton Group research?

- Drug discovery and development.
- Drug discovery is being compromised by poor biological disease modelling. It is difficult to predict the actions of new drugs. Many current models used to test new drugs are not effective. As a consequence, only 10% of all drugs developed make it to chemist shelves.
- Use of stem cells to model neurodegenerative diseases and to screen potential drug therapies.
- There is a particular focus on how cells become and stay degenerate. What causes the cell degeneration process? There is a need to develop drugs which can slow down the degeneration process.

What is the science?

- Drugs are developed to treat diseases.
- Neurodegenerative diseases, such as multiple sclerosis (MS), Alzheimer's and Parkinson's disease develop over many years. The process of neural degeneration is not well understood. There are currently no drugs which can limit neuron degeneration. Therefore, there is limited treatment available for these diseases.
- Microglial cells are immune cells of the brain. They are involved in brain repair and maintenance. Microglia produce a molecule called MERTK, which attaches to dead cells and debris in the brain and triggers microglial cells to clean them up.
- In people with MS, the MERTK molecule function is corrupted. One possible treatment for MS might be to inject functioning microglial cells into the brain of people with MS. These microglial cells would be, in theory, grown from stem cells in a laboratory.
- Some research into microglial transplants have already been conducted on animals, however the next step is to move to human trials.
- Growing stem cells in the laboratory takes time. It takes 60 days for an embryonic stem cell to mature into a mid-brain neuron cell.

Where is the Science as a Human Endeavour?

- The general nature of scientific endeavour, such as:
    - Lab structure and pathways: Research students (Honours, Masters and PhD) and Early Career Researchers (ECRs) are an important part of the research group as they often bring new and innovative ideas. There are benefits for working with young people and encouraging them to think creatively about a problem.
    - Nature of science: Working as a scientist is like detective work. Science is like “a puzzle. A really big puzzle. It’s like trying to do a jigsaw, in the dark, and there’s no picture. And you don’t even know if you have all the bits” (Dr Haynes).
    - Models: The creation and use of models to simulate biological environments as an alternative to animal and human testing of drugs and treatments
    - Collaboration: Collaboration between scientists and research laboratories locally and internationally to enhance knowledge development and scientific advancement
    - Publishing: Sharing research findings advances scientific endeavour (i.e. developing and sharing methods for new biological models helps other scientists test their drugs and disease treatments more efficiently).
    - Social, cultural and economic influences on scientific research and ethical aspects: In this case, the more efficient development of models for drug testing and exploring ways of slowing down brain cell degeneration.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 - 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Structure of scientific laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, ECR, associate professor etc.)	• This video features Professor Colin Pouton and Dr John Haynes from the Monash Institute of Pharmaceutical Sciences (MIPS). • Dr Haynes and Professor Pouton talk about the value of bringing students and young people into the lab as they bring with them new and innovative ideas. They talked about encouraging scientists to think creatively to look at problems from multiple perspectives to develop innovative solutions. • Professor Pouton and Dr Haynes talked about the importance of creativity, innovation and the capacity to think for themselves and on their feet. • Research laboratories support and induct research students into the laboratory via training. • Training and induction are important processes when staring a new job as laboratories can be dangerous places which often contain hazardous chemicals and expensive equipment. Careful induction and training ensure the safety of staff, the safe handling and use of lab equipment and ensures staff are able to use the lab	• What might be the difference between a research lab (at CSIRO https://www.csiro.au/ see the Laslett Group, for example) a research group (e.g. at ARMI https://www.armi.org.au/ for example, see the Ramialison group) and an Institute (e.g. the Monash Institute of Pharmaceutical Sciences (MIPS))? • What is the focus of MIPS? • Professor Colin Pouton is the 'head' of the Pouton Lab – what might his role entail? • Professor Pouton and Dr Haynes talked about the value of inviting new people into the lab, such as students and new scientists. Think of a time when you were new to a workplace, school, club or team. What new ideas did you think of and how might/did they benefit the group? • Professor Pouton and Dr Haynes also talked about the importance of creativity, innovation and capacity to think. • Draw up a 3 column by 3 row table. Use 'creativity', 'innovation' and 'capacity to think' as the column headings. Use 'looks like', 'feels like' and 'sounds like' as the row headings. Fill in the table, describing what creativity, innovation and capacity to think looks like (when you see yourself or others do it), feels like (when you do it) and sounds like (what words do you associate with these capabilities?). NB it might be helpful to define what the words mean.

			equipment most effectively. You may like to refer to the companion module Life as a Researcher.	• Induction (i.e. the process of introducing a new person to the processes of a new workplace/ environment to ensure they can carry out tasks safely) into a new environment is common, particularly for safety reasons. Think about the last time you travelled on an aeroplane. Do you remember the safety briefing? In particular, how to use the life jacket. This was to ensure you knew the process of how to safely and effectively operate the life vest in case of an emergency. When starting at a new school, workplace, club etc., did you receive any induction/ workplace/ safety training? What made the training/ induction helpful? Not helpful? In the case of not helpful, what could have been done to make it more useful? • If you had to induct a new student into your science classroom, what things would you pay attention to? Create a list of 10 points you would cover in a science lab induction for new students. Briefly explain each item you include. NB: not all of your ideas have to be related to safety.
	7-12	Working like a scientist E.g. People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE136	• Scientists often comment that they enjoy solving problems, enjoy planning and conducting their own research and enjoy working collaboratively. • Dr John Haynes said he enjoyed working as a scientist because it was like detective work and solving puzzles. Every day he gets to work a bit more on the puzzle. Although John compares his work to a jig-saw puzzle, there are some similarities and differences in the way he works as an experimental scientist. These include: - Jigsaws only have one solution. John's work may result in multiple possible solutions, each one with benefits and	• Dr John Haynes said that science was like "…a puzzle. A really big puzzle. It's like trying to do a jigsaw, in the dark, and there's no picture. And you don't even know if you have all the bits". What do you like (or not like) about puzzles or detective work? • In John's quote above he likens his work as a scientist to completing a puzzle. A key feature of is description is the uncertain nature of his work. An experiment is big puzzle and he does not have instructions or a picture to see if his work is going to be useful. How do you think science is (and is not) like a jig-saw puzzle? Draw up a two-column table and list all the ways science is and is not, like a jig-saw puzzle. • John and Colin are working in a laboratory where they are planning and conducting experiments to develop new

			limitations. Science rarely results in one correct or 'right' answer. - Jigsaws are a copy of a pre-existing image. The aim of a jigsaw is to make the same image as the picture on the box. When scientists start out, they don't have a specific solution in mind, and they don't have a picture to follow. Similar to the point above, there may be many different solutions, not one right solution. Therefore, there can be no picture to follow. - Jigsaws require trial and error, finding patterns in multiple pieces (e.g. looking for blue pieces which might make the water part of a landscape picture). Experimental science also requires trial and error when trying new method and procedures. - The aim of a jigsaw is to make the finished picture. Although scientists might have an end point in mind when they start out (e.g. they want to develop a method for growing an embryonic stem cell into a brain neuron), but they may not know specific details on how to achieve this. The process involves figuring out how to solve the problem. - A jigsaw consists of paper, wood or plastic pieces cut into similar shapes. The process of scientific endeavour requires the use of different methods, equipment and consumables. As John said in the video, scientists are trained in different methods and techniques, so they have a	knowledge about developing reliable models for drug testing. However, scientific knowledge can arise through many different ways, not just performing experiments. This also requires creativity, innovation and the capacity to think about unexpected results. It also requires a curiosity about the world around you. Compare how the Pouton Lab's work is similar and different from Alexander Fleming. (NB Fleming discovered penicillin growing in unwashed petri dishes).

			variety of methods to use when solving their puzzles. • Students who enjoy puzzles and solving problems may enjoy a career in one of the STEM disciplines (Science, technology, engineering and maths).	
	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• In the past, not much has been known about the way neurodegenerative diseases develop. Diseases such as multiple sclerosis (MS), Alzheimer's and Parkinson's disease occur because neurone cells are compromised. These diseases develop over years, meaning support and treatment for sufferers of these diseases have social, cultural and financial implications. Neurodegenerative diseases affect a large number of people worldwide. • Our understanding of these diseases has changed, as new evidence has become available. For example, the role that microglial cells play in brain clean up and repair. • Our understanding of neurons and whether or not they can be repaired has also changed in recent years. Neuroplasticity describes the changes in neural connections. See for example: https://faculty.washington.edu/chudler/plast.html • Stem cells also offer the potential for supporting patients with neurodegenerative diseases.	• Select one of the following neurodegenerative diseases and find out more about it. Use the questions below to guide your research. • Multiple Sclerosis (MS) – see https://www.ms.org.au/ • https://www.closerlookatstemcells.org/stem-cells-medicine/multiple-sclerosis/ • Alzheimer's disease - see http://www.alz.org/au/dementia-alzheimers-australia.asp • Parkinson's disease – see https://www.parkinsons.org.au/ • Motor neurone disease (MND) - https://www.mndaust.asn.au/Home.aspx • Huntington's disease - see https://www.huntingtonsvic.org.au/ • What is the condition? • Which organs or tissues are impacted? • How many people does it affect (in Australia and work wide?) • What is the current state of treatment options available? • Is this disease inherited or can it be acquired? • What are the symptoms? • Explain the nature of support networks for people with the disease. • What are some advances in science research related to this disease? • What is currently known and not known about this disease?

				• Where are scientists currently focusing their research for this disease? What are they hoping to achieve in the short term and long term? • Explain how groups are raising awareness of the disease (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop poster) to raise awareness and/or fundraising for the disease you have researched. • Stem cells could help people with neurodegenerative diseases. Use the Stem Cells Australia website 'Body Map' to find out how stem cells can or may have the potential to treat different conditions.
	7 & 8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE223/226	• The Pouton lab scientists at MIPS are currently developing stem cell models that are of interest to Professor Trevor Fitzpatrick and colleagues at the Florey Institute of Neurosciences and Mental Health. Although working on different aspects of stem cell science and on different diseases, working together, these groups are able to collaborate and share their findings to advance our understanding about potential treatments for MS. The Pouton lab is working on growing stem cells into microglial cells and the group at the Florey can use the findings from that research to advance their research on MS.	• Access the article "*'Enlisting the brain's immune cells to fight MS'* from the Stem Cells Australia website. • Draw a cartoon strip or flow chart to explain the role of microglial cells in the brain. • Draw a mind map to explain how the Pouton lab and the scientists at the Florey are working together to find out more about neurodegenerative diseases.
	7 & 8	Solutions to contemporary issues that are found using science	• In science research, models are used to test hypotheses and run investigations to test new ideas. These can include non-human models (such as rodents, insects and non-	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn

		and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	human primates), computer modelling and new advances in stem cell research. • Use of human and non-human models has ethical implications as non-human animals are unable to grant consent. How might ethical animal testing be regulated? Who decides what is appropriate and not appropriate for animal handling and use in research? How might these decisions be made? This is an opportunity to consider the creation of international bodies and committees to discuss these questions and formulate guidelines for practice.	diagram to compare and contrast the benefits and limitations of different models. • There are a number of ethical considerations around using animal models in scientific research. You may like to refer to the companion module Ethics and Stem cells • Support video which highlights some of the different models that scientists use. The video also covers ethical implications in the use of animals in research: https://www.brainfacts.org/in-the-lab/animals-in-research/2013/understanding-animal-research
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157 AND Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	• Brain neuron cells grown from stem cells in a laboratory environment can be used as models for testing anti-degeneration drugs and treatments without having to test on people or animals. • Growing brain neuron cells in a dish enables scientists to test new drugs and treatments for people with neurodegenerative diseases. • Previous models for testing new drugs have been unreliable. Causing about only 10% of all drugs developed to make it to chemist shelves. The lack of success for 90% of developed drugs has significant impact on the amount of funding being invested into drug research and development. If the process were made more efficient, funding could be more efficient, and funds could be shared elsewhere. • This video is a good catalyst for exploring the pros and cons of using animal models in research.	• See questions and activities in the section above • Building tumours in the lab – see https://scienceblog.cancerresearchuk.org/2016/07/04/building-tumours-in-the-lab-a-how-to-guide/ • Create a two column table to compare the strengths and weakness of using a non-human based models (i.e. animal testing) to test breast cancer treatments. • There has been discussion and debate about the use of animal models for neuroscience research. Access the following article: https://www.ncbi.nlm.nih.gov/books/NBK100126/ NB Encourage students to find information they need, rather than reading all of these articles as the language is inaccessible in multiple locations. However, the arguments are interesting. • Why have rodents and non-human primates been used for neuroscience research? Draw up a table to organise your thinking into benefits and limitations for each animal model. Consider biological and ethical considerations.

			• The following resources may be helpful: • This article links to various articles. The article is useful for background and sections may be useful as an extension reading. https://www.cell.com/neuron/pdf/S0896-6273(16)30784-X.pdf • Brain facts.org – This website has information on different neurodegenerative diseases. Also see the tab 'in the lab' for information and interactive media related to animals in research and scientific tools and techniques. https://www.brainfacts.org/	• Video about how and why scientists use animal research models: https://www.brainfacts.org/in-the-lab/animals-in-research/2013/understanding-animal-research
		Values and needs of contemporary society can influence the focus of scientific research ACSHE230	• Millions of people around the world are impacted by neurodegenerative diseases and acquired brain injuries. • Diseases such as Multiple Sclerosis (MS), Alzheimer's and Parkinson's disease occur because neurons are compromised. • Some neurological diseases develop over years, meaning support and treatment for sufferers of these diseases have social, cultural and financial implications (i.e. people with the disease may need ongoing specialised care, there may be cultural stigmas associated with brain disease and there are financial costs associated with supporting and treating people affected by neurological diseases). Neurodegenerative diseases affect a large number of people worldwide. • The values of society influence the direction of funding and research into better understanding the nature and potential	• Select one of the following neurodegenerative diseases and find out more about it. Use the questions below to guide your research. • Multiple Sclerosis (MS) – see https://www.ms.org.au/ • https://www.closerlookatstemcells.org/stem-cells-medicine/multiple-sclerosis/ • Alzheimer's disease - see http://www.alz.org/au/dementia-alzheimers-australia.asp • Dementia - see https://www.dementia.org.au/ • Motor neurone disease (MND) - https://www.mndaust.asn.au/Home.aspx • Huntington's disease - see https://www.huntingtonsvic.org.au/ • What is the condition? • Which organs or tissues are impacted? • How many people does it affect (in Australia and worldwide?) • What is the current state of treatment options available? • Is this disease genetic or can it be acquired? • What are the symptoms?

			treatments and prevention methods for neurodegenerative diseases and disorders. • Alzheimer's disease and dementia have become of greater interest in recent years, possibly due to humans living longer and the increased prevalence and awareness of neural degeneration in the ageing population.	• Explain the nature of support networks for people with the disease. • What are some advances in science research related to this disease? • What is currently known and not known about this disease? • Where are scientists currently focusing their research for this disease? What are they hoping to achieve in the short term and long term? • Explain how groups are raising awareness of the disease (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop poster) to raise awareness and/or fundraising for the disease you have researched.
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions ACSSU149	• The brain is made up of neurons (nerve cells) and glial cells. • Glial cells are essential for healthy neuron function. Students can learn about glia within the context of better understanding how disorders which involve neurons can impact brain repair and function. • Aseptic technique is mentioned in the video related to growing stem cells in the laboratory. Special care needs to be taken to avoid introducing foreign materials and contaminants into the stem cell cultures. • This is a great opportunity to introduce basic aseptic techniques and the reasons why they exist in laboratories at the year 7 and 8 level. Aseptic techniques aim to avoid introducing bacterial or fungal cells into culture dishes. These kinds of cells grown well in the warm,	• You have probably heard of neurons… but have you heard of glial cells? They are very important cells found in the brain. Find out what glial cells are and what they do for you to keep your brain healthy: https://faculty.washington.edu/chudler/glia.html • What would happen to your brain if there were no glia? • Find out more about basic aseptic techniques in a laboratory and the reasoning behind them. See for example: • https://www.youtube.com/watch?v=cuCSELaQ_Go • https://www.healthline.com/health/aseptic-technique#types • When have you seen different kinds of aseptic techniques around the home or in other places? Think about what happens when you cut yourself, or when cleaning bathrooms or when maintaining your personal hygiene. What kinds of products have you seen which are used to control or limit bacterial and fungal cell growth?

			nutrient rich environments of the enclosed dishes and can comprise the stem cell cultures.	• Is it always a good idea to control bacterial and fungal cell growth in our everyday lives?
	8	Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce ACSSU150	• In the video, Dr Haynes talks about turning embryonic stem cells into mature mid-brain neurones. These cells are responsible for controlling key functions of the brain, such as voluntary movement and working memory. • Different kinds of cells make up the brain tissue. Different cells play different roles to maintain brain function. • It is cells like these mid-brain neurons which can be affected when the brain is damaged. This can have flow on effects for movement, memory and other functions.	• Read more about the architecture of the brain and the different kinds of cells which make this remarkable organ and the nervous system. • See for example - Brain basics: https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Life-and-Death-Neuron • Create an informative brochure or media piece which explains how the cells and tissues of the brain are affected in a person who has been diagnosed with a neurodegenerative disease.
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment ACSSU175	• This video highlights research on the brain. The brain is part of the nervous system, which coordinates movement and helps the body respond to the environment. • Many diseases interfere with the function of the nervous system (see examples above). Use the context of irregularities of nerve cells (as brought about by a number of disorders or inquiries) as a context to unpack the role of different organs, tissues and cells of the nervous system.	• Additional neuroscience support websites: • Centre for neurotechnology lesson plans: http://csne-erc.org/content/lesson-plans • https://thepsychologist.bps.org.uk/volume-29/august/why-research-using-animals-important-psychology • Combine with ACSHE230 above
	9/10 VC	An animal's response to a stimulus is coordinated by its central nervous system	• In the video, Dr Haynes talks about turning embryonic stem cells into mature mid-brain dopamine neurons. These cells are responsible for controlling key functions of	• Encourage students to learn about the different types of stem cells using to the Stem Cells Australia website. • What is the difference between tissue stem cells and pluripotent stem cells (iPSCS)?

		(brain and spinal cord); neurons transmit electrical impulses and are connected by synapses (VCSSU118) NB This SU descriptor is from the Victorian Curriculum	the brain, such as voluntary movement and working memory. These cells produce dopamine, a neurotransmitter which is a molecule that transmits signals between nerve cells. • It is the dopamine producing nerve cells in the substantia nigra which are reduced in people with Parkinson's disease. • NB Teachers can use the Pouton group video in conjunction with videos and resources from the Parish, Bourne and Merson groups to compare and contrast stem cell research related to the nervous system	• Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • Which type of stem cells are more likely to be used for treating neurodegenerative diseases?
Senior Biology Australian Curriculum – Science as a Human Endeavour		Structure of science laboratories and staff	• See SHE (red) section above to initiate conversations about the nature and structure of a scientific laboratory as a workplace, such as the value of research students and early career researchers.	• See SHE (red) section above
		Working like a scientist	• See SHE (red) section above to initiate conversation about the nature of scientific endeavour. In particular the role of creativity, innovation and the capacity to think critically as doing science is compared to doing puzzles and requires certain attributes. These attributes extend to jobs outside science and are relevant for students' everyday decisions, such as making purchases, how to maintain a healthy lifestyle and how to act safely. These can be considered transferable skills. • Compare to other characteristics of scientific endeavour, such as the value of failure and mistakes (see the Merson Group) and problem solving (see the Laslett Group).	• See SHE (red) section above in relation to questions and activities related to creativity, innovation and capacity to think critically.

		The role of models and modelling in science: Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	• Growing brain neuron cells in a dish enables scientists to test new drugs and treatments for people with neurodegenerative diseases. • See section (ACSHE135) above about animal modelling	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. • See section above about animal modelling. • Students can explore the pros and cons of using different kinds of models for testing, in particular animal testing and how this kind of testing can be reduced or replaced by other kinds of models.
		• The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)	• See ACSHE135, ACSHE157 and ACSHE230 above	• Consider the role of values in scientific research – do some disorders or diseases get more funding or awareness than others? Are there stigmas and biases towards some conditions more than others?
Senior Biology Australian Curriculum – Science Understanding (SU)	Unit 2	• Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs and systems (ACSBL054) • The specialised structure and function of tissues,	• See resources above related to the different kinds of nerve cells, brain tissue and the role of these cells for maintaining body function. • In the video, Dr Haynes talks about turning embryonic stem cells into mature mid-brain dopamine neurons. These cells are responsible for controlling key functions of the brain, such as voluntary movement and working memory. • These cells produce dopamine, a neurotransmitter which is a molecule that transmits signals between nerve cells.	• What are tissue stem cells and how are they similar and different to pluripotent stem cells? • Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • In the Pouton lab example, explain why the scientists are using embryonic stem cells. • Access the article "Enlisting the brain's immune cells to fight MS" • Draw on the article and other reference material to compare the roles of nerve cells and microglial cells –

		organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• The Pouton group uses embryonic stem cells, which can give rise to many different cell types. ESC's can be compared to pluripotent stem cells (see for example the Laslett group)	what do they do and why are these important specialised cells? • See also sections above regarding specific cell types and functions.

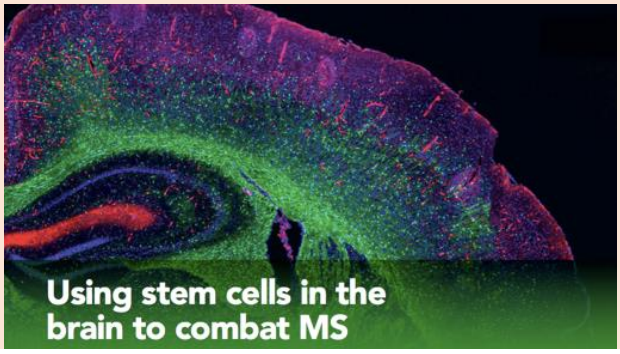
2.4 The Merson Group: Using stem cells in the brain to combat MS

Dr Toby Merson

Monash University

"MS is estimated to impact over 25,000 people in Australia. On average over 10 people a week are diagnosed with MS." (MS Australia)

Accompanying Resources:
Refer to the Stem Cells Australia web page *'Using stem cells in the brain to combat MS,'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.



What is the focus of the Merson Group research?

- Development and differentiation of stem cells in the brain.
- Understanding how the myelin compound of nerve cells is produced and how myelin might be regenerated in cells where it is damaged.
- Use of different microscopy techniques and technologies to visualise what happens to stem cells in their natural environment.

What is the science?

- Stem cells in the brain can lead to the production of many different specialised brain cells.
- Myelin is a compound produced by nerve cells to provide insulation for the nerve signal. The myelin sheath enables nerve action to occur at efficient rates.
- In people with multiple sclerosis (MS), the myelin sheath is damaged and nerve cell function is reduced. This can lead to difficulty controlling body movements.
- Modern day microscopy technology enables the visualisation of cells:
    - This can include fluorescent microscopy, which uses fluorescent markers to light up specific sections of cells and particular molecules within and outside cells.
    - Electron microscopy enables very high magnification of cells to visualise what is happening at the cellular level.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Interest: Being excited about the laboratory work can lead to increased interest. Building passion and ownership can lead to increased job enjoyment and satisfaction.
    - Nature of science: An important part of doing science is learning through mistakes. ".. an important part of doing science is learning through mistakes. Science isn't perfect. Sometimes in discovery it's actually when people have done something that

they didn't intend to do, so it's really important to give people that spirit of discovery." (Dr Merson)

- Agency: Moral imperative related to research into brain stem cells to understand more about these cells to help people living with MS.
- social, cultural and economic influences on scientific research and ethical aspects – in this case, the moral imperative of better understanding the role of brain stem cells to help people living with MS.

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 - 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Working like a scientist involves making mistakes and learning from them E.g. People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE136	• Scientific endeavour is driven by a need to know, a keen interest and passion to know something. • The accompanying activities (see right) ask students to explore the nature of some of failures and serendipitous moments which have led to new knowledge. • Highlighting these kinds of stories are beneficial because they show that scientists are humans and are fallible. Research suggests this can help students relate better with scientists as these kinds of stories 'normalise' scientists and can lead to increased student progression into STEM disciplines. In addition, these kinds of stories address the myth that there is only one scientific method. Knowledge can be generated in number of ways – experiments are just one way. Mistakes, failures, intuition and serendipitous moments are valuable experiences for the development of knowledge. Speaking about the value of these experiences further humanises scientific endeavour. • See for example:	• Many scientific discoveries which have changed our lives have come from mistakes or serendipitous moments rather than from experimental investigations. Some examples are listed below. Find out more about some discoveries that were made by mistake or misadventure and how they have changed our lives. For example: • Discovery of quinine • Discovery of X-rays by Wilhelm Roentgen • Discovery of the sweetener Sweet'N Low • Discovery of penicillin by Sir Alexander Flaming • Discovery of insulin • See for example: • https://www.sciencealert.com/these-eighteen-accidental-scientific-discoveries-changed-the-world • https://www.popularmechanics.com/science/health/g1216/10-awesome-accidental-discoveries/ • https://www.npr.org/2016/02/24/467805055/whoops-twelve-tales-of-accidental-brilliance-in-science • Louis Pasteur suggested that "fortune favours the prepared mind". Scientists who have made discoveries through mistakes did have some assistance. They had some knowledge of the field in which they were working, they had a keen sense of curiosity and a degree of open-mindedness, which enabled them to consider things that were different or out of the ordinary.

			• Opinion: To Groom Better Scientists, Harness the Power of Narrative https://undark.org/2019/01/24/to-groom-better-scientists-harness-the-power-of-narrative/ • The Value of Failing: https://www.theatlantic.com/education/archive/2018/04/the-value-of-failing/558848/ • An astronaut is challenging students and teachers to change education to embrace failure – and enhance success: https://australiascience.tv/vod/lessons-from-an-astronaut-we-have-to-teach-students-how-to-fail/ • In the video Dr Merson said: "When I train people in the lab, I think it's really important to excite people about the work that they're going to be pursuing. But an important part of doing science is learning through mistakes. Science isn't perfect. Sometimes in discovery it's actually when people have done something that they didn't intend to do, so it's really important to give people that spirit of discovery, the freedom to explore and really that builds the passion that people have ownership over what they're doing."	• Dr Merson talks about mistakes as being an important part of learning. Scientific endeavour is all about questions we do not yet know the answer to. There is no recipe to follow. Therefore, scientists have to rely on mistakes and failures as a way of learning. Science is an uncertain journey of discovery, where the end product is not known, and new knowledge is developed in small steps. In addition, not every experiment ends in success or goes as a scientist expects. Sometimes experiments will raise more questions than they answer. • Consider when you have failed or made a mistake. What did you learn? How did it alter your behaviour in the future? • We do not often read about failure and mistakes in science. Scientific discoveries and advances are often reported and communicated when they are finished or deemed 'successful'. The failures that were integral to the development of the new knowledge are not reported. This can give a false sense of how science is really done. The following articles are written by scientists about the important role of failure. • Scientists need to talk about failure. Emily Dreyfuss: https://www.wired.com/story/scientists-need-more-failure-talk/ • *Failure in Science Is Frequent and Inevitable--and We Should Talk More about It* - Maryam Zaringhalam https://blogs.scientificamerican.com/guest-blog/failure-in-science-is-frequent-and-inevitable-and-we-should-talk-more-about-it/ • How might your school science experience be similar and different to the scientific endeavour highlighted by these scientists? • Why might knowing the important role of failure and uncertainty be useful for people when thinking about science?

	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• In the past, little was known about the way neurodegenerative diseases develop and how to treat people who had such diseases. • Diseases such as multiple sclerosis (MS), Alzheimer's and Parkinson's disease occur because neuron cells are compromised. • These diseases develop over years, meaning support and treatment for sufferers of these diseases have social, cultural and financial implications. That is, as more about the disease and the needs of the people who are affected by them becomes known, there will be social, cultural and financial implications. • Neurodegenerative diseases like MS affect a large number of people worldwide. • Our understanding of MS has changed, as new evidence has become available. For example, the role that myelin plays in the insulation of nerve cells has become better understood. The process of myelin replacement is called remyelination. In people who have MS, remyelination fails. There are currently no therapies for replacing lost myelin. • Stem cells also offer the potential for supporting patients with MS.	• Multiple Sclerosis (MS) is a neurodegenerative disease. Find out more about it, using the questions below to guide your research. • Multiple Sclerosis (MS) – see https://www.ms.org.au/ • How could stem cells help? See https://stemcellsaustralia.edu.au/conditions/explore/multiple-sclerosis/ • Which organs or tissues are impacted? • How many people does it affect (in Australia and worldwide?) • What is the current state of treatment options available? • Is this disease genetic or can it be acquired? • What are the symptoms of MS? • Explain the nature of support networks for people with MS. • What are some recent advances in science research related to MS? • Where are scientists currently focusing their research for MS? What are they hoping to achieve in the short term and long term? • Explain how groups are raising awareness of MS (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop poster) to raise awareness and/or fundraising for MS.
		Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may	• In the video Dr Merson speaks of a 'moral imperative' to assist people with MS. • Dr Merson also talks about the use of imaging in the form of microscopy to find out more about nerve stem cells in their natural environments.	• After finding out more about MS and what it might mean for people living with the disease, why might Dr Merson say that research into stem cells is a 'moral imperative'? • Explore the timeline of advances in microscopy: https://www.sciencelearn.org.nz/resources/1692-history-of-microscopy-timeline

		involve ethical considerations ACSHE135		• What would you say at the two most important advances in the timeline of the microscope? Provide an explanation for your answer.
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157	• Dr Merson uses the analogy of a tree to explain the nature of stem cells. Consider the nature of the analogy and how it is similar and different to the nature of stem cells. For example, a tree has specialised tissues which play important roles, such as the roots, vascular tissue, wood, branches, leaves etc. • Comparing how stem cells and the tree analogy are similar and different can help students clarify their understanding of stem cells and the structure of plants and create a 'need to know'.	• Dr Merson uses the analogy of a tree to explain the nature of stem cells. Although analogies are useful for helping us connect new ideas to things we already know, they are not entirely accurate. See related questions and activities in the section above. • Compare how stem cells are similar and different to the tree analogy. Use a Venn diagram to organise your thoughts. • Using an analogy, like the tree analogy, is a kind of model. Think of another analogy through which you could explain the nature of stem cells to a student in year 7 or 8.
		Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192	• Advances in technology and science has led to greater understanding of the nature of MS and how to help people living with MS. Students can learn more about MS by exploring the history of the disease and learning about how the modern-day understanding of MS has come about. Through this exercise, the nature of science can be highlighted, such as: changes in knowledge as new evidence becomes available (see also ACSHE119/134), the use of multiple disciplines, such as STEM disciplines to develop new knowledge, the nature of new discoveries science, experimentation and the ethics of such (e.g. experimentation with the use of strychnine, gold and silver injections etc.) and the important role of mistakes and failure in knowledge development.	Explore the history of what is known about MS by reading the following "History of MS: The Basic facts" by Dr Loren Rolak. https://www.nationalmssociety.org/NationalMSSociety/media/MSNationalFiles/Brochures/Brochure-History-of-Multiple-Sclerosis.pdf • Create a timeline which highlights some of the main discoveries related to MS. How have each of the discoveries been beneficial for patients and/or researchers? • What would you say are the three most significant discoveries related to MS? Provide a brief reason for your choices. • In the video Dr Merson talks about the important role of mistakes. He said "… But an important part of doing science is learning through mistakes. Science isn't perfect. Sometimes in discovery it's actually when people have done something that they didn't intend to do, so it's really important to give people that spirit of discovery, the freedom to explore and really that builds the passion that people have ownership over what they're doing."

			• This is a good opportunity to highlight the nature of knowledge development. In science, the answer is not yet known. It is the desire to know and answer questions that drives scientific endeavour. • Dr Merson also talks about the use of imaging in the form of microscopy to find out more about nerve stem cells in their natural environments. Advances in microscopy has come about due to the STEM disciplines working together.	• What were some mistakes or failures along the way that helped scientists to learn more about MS? • When have you learned from mistakes or failures? Advances in microscopy: • Explore the timeline of advances in microscopy: https://www.sciencelearn.org.nz/resources/1692-history-of-microscopy-timeline • Which 2 advances would you argue were the most significant and why? • What is the difference between light microscopy and fluorescence microscopy? Create a chart which compares the two - but add a third column. Once you have compared these two, add electron microscopy to your table. How does it compare to the other kinds of microscope technologies? • Light and fluorescence microscopy compared: https://www.news-medical.net/life-sciences/Fluorescence-Microscopy-vs-Light-Microscopy.aspx • Electron microscopy: https://www.explainthatstuff.com/electronmicroscopes.html • How might scientists be using fluorescence and electron microscopy to examine myelin production in nerve stem cells? See for example: New strategy for brain repair in multiple sclerosis https://www.eurostemcell.org/new-strategy-brain-repair-multiple-sclerosis
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE230	• Millions of people around the world are impacted by neurodegenerative diseases and acquired brain injuries. Diseases such as multiple sclerosis (MS), Alzheimer's and Parkinson's disease occur because neurons	• The Merson group is focusing its research on stem cells in the brain which are linked to multiple sclerosis. Find out more about MS and why the Merson group is focusing research on the regeneration of myelin. • Multiple Sclerosis (MS) – see https://www.ms.org.au/

			are compromised. Some neurological diseases develop over years, meaning support and treatment for sufferers of these diseases have social, cultural and financial implications (i.e. people with the disease may need ongoing specialised care, there may be cultural stigmas associated with brain disease and there are financial costs associated with supporting and treating people affected by neurological diseases). Neurodegenerative diseases affect a large number of people worldwide. • The values of society influence the direction of funding and research into better understanding the nature and potential treatments and prevention methods for neurodegenerative diseases and disorders. • MS is estimated to impact over 25,000 people in Australia. On average over 10 people a week are diagnosed with MS. • The high incidence of people developing MS has led to increased funding and scientific research into prevention and treatment of MS.	• Multiple sclerosis: how could stem cells help? (Euro Stem cells): https://www.eurostemcell.org/multiple-sclerosis-how-could-stem-cells-help • What is multiple sclerosis? • Which organs or tissues are impacted? How many people does it affect (in Australia and worldwide?) • What is the current state of treatment options available? • Is this disease genetic or can it be acquired? • What are the symptoms? • Explain the nature of support networks for people with the disease. • What are some advances in science research related to this disease? • What is currently not known about this disease? • Where are scientists currently focusing their research for this disease? What are they hoping to achieve in the short term and long term? • How might stem cells be useful for people with MS? • Explain how MS support groups are raising awareness of the disease (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop poster) to raise awareness and/or fundraising for MS.
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions ACSSU149	• "Neurons are the structures in the nervous system that allow us to think, see, hear, speak, feel, eliminate (bowel/bladder) and move. Each neuron is made up of a cell body and an axon (the extension of the cell body that carries messages). Most of the axons in the central nervous system are wrapped in myelin, a substance rich in lipids (fatty substances) and proteins. Like the coating around an electrical wire, myelin insulates	• NB This section could be explored in the context of ACSHE134 above. Students can learn about the structure of neurons as they learn about the nature of MS, such as how a decrease in myelin surrounding nerve cells can lead to a decrease in motor skills. • You have probably heard of neurons… but have you heard of myelin? Myelin is a very important substance which insulates nerve cells.

			and protects the axon and helps speed nerve transmission. Myelin is present in the central nervous system (CNS) and peripheral nervous system (PNS); however only the central nervous system is affected by MS. CNS myelin is produced by special cells called oligodendrocytes. PNS myelin is produced by Schwann cells. The two types of myelin are chemically different, but they both perform the same function — to promote efficient transmission of a nerve impulse along the axon." https://www.nationalmssociety.org/What-is-MS/Definition-of-MS/Myelin.	• Find out what why myelin is so important for nerve cells: https://www.eurostemcell.org/multiple-sclerosis-how-could-stem-cells-help • What is Myelin? (YouTube) https://www.youtube.com/watch?v=d9pGc2BeVvE • How is myelin produced? • Draw a flow chart to explain what would happen to a person who was walking if myelin was removed from their nerve cells. Include the following words: nerve cell, axon, myelin, muscle tissue, footstep.
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175 AND An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by	• This video highlights research on nerve cells, in the context of MS and the importance of myelin for nerve function. • Nerve cells are present in the brain, which is part of the nervous system, which coordinates movement and helps the body respond to the environment. • MS is a disease which interferes with the function of the nervous system. Use the context of irregularities of nerve cell function, as brought about by a degeneration of myelin in people with MS, as a context to unpack the role of different organs, tissues and cells of the nervous system. • Consider the purpose of the myelin sheath. Glial cells called oligodendrocytes are responsible for making myelin. See: https://www.eurostemcell.org/new-strategy-brain-repair-multiple-sclerosis	• Find out more about the role of myelin which insulates nerve cells: • Jonathans Story - Cells (oligodendrocytes) and myelin production (Euro stem cells): https://www.eurostemcell.org/jonathans-story-stem-cells-and-myelin • New strategy for brain repair in multiple sclerosis https://www.eurostemcell.org/new-strategy-brain-repair-multiple-sclerosis • Can combine with ACSHE230 above

		synapses (VCSSU118) NB This SU descriptor is from the Victorian Curriculum	• See video from Euro Stem Cells – Jonathan's story about oligodendrocytes and how they lead to myelin production.	
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	Unit 2	Working like a scientist	• See SHE (red) section above for stimulating conversations about the role of failures, mistakes and uncertainty in scientific endeavour. • Resources from above and other videos can be used to highlight the nature of scientists' work, such as detective work, solving puzzles, being curious, posing questions, learning from failure, collaborating with a range of people from different backgrounds and experiences.	• Consider other mistakes or failures in areas of biology that have led to advances in knowledge. The discovery of penicillin is a good example for senior biology. • Use the articles from practicing scientists (see Dreyfuss and Zaringhalam in the red section above) to explore the nature of scientists' work – additional articles are listed below, which offer greater insights into the everyday realities and nature of the work of these scientists. • One reason young people don't go into science? We don't fail well. https://www.statnews.com/2017/03/21/science-research-fail/ • An Experiment That Didn't Work. Zaringhalam (2017) https://blogs.scientificamerican.com/observations/an-experiment-that-didnt-work/ • See resources in the section above to discuss what is involved in working as a scientist. Contrast with other videos – for example, contrast the role of failure highlighted by Dr Merson in the Merson group video with Dr Haynes in the Pouton group who talks about science work as being like a puzzle.
		The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)	Social, cultural, economic and ethical factors: • "Multiple sclerosis (MS) is an autoimmune • MS is estimated to impact over 25,000 people in Australia. On average over 10 people a week are diagnosed with MS. • The high incidence of people developing MS has led to increased funding and scientific research into prevention and treatment of MS.	• Formulate a debate and consider the cost of medical research into MS. Where and how should research funding be distributed? Consider the economic questions related to resourcing for research and treatment. Cultural and social considerations may include exploring the values of different cultures - which diseases tend to be given preference or are valued more than others?

Senior Biology Australian Curriculum – **Science Understanding (SU)**	Unit 2	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• See resources above related to the different kinds of nerve cells in the brain, in particular the role stem cells play in the production of myelin. • Although this video does not specify a type of stem cell, there are various resources available (see right) which can be used to learn about the different kinds of stem cells that are currently being used for research into MS.	• Use the information from the MS association websites (see above) to set a rich context for exploring the nature of nerve cells, in particular the structure of the nerve cells, such as the axon, dendrites and the myelin sheath and what happens when these cells are damaged. • In the video Dr Merson said: "we now know that certain stem cells have a greater capacity to regenerate the myelin that's damaged in MS". Use the links above to explore what is currently known about stem cells and how they might be used to stimulate remyelination. • Stem cell related resources for exploring the different types of stem cells within the context of MS: https://stemcellsaustralia.edu.au/conditions/explore/multiple-sclerosis/ • Jonathan's Story - Cells (oligodendrocytes) and myelin production (Euro stem cells): https://www.eurostemcell.org/jonathans-story-stem-cells-and-myelin

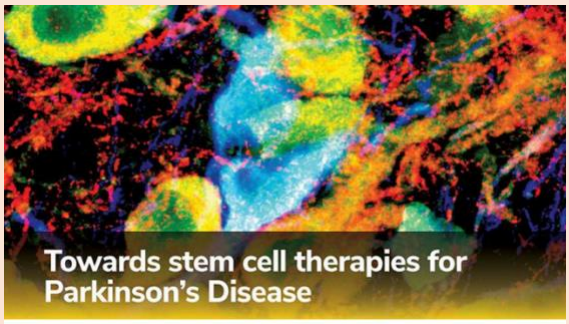
2.5 The Parish and Thompson Group: Towards stem cell therapies for Parkinson's

Professor Clare Parish and Associate Professor Lachlan Thompson

Florey Institute of Neuroscience and Mental Health

Parkinson's is one of the most prevalent forms of brain disease, affecting approximately 700,000 Australians.

Accompanying Resources:
Refer to the Stem Cells Australia web page *'Towards stem cell therapies for Parkinson's*, or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.



What is the focus of the Parish Group research?

- Parkinson's is one of the most prevalent forms of brain disease, affecting approximately 700,000 Australians.
- Parkinson's is linked to a single type of cell which makes stem-cell-based therapy to replace or repair cells in the damaged region feasible.
- Stem cell therapies could be used to repair damaged neurones the brain of people with Parkinson's disease.
- Findings from the research on Parkinson's disease could impact research on other neurodegenerative diseases such as Alzheimer's and Huntington's and acquired brain injury from stroke or trauma.

What is the science?

- Parkinson's disease is a neurodegenerative disease which is caused by a loss of dopamine-producing neurons, predominantly in the substantia nigra – an area of the brain.
- The brain is a hostile environment, so introducing stem cells to repair damaged neurons is problematic.
- Bioengineering, which involves creating scaffolds (similar to how the cells would otherwise exist) and hydrogels to support the transplanted replacement cells, could provide a way forward for the treatment of Parkinson's disease.
- The Parish and Thompson Groups has refined the process of generating neurons from pluripotent stem cells.

Where is the Science as a Human Endeavour?

- The general nature of scientific endeavour, such as:
    - social, cultural and economic influences on scientific research and ethical aspects – in this case, the moral imperative of better understanding the nature of neuron degeneration in people with Parkinson's disease

Links to the curriculum and suggested teaching and learning activities

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 – 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• In the past, little was known about the way neurodegenerative diseases develop and how to treat people who had such diseases. • Diseases like Alzheimer's and Parkinson's occur because neurone cells are compromised. • These diseases develop over years, meaning support and treatment for people suffering from these diseases have social, cultural and financial implications. That is, as more about the disease and the needs of the people who are affected by them becomes known, there will be social, cultural and financial implications. • Parkinson's is estimated to affect a large number of people worldwide (i.e. 700,000 in Australia alone). The exact cause of Parkinson's disease is still unknown. • Our understanding of Parkinson's has changed, as new evidence has become available. For example, the role of dopamine producing neurons in the brain and what happens to the body when these cells are damaged. However, as Professor Parish outlines in the video, it has been 50 years	• Parkinson's disease is a neurodegenerative disease. Find out more about it, using the questions below to guide your research. • You might like to use the context of Michael J Fox (a well-known actor who played Marty McFly in the Back to the Future movies. Michael was diagnosed the Parkinson's disease in 1991) https://www.michaeljfox.org/michaels-story • • Parkinson's disease – see https://www.parkinsons.org.au/ and https://www.parkinson.org/Understanding-Parkinsons/Causes • What is Parkinson's disease? • Which organs or tissues are impacted? • How many people does it affect (in Australia and worldwide?) • What is the current state of treatment options available? • Is this disease genetic or can it be acquired? • What are the symptoms of Parkinson's? • Explain the nature of support networks for people living with Parkinson's. • What was the most recent advances in knowledge about Parkinson's? • What is currently not known about Parkinson's that scientists want to know?

			since the last big breakthrough for this disease. • Stem cells also offer the potential for supporting patients with Parkinson's disease. https://stemcellsaustralia.edu.au/conditions/explore/parkinsons-disease/	• Learn more about the history of what is known about Parkinson's by reading the following: "Description, incidence and theories of causation". https://e4560aba-a272-4149-be157d94aa1afac2.filesusr.com/ugd/bfe057_34024982ceed4546803bace895e9d86e.pdf • Where are scientists currently focusing their research for Parkinson's? What are they hoping to achieve in the short term and long term? • Explain how groups are raising awareness of Parkinson's disease (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop poster) to raise awareness and/or fundraising for Parkinson's OR to explain Parkinson's disease to a primary school student.
		Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135 AND Science knowledge can develop through collaboration across	• The work of Professor Parish and Associate Professor Thompson includes bioengineering. • The aim of bioengineering in Parkinson's research is to find ways of creating scaffolds and hydrogels to support the transplantation of replacement cells in a person's brain. The brain is a hostile environment, and stem cells cannot be placed directly into the brain, as they are easily damaged. A scaffold most be used to ensure the transplanted stem cells have the greatest change of survival and impact. • There is also an opportunity here to highlight that Professor Parish and Associate Professor Thompson are collaborating and publishing	• Read the article "Towards stem cell therapies for Parkinson's" • The article raises the concept of bioengineering. The term bioengineering consists of the words: 'bio' and 'engineering'. What are the characteristics of each of these disciplines? • Why might it be beneficial to draw on both of these disciplines for Parkinson's' research? • The article highlights that Parish and Thompson labs have made a series of 'rapid advances' which may benefits scientists working on other neurodegenerative diseases. Compare what you have learned about Parkinson's and the work of the scientists here to the other groups, such as the Merson and Bourne groups. How might knowledge from one group benefit the work of another?

		the disciplines of science and the contributions of people from a range of cultures ACSHE223/226	research together. This is common for scientists to collaborate across laboratories locally, nationally and internationally.	
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192 AND Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157	• Advances in technology and science has led to greater understanding of the nature of Parkinson's and how to help people living with the disease. • In the video, Professor Parish mentions that it has been 50 years since that last breakthrough for Parkinson's disease. • This is a good opportunity to highlight the nature of knowledge development. In science, the answer is not always certain and often, as new evidence becomes available, scientific knowledge changes. This can lead to claims of 'fake news' and scepticism about scientific research. Compare the rate of scientific progress for Parkinson's compared to other neurodegenerative diseases. • Some areas of research progress faster than others. • The media represents science and the work of scientists in different ways. This often depends on the purpose of the media piece. • Bioengineering is the amalgamation of knowledge, skills and characteristics from biology and engineering, working together to find a solution to the problem. Developing	Explore the history of what is known about Parkinson's by reading "description, incidence and theories of causation". • https://e4560aba-a272-4149-be15-7d94aa1afac2.filesusr.com/ugd/bfe057_34024982ceed4546803bace895e9d86e.pdf • 200 Years of Parkinson's disease: what have we learnt from James Parkinson? https://academic.oup.com/ageing/article/47/2/209/4791137 • https://www.parkinsons.org.au/ • Create a timeline which highlights some of the main discoveries related to Parkinson's. How have each of the discoveries been beneficial for patients and/or researchers? • What would you say are the three most significant discoveries related to Parkinson's? Provide a brief reason for your choices. • Significant scientific discoveries are often picked up by mainstream media and published in the news. This mostly happens when a significant or topical breakthrough or discovery occurs. Most scientific research findings are communicated in specialised journals and conferences. • Professor Parish said: "It has been more than 50 years now since we've had our last breakthrough for Parkinson's disease. So, we're still treating the disease using the same drugs discovered that long ago." Yet, a search for 'Parkinson's disease" on media sites reveals a number of articles.

			new technologies also requires creativity and imagination to advance our knowledge.	• Consider a range of media articles related to Parkinson's disease discoveries. What is the purpose of the article? Is there a 'breakthrough' or 'newsworthy' aspect? What does it relate to (i.e. the science, raising awareness, treatments etc.)? How is the article related to Parkinson's disease? How has the article tackled the science? How much detail have they offered? • 2011 - https://www.abc.net.au/news/2011-11-10/parkinsons-stem-cell-breakthrough/3656630 • 2019 - https://www.abc.net.au/news/2019-04-11/living-with-parkinsons-disease-from-a-young-age/10976770 • 2019 - https://www.abc.net.au/news/science/2019-01-23/rem-sleep-behaviour-disorder-parkinsons-disease-dreams-brain/10736268 • 2018 - https://www.abc.net.au/news/2018-08-01/alan-alda-from-mash-reveals-he-has-parkinsons-disease/10059686 • (More articles can be easily found via sites like ABC news) Bioengineering may support stem cell therapies for the treatment of Parkinson's. These advanced rely on a number of disciplines, working together. It also requires imagination and creativity to think of novel ways to tackle treatment of the disease. The following are examples of new technologies: • A new technique maps the brain circuit for Parkinson's disease tremor https://bioengineering.stanford.edu/news/new-technique-maps-brain-circuit-parkinson-s-disease-tremors • '5-D protein fingerprinting' could give insights into Alzheimer's, Parkinson's https://bme.umich.edu/tag/alzheimers-parkinsons/ • Screening tech advances early detection of Parkinson's disease https://www.rmit.edu.au/news/all-news/2019/nov/screening-tech-detection-parkinsons

				• For each article, consider the nature of the idea or advancement. Identify the knowledge and skills which are characteristic to science, technology, engineering, maths. How have people from the respective disciplines worked together to develop this new technology? • Can you find any other examples of different disciplines working together for Parkinson's research? • See also ACSHE135 and ACSHE226 above related to collaboration between research laboratories and comparison with the Merson and Bourne groups. • Examples of other collaborations: See how scientists in Europe are collaborating with neurologists, neurosurgeons and ethicists to explore new treatment options for Parkinson's disease https://www.eurostemcell.org/interview-malin-parmar-cell-therapy-parkinsons-disease
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE230	• Millions of people around the world are impacted by neurodegenerative diseases and acquired brain injuries. • Diseases such as Parkinson's disease occur because neuron cells are compromised. Some neurological diseases develop over years, meaning support and treatment for sufferers of these diseases have social, cultural and financial implications (i.e. people with the disease may need ongoing specialised care, there may be cultural stigmas associated with brain disease and there are financial costs associated with supporting and treating people affected by neurological diseases).	• See section above (ACSHE134) • What are some advances in science research related to this disease? • What is currently not known about this disease? • Where are scientists currently focusing their research for this disease? What are they hoping to achieve in the short term and long term? • How might stem cells be useful for people with MS? • Explain how MS support groups are raising awareness of the disease (e.g. is there a 'day', colour scheme, slogan etc.). How effective do you think the marketing is? • Design a brochure, commercial or billboard (e.g. highway or bus stop poster) to raise awareness and/or fundraising for MS.

			• The values of society influence the direction of funding and research into better understanding the nature and potential treatments and prevention methods for neurodegenerative diseases and disorders.	• Explore how Michael J Fox, a well-known actor who played Marty McFly in the Back to the Future movies, has raised awareness about Parkinson's disease (Michael was diagnosed the Parkinson's disease in 1991) https://www.michaeljfox.org/michaels-story • Michael has worked hard to raise awareness of Parkinson's disease. What impact might he have had? Would it be different if he was not a high-profile actor?
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions ACSSU149	• The brain is made up of neurons (nerve cells) and glia cells. • "Parkinson's disease (PD) is a neurodegenerative disorder that affects predominately dopamine-producing ("dopaminergic") neurons in a specific area of the brain called substantia nigra." https://www.parkinson.org/understanding-parkinsons/what-is-parkinsons	• NB This section could be explored in the context of ACSHE134 above. Students can learn about the structure of neurons and the role of dopamine as they learn about the nature of Parkinson's disease.
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175 AND	• "Parkinson's disease (PD) is a neurodegenerative disorder that affects predominately dopamine-producing ("dopaminergic") neurons in a specific area of the brain called substantia nigra." https://www.parkinson.org/understanding-parkinsons/what-is-parkinsons • Use the context of Parkinson's disease to explore the nature of neurones and the role of dopamine in the brain.	• Have you heard of dopamine? It is an important molecule produced by neurones in your brain. Find out more about this important molecule, such as what it does and how it is produced. • https://www.psychologytoday.com/au/basics/dopamine • More advanced: Explainer: What is dopamine? https://www.sciencenewsforstudents.org/article/explainer-what-dopamine NB this article compares the role of dopamine and compares how Parkinson's and drug affected brain tissue has fluctuating levels of dopamine.

		An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by synapses (VCSSU118) NB This SU descriptor is from the Victorian Curriculum	NB Teachers can use the Parish group video in conjunction with videos and resources from the Merson, Bourne and Pouton groups to compare and contrast stem cell research related to the nervous system.	• Draw a flow chart to explain what would happen to a person who was walking if dopamine was removed from their nerve cells.
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	11 (Unit 2)	• Working like a scientist	• Resources from above and other videos can be used to highlight the nature of scientists' work, such as creativity and imagination and collaboration between with a range of people from different backgrounds and experiences.	• See resources in the section above to discuss what is involved in working as a scientist, in particular the nature of developing new ideas, technology and knowledge. Creativity and imagination are import for all aspects of scientific endeavour, not just communicating findings. • Contrast with other videos – for example, contrast the role of failure highlighted by Dr Merson in the Merson group video with Dr Haynes in the Pouton group who talks about science work as being like a puzzle.
		• The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)	Social, cultural, economic and ethical factors: • The high incidence of people developing Parkinson's, coupled with the lack of clear understanding about why the disease develops, has led to increased funding and scientific research into prevention and treatment of Parkinson's.	• Formulate a debate and consider the cost of medical research into Parkinson's disease. Where and how should research funding be distributed? Consider the economic questions related to resourcing for research and treatment. Cultural and social considerations may include exploring the values of different cultures - which diseases tend to be given preference or are valued more than others?

Senior Biology Australian Curriculum – Science Understanding (SU)	Unit 2	Understand that the structure and function of cells and their components are related to the need to exchange matter and energy with their immediate environment	• See resources above related to nerve cells in the brain, in particular the role stem cells play in the production of dopamine. • The article and video highlight that the Parish lab works with pluripotent stem cells. Pluripotent stem cells can grow into any cell type in the body under the right conditions. • Learn more about the nature of pluripotent stem cells and why the offer potential for scientists working on Parkinson's disease.	• Use the information from the various Parkinson's associated websites (see above) to set a rich context for exploring the nature of nerve cells, in particular the structure of the nerve cells, the role of dopamine (a chemical messenger) and what happens when these cells are damaged. (See also Unit 4 below) • What are pluripotent stem cells and how are they similar and different to tissue-specific stem cells? • https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • How are pluripotent stem cells being used in research into Parkinson's disease?
	Unit 2	Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs and systems (ACSBL054) And The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• Bioengineering is the amalgamation of knowledge, skills and characteristics from biology and engineering, working together to find a solution to the problem. Developing new technologies also requires creativity and imagination to advance our knowledge. • In the video Associate Professor Thompson says "The great thing about a stem cell approach is that it's truly regenerative. So, all the therapeutic options you have available to you as a patient with Parkinson's disease treat the symptoms, but they don't alter the disease course." Explore how stem cells therapies can be considered regenerative. Benefits and limitations can be explored.	• Bioengineering may support stem cell therapies for the treatment of Parkinson's. These advances rely on a number of disciplines, working together. It also requires imagination and creativity to think of novel ways to tackle treatment of the disease. • Read the article "Towards stem cell therapies for Parkinson's" • The article raises the concept of bioengineering. How have the Parish groups drawn on biology and engineering in their research into scaffolds and hydrogels? • Using your knowledge of cell and tissue growth and development, how would a bio-scaffold work and why might it be important in the case of stem cell therapies? • Find out more about the process of engrafting. Why is it relevant in this case? • How might a scaffold work? How might it be similar and different to how cells normally exist?

				• NB There is an opportunity here to link to disease and immune response. I.e. how the body may respond to new stem cells if they were introduced into the brain without scaffolding and support. • See also examples of new technologies above (ACSHE157):
	Unit 4	Homeostasis involves a stimulus-response model in which change in external or internal environmental conditions is detected and appropriate responses occur via negative feedback; in vertebrates, receptors and effectors are linked via a control centre by nervous and/or hormonal pathways (ACSBL110) AND Neural pathways consist of cells that transport nerve impulses from sensory receptors to neurons and on to effectors; the passage of nerve impulses	• "Parkinson's disease (PD) is a neurodegenerative disorder that affects predominately dopamine-producing ("dopaminergic") neurons in a specific area of the brain called substantia nigra." https://www.parkinson.org/understanding-parkinsons/what-is-parkinsons • Use this context to explore the role dopamine plays in homeostasis and its role in the nervous system.	• Use dopamine as a context to explore the role of chemical messengers for cell-to-cell communication in the nervous system. • This is an opportunity to teach about how understanding of chemical messengers has developed. This is a powerful way to help students learn the concepts within a rich context. • Dopamine is a chemical messenger – how our understanding of the role of dopamine has changed: https://www.brainfacts.org/thinking-sensing-and-behaving/movement/2015/dopamine-and-movement

		involves transmission of an action potential along a nerve axon and synaptic transmission by neurotransmitters and signal transduction (ACSBL112)		

3. The Eye

3.1 The Pébay Group: Seeing eye disease clearly with robotics

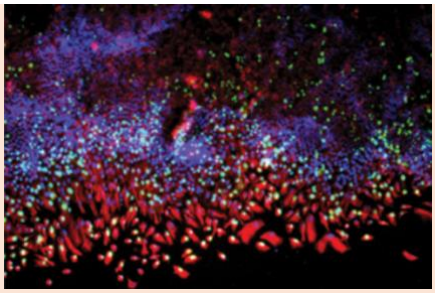
Professor Alice Pébay and Dr Grace Lidgerwood

Centre for Eye Research Australia (CERA) and the University of Melbourne

"Nearly half a million Australians live with a form of vision impairment or blindness.

By far, most of these cases – 80% or more – are treatable with prescription eyewear or surgery.

However, within the remaining cases lurk several debilitating forms of eye disease, many rooted in genetic abnormalities that lead to blindness.



With no interventions or cures, Australians with hereditary eye conditions that result in blindness face a significantly decreased quality of life, mobility and ability to contribute to the community."

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Seeing eye disease clearly with robotics*,' or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Pébay Group research?

- Together with Associate Professor Alex Hewitt, Pébay is using technology to reprogram skin cells to create eye cells for disease modelling and drug testing.
- Ground-breaking advances in cell culture technology has enabled researchers to culture and store stem cells from a large number of people.

What is the science?

- Skin cells can be reprogramed into induced pluripotent stem cells which can then be grown into eye cells. These cells can be used to study various eye diseases through modelling how certain diseases occur.
- Robotic cell culture technologies enable the growth and culture of stem cells from a large number of donors.
- The retina can be affected by various diseases, which limits function and can lead to blindness.
- CRISPR technology has been used to successfully edit gene errors which cause genetic eye disease.
- Genetic intervention, such as gene editing, can be considered controversial because of the safety risks and potential implications of genetic changes being passed down to future generations.
- The optic nerve can be affected by a specific type of mitochondrial disease.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:

- Collaboration: Collaboration is essential for scientific endeavour and advancement. In this case, collaboration between scientists, clinicians and other front-line medical staff. Collaboration also exists between scientific research groups (e.g. the Pébay and Hewitt Groups).
- Lab structure and pathways: Science laboratories consist of a diverse mix of people at different stages of their careers. Early career researchers are valuable for bringing fresh perspectives and ideas as well as conducing valuable hands-on aspects of research.
- Nature of science: Asking questions is an integral element of scientific endeavour. Science as a career offers intellectual freedom.
- Discoveries and breakthroughs in science create new knowledge. As new evidence becomes available, knowledge changes.
- Advances in scientific knowledge often rely on technological advances: Advances in one field can influence other areas of science, technology and engineering.
- Social, cultural and economic influences on scientific research and ethical aspects: in this case, the controversy surrounding alteration of genes and what this kind of technology might be used for (i.e. technologies may have the potential for beneficial and harmful uses. Should there be regulations around the use of these technologies to minimise harm? Who is responsible for creating guidelines?

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level /s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum Science as a Human endeavour (SHE)	7-12	Structure of scientific laboratories and staff	• This video features Professor Alice Pébay and Dr Grace Lidgerwood. • Research laboratories consist of a range of people (younger and more senior) from a variety of career stages (Early career researchers (ECR), students (e.g. Honours and PhD) to mid-career and highly experienced researchers (e.g. Professors and Associate Professors)) • The video also features Dr Grace Lidgerwood who is an early career researcher (ECR) – this means she is within 5 years of commencing her role as a post-doctoral researcher. A post-doc is a person who has completed a PhD. Grace would be mentored by a more senior researcher.	• In the video Dr Grace Lidgerwood talks about how she came to be in the Pébay research group. What are the stages of her transition from high school to her current role? • What prompted Grace to pursue her current career? • Many of the scientists in this video series have highlighted the value of having experienced and beginning scientists (i.e. Honours, Masters and PhD students) as part of the lab team. List some qualities you think students would bring to the team. How might the knowledge and skills of an Honours student be different to a post-doc? • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.
		Working like a scientist involves asking questions, working as a team and collaborating with other people.	• In the video Alice emphasises the role of collaboration such as working with clinicians and front-line medical staff (to better understand the needs of patients and the realities of the clinical setting) • In the video, Alice emphasises the role of asking interesting questions – which happens when you work with other people, reading	• In the video Grace talks about her work as 'helping to build pieces of the puzzle' – what does she mean by this? How is scientific endeavour like a puzzle? How is it not like a puzzle? • In the video Alice talks about working with clinical staff (e.g. doctors, phlebotomists and nurses). What value is there in these collaborative relationships? • What is a phlebotomist? What do they do? Is there a qualification to become a phlebotomist?

		Scientific endeavour has its own individual beauty.	other people's work and appreciating different perspectives. Asking questions and reading literature leads to new ways of thinking. This offers fresh insights and perspectives to problem solving. • Alice talks about the beauty of science. Science is a quest to understand what is not yet known. Science is a creative endeavour which relies on the creativity and imagination of scientists to conceptualise problems, develop ways of solving problems, analysing and working with data to find patterns and make meaning. There is an element of intellectual freedom in science, which nurtures creative thinking. • Science has unique conventions and languages, which have beauty. For example, science is driven by the desire of people to develop new knowledge and help others. There is a beauty in this sense of value and agency. Scientific knowledge is often parsimonious – the simplest explanation is often the best. There is beauty in simplicity and elegance of theories.	• In the video, Alice emphasises the role of asking interesting questions – which happens when you work with other people, read other people's work and appreciate different perspectives. Think of an example recently when you encountered a new idea that prompted you to think differently or to see another perceptive. What happened? What did you learn? How did this new perspective change your behaviour or thinking in the future? • What value is there in asking questions? How does reading and working with others lead to 'thinking in new ways'? • Describe a time when you have worked with another person or a group of people and your ideas changed and developed as a result of the collaboration. • Alice talks about science as being beautiful. Create a list of the different ways in which science could be considered beautiful. Think of how other people might see beauty in science, even if you do not necessarily agree (this is an example of being able to appreciate other perspectives, even if we do not agree with them). Hint: Think about the unique conventions and language of science, scientific knowledge, what scientists do, what scientists value, the nature of scientific theories and concepts etc. How might all of these things have a beauty about them?
Australian Curriculum Science as a Human endeavour (SHE)	8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• In the video, Alice talks about knowing more today than we did in the past. This is an example of how knowledge changes over time as new evidence becomes available. Alice's remarks highlight the nature of scientific knowledge development. People create new knowledge and put that knowledge into the world for scrutiny and review. Other people build on the work of those before them as a springboard to	• In the video, Alice says "We know so much more today than we used to know 20 years ago, and this is again the really beautiful thing to consider because we see that we grow in a dynamic environment where knowledge is being brought to the table every single day and surely that knowledge will be applied, I hope, in the best way for finding treatments for people." • What does Alice mean by this statement? What kinds of changes might she be thinking about in relation to what we know about the eye and causes/treatment of blindness?

			stimulate new knowledge. As new evidence becomes available, the scientific discourse changes and evolves. This leads to changes in currently held scientific conceptions. This is a prime example of science knowledge being tentative, yet durable. • In the case of vision loss, the current understanding about genetic eye diseases varies. Students can research a specific genetic eye disease to learn more about what is currently known and what is not known about the disease. The next step is to explore how gene therapies are being developed as a new way of potentially treating genetic eye diseases. This is an example of new knowledge development in action.	• Find out what is currently known about inherited retinal dystrophies (IRD's): https://www.asharedvision.com/understanding-irds • Explore one IRD listed on A Shared Vision website (see link above) – what happens to the eye to cause vision loss? What are the current treatment options? How might this knowledge have changed over the last 20 years? • Research into eye related disorders is supported by organisations like the Centre for Eye Research Australia (CERA): https://www.cera.org.au/ • Who is CERA? Why does CERA exist? What is their mission statement? What does CERA they value? Who does CERA collaborate with? • Explain how Alice's quote is an example of scientific knowledge being tentative yet durable. What do these terms mean? • Navigate to the Vision Australia website to find out more about vision impairment: https://www.visionaustralia.org/ • Navigate to 'Information' then 'Eye conditions'. Read the information for one of the following genetic eye diseases: Leber's Congenita, Keratoconus, Optic Atrophy, Retinitis Pigmentosa, Stargadt's Disease. • What is the nature of the disorder you chose? What are the symptoms? How might this disease impact a person's daily life? What are the current treatments? What new knowledge would be helpful for scientists trying to treat people with the disease you chose?

				• Vision Australia (VA) is a patient support organisation. Learn more about this organisation and the support they provide. https://www.visionaustralia.org/ • Who are Vision Australia (VA)? What is their aim/ mission? What services does VA provide?
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226	• In the video Professor Pébay talks about working with clinicians, phlebotomists and nurses to gain a better understanding of the medical context. This can be compared to the Chong group, where Associate Professor Chong is a doctor and a researcher, so he is able to bridge the divide between research and clinical settings. Alice emphasis the value of working closely with clinicians to understand the needs of patients and those who seek to treat them, to ensure her research has the desired impact. • The article 'Seeing eye disease clearly with robotics,' explains how Professor Pébay has been working closely with Associate Professor Alex Hewitt from the University of Tasmania. This is an example of how scientists work collaboratively, usually across disciplines, to share knowledge and expertise to advance scientific endeavour.	• In the video, Professor Pébay talks about the value of working with hospital staff, such as doctors, phlebotomists and nurses. Why might Alice value these partnerships? What value would they add to her Group's research? • Read the article '*Seeing eye disease clearly with robotics*,.' Alice also works with Associate Professor Alex Hewitt from the University of Tasmania. How have the Pébay and Hewitt labs been collaborating? • What new knowledge the Pébay and Hewitt Groups have contributed to our understanding of inherited eye disease? • Compare the collaboration of the Pébay and Hewitt compares to the collaboration of the Porrello and Hudson (See the Porrello group) or the collaborations of the Palpant and Powell groups (see the Palpant Group). How are the collaborations similar or different? What are some common characteristics of collaborative relationships?
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and	• In science research, models are used to test hypotheses and new ideas. Development of stem cell technologies has enabled scientists to create models of human tissue by reprograming patient's cells and growing those cells into cells of interest. In this case,	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research and stem cells

		may involve ethical considerations ACSHE135	cells affected by eye diseases. Modelling enables scientists like Alice and her team to study how eye disease occurs and to test novel interventions to treat vision loss. This case offers the opportunity to explore the nature of such models with students to understand how stem cell technology enables modelling of tissue, to better understand disease and treatments, rather than being used directly for treatment. • The article '*Seeing eye disease clearly with robotics*,' mentions the use of robotics culture techniques. This technology enables large quantities of cells to be cultured. This article offers the opportunity to explore the interdisciplinary nature of scientific research – which relies heavily on technological and engineering advancement to conduct scientific research.	offers flexibility when it comes to growing viable models in the lab. • Having watched the video and read the article '*Seeing eye disease clearly with robotics*,' explain how the Pébay lab are using stem cells as a model for eye disease. Why do stem cell models offer flexibility for the Group's research? Explain how the model tissue is grown in the lab. What kind of stem cells does this group use and why? • Thought experiment: Create a Venn diagram to compare the benefits and limitations of using a lab grown biological model to being able to use a human or animal-based model. • The article '*Seeing eye disease clearly with robotics*,' mentions the use of robotics culture techniques at CERA's Automated Stem Cell Facility. Explain the robotic technology being used by the Pébay and Hewitt groups. Why is this technology useful for the two Groups? Describe one advance in knowledge that has resulted from the new robotic technology? How might this technology be applied to other areas of research?
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157/191	• See section above (ACSHE135) related to the use of stem cells for creating model eye tissue to explore the nature and action of eye diseases. • The article offers an opportunity to draw attention to publication of journal articles (also known as papers) as a form of communicating research findings and new scientific knowledge.	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research and stem cells offers flexibility when it comes to growing viable models in the lab. • Having watched the video and read the article '*Seeing eye disease clearly with robotics*,' explain how the Pébay lab are using stem cells as a model for eye disease. Why do stem cell models offer flexibility for the Group's research? Explain how the model tissue is grown in the lab. What kind of stem cells does this group use and why?

				• The article mentions a paper published in 2017 by Pébay and Hewitt about the use of gene-editing platform CRISPR which reported on success editing gene errors that cause inherited eye disease. What is a 'paper' and what purpose using this form of communication serve for scientists? Access the paper abstract here: https://www.sciencedirect.com/science/article/pii/S1350946216300258 • While on this webpage, look at the list of authors. How many are there? Click on their names and see which institutions they work at. What do you notice? The call out box shows links to their other publications. • In scientific writing, sometimes there is no list of authors, simply one name followed by 'et al.' This is Latin for 'and others'. What does this mean in the context of a list of authors? Why might 'et al' be useful when citing scientific publications? • Click on the journal title "Progress in retinal and eye research". The link will take you to the journals home page. If the link does not work, the site is: https://www.sciencedirect.com/journal/progress-in-retinal-and-eye-research • While on the site, click on the 'aims and scope'. What are the aims of the journal? Which scientists/groups of people might this journal be relevant for? • On the journal homepage you will notice some numbers called CiteScore and Impact Factor. Journals are rated according to how often articles are cited by other people. The higher the scores, the more prestigious the publication is deemed. Scientists often try to publish in top ranking journals. It is quite a competitive process.

	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192	• Advances in technology and science have led to greater understanding of the heart and how it develops. (See ACSHE134 above) • Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life. • See also ACSHE160/194 below on gene editing as a scientific discovery which has advanced scientific understanding, and involves advances in technology.	• Read about the first stem cell based medicinal product: "Holoclar® uses a particular type of eye stem cell, called a limbal stem cell, to repair the cornea after injury; restoring sight." https://www.eurostemcell.org/story/europe-approves-holoclar-first-stem-cell-based-medicinal-product • What is Holoclar®? How does it help people who have eye injuries? • What is the cornea and what function does it play? • What are limbal cells and how can they assist to repair damaged corneal cells? • How long did it take to develop this therapy?
	9 & 10	People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities ACSHE160/194	• Gene editing, such as CRISPR, has opened the door to ethical discussions about editing the genome of living things. The video and article offer an opportunity to discuss the ethical considerations of gene editing when teaching about genetics. • Find out more about CRISPR on the NIH website: Genome Unlocking life's code: https://unlockinglifescode.org/crispr-teaching-tools • The website has links to other sites and lesson plans related to CRISPR technology.	• What is gene editing? Why might the Pébay group be interested in gene editing? What is CRISPR? How might this technology affect people's lives in the future? • Navigate to the NIH website: Genome Unlocking life's code website to learn more about CRISPR technology: https://unlockinglifescode.org/crispr-teaching-tools
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE228/230	• The article '*Seeing eye disease clearly with robotics*,' established the need for research into blindness. The 'gift of sight' is highly valued, yet many people are impacted by reduced vision. The Pébay Group video and article offers an opportunity to explore how values guide research. The article opens with a statement of a large issue – half a million Australians live with some form of vision	• The opening paragraph of the article Seeing eye disease clearly with robotics, states "Nearly half a million Australians live with a form of vision impairment or blindness. By far, most of these cases – 80% or more – are treatable with prescription eyewear or surgery. However, within the remaining cases lurk several debilitating forms of eye disease, many rooted in genetic abnormalities that lead to blindness. With no interventions or cures, Australians with hereditary eye conditions that result in blindness face

			impairment – and 20% of those are not currently treatable. When a large number of people are unable to find treatment for vision impairment, research can be focused towards those areas. • To apply understanding of different values and perspectives, students can construct arguments for why research may or may not (should or should not be) be invested into treatment and prevention of blindness.	significantly a decreased quality of life, mobility and ability to contribute to the community." • What is being valued in this paragraph? Why might research be directed towards research into blindness? • Fred Hollows was a humanitarian and eye surgeon helping thousands of people in Australia and overseas regain their sight. His vision was to work towards a world where no person was unnecessarily blind, no matter whether they were rich or poor. He believed everyone deserved the right to high quality affordable eye care. Fred once said: "I believe the basic attribute of mankind is to look after each other". What does this say about what Fred values? How might his values have influenced is work? • Read more about the work of Fred Hollows: https://www.hollows.org/au/about-fred • How are the Pébay and Hewitt groups using research to create social impact? (i.e. think about what advances might cause long term changes to people's health and changes which might impact the health system)?
Australian Curriculum Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions ACSSU149 AND Multi-cellular organisms contain systems of organs	• The eye consists of different groups of specialised cells organised into tissues. • Sight, along with other sensory organs and system enable multicellular organisms to perceive the world around them.	• They eye is a fascinating organ. It enables us to see the world around us. Learn more about the structure of the eye and how it works: • https://www.eurostemcell.org/eye-and-stem-cells-path-treating-blindness • Draw a diagram of the eye and label the following parts: cornea, lens, retina, optic nerve, retinal pigment. • Explain how the eye works – what is the function of each part of the eye?

		carrying out specialised functions that enable them to survive and reproduce ACSSU150		• There are different kinds of cells in the eye. Name 2 cell types and explain how they enable sight. • What might happen if these cells were damaged? Can the cells regenerate or repair? • How does the body repair the cornea? What happens if the limbal stem cells are damaged? How have stem cells been used to repair cornea damaged? • What causes blindness? How might stem cells be used in the future to repair eye injury or blindness? • Use in conjunction with ACSHE134 above
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment ACSSU175	• This video offers the opportunity to consider the nature of the eye as an important sensory organ. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells, like skin cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	• See ACSSU150 above as a context for students to explain the different parts of the eye and to predict what might happen if particular specialised cells associated with the eye did not function. • In the video, Alice explains the process of creating pluripotent stem cells. Draw a flow chart of the process she describes from skin cell to stem cell. • What are induced pluripotent stem cells? Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/
	10	Transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)	• The Pébay group video and article offer the opportunity for students to apply their knowledge about inheritance to the context of inherited eye disease. • The A Shared Vision website offers an interactive and informative overview of mutations and the process of gene therapy. This could be used to introduce these ideas to students or consolidate them.	• Apply your knowledge of genetics – or learn more about inheritance through the context of inherited retinal dystrophies (IRD's). Navigate to the following site: https://www.asharedvision.com/understanding-irds • What are IRD's? Pick one example and explain in your own words what the disorder is and what impact it has on a persons vision. What are the current treatment options for this disease?

				• Navigate to the tab called “Gene therapy Research”. Scroll down to “Understanding genetic disease” and click on ‘unlocking the mystery’. • Explain how a mutation can lead to genetic eye disease. • Click ‘dive into the science’ • How might gene therapy treat eye disease? • What is a viral vector and what role does it play for gene therapy • More information on gene therapy for IRD can be found at: Navigate to the following website to learn more about current treatment options see: https://www.asgct.org/education/inherited-retinal-diseases
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	Unit 2	Working like a scientist And Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to aspects of working as a scientist, such as questioning, intellectual freedom, drawing on the work of others and recognising the beauty of science. • This video offers the opportunity to draw attention to pathways into scientific research as a career (e.g. Grace Lidgerwood’s pathway of Science degree, Honours, PhD). The video also highlights the value and importance of early career researchers as being an integral part of a research laboratory.	• See the SHE (RED) section above related to collaboration and lab structure for resources.
	Unit 2	Science is a global enterprise that relies on clear communication, international	• The article offers an opportunity to draw attention to conventions associated with publishing research findings, such as publication of journal articles (also known as	• Scientists communicate research findings through a variety of ways. One of the more common forms of communication is writing articles for scientific journals. Scientists spend a lot of time writing articles and reading articles written by other scientists from around the world. Thanks to online

		conventions, peer review and reproducibility (ACSBL037)	papers) as a form of communicating findings and new scientific knowledge. • See also ACSHE157/191 above to explore the nature of journals as a means of publishing research findings	databases, scientists can access journal articles from around the world. • Journals publish articles, usually in issues via print (hard copy magazine style) or online. The Journal will specify how articles need to be formatted. There are usually style guides and conventions, such as file type, font and font size, section headings, word limits, referencing conventions, how to format and structure tables and figures etc. Authors need to submit de-identified versions of their papers for blind peer review. • Journal articles published from scientists are broadly categorised as empirical – they report on findings from research. Articles have some common features and conventions, such as: a title, an abstract (which offers a short summary of the entire article and is commonly brief (e.g. can range between 150-300 words)), key words (so articles can be easily found using search engines), an introduction (to set the scene for the article), a literature review, method, results, discussion, conclusion, acknowledgment of funding sources and references. • Findings from research can also be communicated at conferences via oral presentations, symposia (which is a number of similar papers being presented together) or posters. The submission and acceptance to present research findings at conferences also follow conventions, such as blind peer review of abstracts or papers. • The article mentions a paper published in 2017 by Pébay and Hewitt about the use of gene-editing platform CRISPR which reported on success editing gene errors that cause inherited eye disease. What is a 'paper' and what purpose does this form of communication serve for scientists? Access the paper abstract here: https://www.sciencedirect.com/science/article/pii/S1350946216300258

				• What is peer review? The article produced by Pébay and Hewitt would have undergone blind peer review, usually by two or more reviewers. What is the purpose of blind peer review of research articles? How might peer review provide a level of rigour and accountability when communicating scientific research? Define what these key terms mean before structuring your response. What is reproducibility? Why might it be desirable? When might it is difficult or limiting? • What conventions are apparent in journal articles? What might conventions be important? • See also ACSHE157/191 above for activities exploring scientific journals as a means of publishing research
	Unit 2 and 3	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability ACSBL043 AND ACSB074	• Gene editing technology (e.g. CRISPR) offers the potential to alter genetic codes to change health outcomes for patients. • However, new technologies and advances such as those from the Pébay and Hewitt groups are still developing important foundational knowledge. It takes time for this knowledge to be generated	• Read the final paragraph of the article '*Seeing eye disease clearly with robotics*,' • Why might the Pébay and Hewitt investigations be 'game-changing' for eye health? How is their work paving the way for greater public understanding of developments in eye health? • The article states that "a recent global survey conducted by the team suggested two-thirds of people support genetic interventions for debilitating or potentially lethal diseases." Why might people support this research? Why might 1/3 of the people surveyed not support genetic intervention? Classifying diseases as 'debilitating' can be subjective. There are many people living with vision, hearing, speech and mobility impediments. • What might be some lasting benefits of the work from Pébay and Hewitt's research? • Consider the current uses of CRISPR technology. Read the following articles and explain how CRISPR is being used and the current state of CRISPR use in human gene editing:

				• https://www.abc.net.au/news/2017-08-03/how-mutant-genes-are-deleted-repaired-replaced/8769288 • https://www.abc.net.au/news/science/2016-04-07/crispr-gene-editing-technology-explainer/7217782 • Why might altering genetic codes to change health outcomes be controversial? • Create a debate arguing for or against the use of CRISPR technology to alter human embryos before implantation.
Senior Biology Australian Curriculum – Science Understanding (SU)	11 (Unit 2)	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• See resources above related to specialised eye cells and tissue. • The article and video highlight the use of stem cells to create biological models to better understand the nature of diseases and to test new treatments. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	• Induced pluripotent stem cells can grow into any cell type in the body under the right conditions. Find out what these cells are why they might be beneficial for the Harvey group. • There are different kinds of cells in the eye. Name 2 cell types and explain how they are specialised to enable sight. • What might happen if these cells were damaged? Can the cells regenerate or repair? • How does the body repair the cornea? What happens if the limbal stem cells are damaged? How have stem cells been used to repair cornea damaged?
	Unit 3, year 12	Biotechnology can involve the use of bacterial enzymes, plasmids as vectors, and techniques including gel electrophoresis, bacterial transformations and PCR (ACSBL087)	• This video provides a context for discussing how gene-editing technology (e.g. CRISPR) can alter the genome, which in turn would alter gene expression. There are a number of unknowns when considering altering the human genome, such as the impact on other genes and gene expression, impacts on other parts of the body as well as the implications or risks to future generations if these genetic changes are inherited.	• Learn about CRISPR as a form of biotechnology, which enables gene editing. Use the following sites: • https://www.pbslearningmedia.org/resource/lesson-plan-gene-editing-and-crispr/lesson-plan-gene-editing-and-crispr/ • https://unlockinglifescode.org/crispr-teaching-tools • https://ghr.nlm.nih.gov/primer/genomicresearch/genomeediting • Read the following article from 2016 - https://www.abc.net.au/news/science/2016-04-07/crispr-gene-editing-technology-explainer/7217782 • And 2017

				• https://www.abc.net.au/news/2017-08-03/how-mutant-genes-are-deleted-repaired-replaced/8769288 • How has understanding and advances in CRISPR technology changed since this article was written? • Explain two reasons why the CRSPR technology is considered controversial.

3.2 The Watson and Di Girolamo Group: Clearing corneas and restoring vision

Professors Nick Di Girolamo and Stephanie Watson

University of New South Wales and University of Sydney

Professor Stephanie Watson and Professor Nick Di Girolamo have used stem cells to repair their patients' vision. It's the culmination of a 15-year collaboration to restore sight in Australians with corneal disease.

"I've always hated having to say to patients 'Medicine can't help you at the moment." Professor Stephanie Watson

This video showcases Professor Stephanie Watson, an international leader of research and innovation with the University of Sydney and practicing corneal surgeon, and Professor Nick Di Girolamo from the University of New South Wales.

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Clearing corneas and restoring vision*,' or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Di Girolamo and Watson Group's research?

- Working together, Nick and Stephanie have transplanted healthy stem cells into patients' damaged eyes in a bid to restore vision. This is an example of a stem cell therapy which is currently being trialled with a small group of patients.
- These researchers are trying to better understand the nature of limbal stem cells, i.e. what they do and the role they play in corneal cell regeneration.
- Stem cells can be used to recreate tissue and cell types in a dish to model disease and develop treatments and therapies for patients.
- Stephanie is a practicing corneal surgeon and researcher. Stephanie emphasises that collaboration between research scientists and clinical staff is critical to ensure treatments can be fast tracked from the lab to the clinic. Research scientists create the ideas and develop new modes of treatment, while the clinicians deliver the treatment.

What is the science?

- The cornea in the eye consists of cells which are constantly replenished via stem cells which exist at the edge of the cornea. When these stem cells are damaged, the corneal cells do not regenerate which leads to corneal disease called Limbal Stem Cell Deficiency.
- This is an example of a current stem cell therapy which has been shown to have improved patient vision. This case compares to other cases which have therapies different stages of development but not necessarily in clinical trials with humans.
- Some clinics are offering some stem cell therapies which are risky and not clinically proven. (See Munsie Group)

- The group was able to restore sight to patients by growing stem cells on an everyday contact lens and even growing stem cells in cultures derived from patients' blood. Before putting new stem cells into the eye, abnormal cells must be removed.
- Clinicians and researchers work closely together to ensure research is specifically targeted to patient need.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Collaboration: Collaboration is essential for scientific endeavour and advancement. In this case, collaboration between scientists and clinicians. (see also the Chong and Pébay Group examples).
    - Nature of science: Research needs to be funded by internal and external sources. The funding process is very competitive.
    - Research is ongoing and is risky: Roadblocks are common, so good researchers need to always have a Plan B.
    - Values: With funds come exploration and development of new technology, which scientists and clinicians hope will become a gold standard used around the world. Scientists have values and agency which influences their work.
    - Social, cultural and economic influences on scientific research and ethical aspects: In this case, stem cell therapies are being trialled in a clinical setting and is having a positive impact on restoring some patient's vision.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
	7-12	Structure of scientific laboratories and staff	• This video features Professor Stephanie Watson who is corneal surgeon and works closely with research scientists. • Stephanie works closely with Professor Nick Di Girolamo, a research scientist.	• Professor Stephanie Watson is a surgeon. How might her experiences as a doctor inform the research being conducted by Professor Nick Di Girolamo? Refer to the video for clues about what is involved with Stephanie's different roles. • Stephanie is a medical doctor. What is the difference between a medical doctor and a person who has a PhD (and is also considered a doctor)? (Hint – this distinction was often made on the popular TV sitcom, The Big Bang Theory)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Working like a scientist involves empathy and values, which guide research. Research requires creativity in the form of risk taking. Scientific knowledge is tentative yet durable, there are no guarantees.	• In the article, Stephanie talks about how she felt unable to help patients in the past. This case offers an opportunity to highlight that scientific endeavour is often driven by need or by an issue. In this case, Stephanie identified a need and collaborated with scientists to help address that need. • Applying for research funding is common in scientific research. Research laboratories/ groups can be based at or affiliated with universities. Funding is required because scientific research is expensive, and universities do not have adequate government funding to fully cover the costs of research (NB Public Universities in Australia are Not for Profit institutions. Public	• In the article, Stephanie said "I've always hated having to say to patients 'Medicine can't help you at the moment.'" • What does she mean by this statement? What does it say about what she values? Which areas of medical research do you know of that currently have no research supported treatment? • Stephanie also said "Fifteen years ago, I was seeing lots of patients with corneal scarring and stem cell deficiency and I didn't have a way to help them. I was very lucky to receive an NHMRC Research Fellowship, which gave me the opportunity to work with Nick." • What is the NHMRC? What is a NHMRC Research Fellowship? Find out more via: https://www.nhmrc.gov.au/funding/find-funding/research-fellowships

			universities rely on various sources for funding, such as government funding, student fees, research funding and philanthropic donations to remain viable – see for example https://www.universitiesaustralia.edu.au/submission/the-facts-on-university-funding/ and https://www.universitiesaustralia.edu.au/policy-submissions/teaching-learning-funding/how-universities-are-funded/). Developing new technologies is expensive and time consuming. • Science is risky and cannot offer guarantees as scientists are developing new knowledge. With innovation and creativity comes failure and success. This kind of endeavour is risky as the outcome is not known at the outset. This is an opportunity to highlight the nature of science as a creative endeavour which involves risk taking.	• What does this funding opportunity offer scientists? How do scientists obtain such funding? • Why might scientists, like Nick and the University of New South Wales and Stephanie at the University of Sydney, need to apply for funding? • In the video Nick says: "Research is risky full stop. You know there are no guarantees. You go down a path and you may hit a roadblock. And so, then a good researcher always has a plan B." What does Nick mean when he says science is 'risky'? Why can science not offer guarantees? What might he mean by roadblocks? • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher. • In 25 words or less, argue why risk is important for scientific endeavour and why failure is vitally important to the process.
Australian Curriculum: Science as a Human endeavour (SHE)	8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• In the article, Stephanie talks about knowing more today that we did 15 years ago. This is an example of how knowledge and technology develop over time and how the two are linked. As new technology is developed, new evidence becomes available and currently held scientific conceptions can change. • This an opportunity to draw attention to the durability of scientific knowledge, but also the tentative nature of science. Science can answer many questions, but not all. There are limitations to what science can do.	• In the article, Stephanie says "Fifteen years ago, I was seeing lots of patients with corneal scarring and stem cell deficiency and I didn't have a way to help them. I was very lucky to receive an NHMRC Research Fellowship, which gave me the opportunity to work with Nick," and "I've always hated having to say to patients 'Medicine can't help you at the moment.'" • Think, Pair, Share: What do these statements demonstrate about the tentativeness of scientific knowledge? • What new knowledge have Stephanie and Nick developed in relation to corneal damage and repair? • Corneal scarring can occur through injury or disease.

				• Injury can occur when fragments, such as metal or other objects, enter the eye and damage the eye cells and tissues. Find out more about the cornea (where it is located and what it does) and conditions of the cornea. https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/corneal-conditions • Are you at risk of damaging your cornea? What can you do to reduce your chances of damaging your corneas?
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226 AND People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE121/136	• The article lists a number of associations that Stephanie has worked with. Collaboration is important for the advancement of knowledge. • In the video, Stephanie talks about working closely with Nick (a research scientist). This is an example of how scientists work collaboratively, usually across disciplines, to share knowledge and expertise to advance scientific endeavour. In the video, Stephanie describes how she collaborates with Nick by bringing together expertise (her surgical and clinical knowledge and Nicks research expertise and technology in his lab), plan projects together, supervise students together, and analyse data together. • Treating eye conditions is an important focus for research, but before treatment there is prevention, which is also a focus for research. This is an opportunity to talk about prevention measures for avoidable eye damage. • Students can support websites designed to support people with vision loss and	• In the article: “Stephanie has worked with colleagues at Stem Cells Australia, the Ophthalmic Research Institute of Australia, the Royal Australian and New Zealand College of Ophthalmologists, and patient groups to raise awareness of the potential of stem cells and to determine funding priorities relevant to patients.” • What does an Ophthalmologist do? • How might these collaborations be beneficial for Stephanie’s work? • In the video, both Nick and Stephanie talk about the value of the researcher/ clinician relationship. • Nick said “A pure scientist cannot achieve a clinical success on their own. So you know my recommendation is to partner with the best clinician in the country, in the world. We have the ideas. It's the clinicians that actually deliver the therapy to the patients.” • Stephanie said “Look it's really important that a clinician and scientists work together. In that way you can really fast track treatments from the lab to the clinic. We both learn from each other. It's really a team of equals.” • Continue watching the video and listen to the rest of Stephanie’s quote. Why do Nick and Stephanie strongly value the clinician/ scientist collaboration? How is the relationship

			champion the work of eye-based research. These organisations work in collaboration with other a range of stakeholders to develop support structures and raise awareness for vision less. • Vision Australia https://www.visionaustralia.org/ who is "Vision Australia is a leading national provider of blindness and low vision services in Australia. We work in partnership with Australians who are blind or have low vision to help them achieve the possibilities they choose in life. • And the Centre for Eye Research Australia (CERA) https://www.cera.org.au/ • "We conduct eye research with real-life impact. We are unravelling the causes of diseases, preventing blindness through earlier diagnosis and better treatments, and restoring sight. … Our ultimate goal is to find solutions for the three major blinding eye diseases that affect Australians – macular degeneration; glaucoma and diabetic eye disease – and to pioneer vision regeneration programs to give hope to people who have lost their sight."	beneficial for: the creation of new knowledge and for the patients? • Describe two other ways Stephanie and Nick work together. Why are these collaborative activities valuable? • Stephanie also highlights that collaboration is required at all levels of the research to treatment process. In the article she says, "We have to collaborate at multiple levels—from doctors and scientists to governments who regulate, to patients and the community as a whole—to really take advantage of what stem cell medicine can offer in its best form." What might she mean by this? What might the community do as a whole? • Compare this case to the Chong case, which showcases James Chong who is also a clinician and researcher. What skills might James and Stephanie develop in their dual roles? • Read the following article "Research calls for renewed focus on eye safety equipment" on the Centre for Eye Research Australia (CERA) website: https://www.cera.org.au/2012/05/research-calls-for-renewed-focus-on-eye-safety-equipment/ • Describe two issues raised in the article. • Claim, evidence reasoning approach: The article states many claims and supports the claims with evidence (often as numbers but can also be descriptions) and reasoning (which justifies why the claim is being made). Pick one claim from the article and identify the claim, the evidence that is used to support the claim and the reasoning for the claim. • What is the purpose of the article? Who is the intended audience? • Who runs the Centre for Eye Research Australia (CERA) and why does it exist? What is its aim or mission statement?

				• People who are living with vision loss are supported by organisations like Vision Australia: https://www.visionaustralia.org/ • Who is Vision Australia (VA)? What is VA's purpose? What are the support services that VA provides? What does VA value? Who does VA collaborate with? • Research into eye related disorders is supported by organisations like the Centre for Eye Research Australia (CERA): https://www.cera.org.au/ • Who is CERA? Why does CERA exist? What is their mission statement? What does CERA they value? Who does CERA collaborate with?
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACS HE135	• In science research, models are used to conduct investigations to test new ideas. Development of stem cell technologies has enabled scientists to culture stem cells in the lab to act as models for research. in this case, Nick and his team want to study limbal stem cells, i.e. what they do, how they function, where they are located so they can be pinpointed and taken out to develop into cellular models in the lab. • This case offers the opportunity to explore the nature of such models with students to understand how stem cell technology enables modelling of tissue to better understand disease and treatments. • This group is also currently trialling treatments with patients. The article *Clearing corneas and restoring vision*, mentions the use of robotics culture techniques. This technology enables large	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research and stem cells offers flexibility when it comes to growing viable models in the lab. • Having watched the video and read the article, explain how the Groups are using stem cells as a model for corneal disease. Why do stem cell models offer flexibility for the Group's research? • In the video, Stephanie says "One of our key findings in the stem cell area was that we could restore the sight to patients through growing stem cells on an everyday contact lens and even growing those cells in the patient's own blood. So we didn't have to use any animal products. And then putting the cells on the patient's eye after the abnormal cells had been removed and doing this we were able to restore sight."

			quantities of cells to be cultured. This article offers the opportunity to explore the interdisciplinary nature of scientific research – which relies heavily on technological and engineering advancement to conduct scientific research.	• Describe the two technologies the group has tried with promising results. Create a Plus, Minus, Interesting chart to highlight how each approach might have benefits and limitations. What is interesting about each approach? What might you like to more about? • Why might a contact lens be a useful medium for delivering stem cells to the eye? What does Stephanie mean by 'growing cells in the patents blood'? Why do abnormal cells need to be removed before a stem cell therapy is applied?
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192 AND People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities ACSHE160/194	• Advances in technology and science have led to greater understanding of the cornea in the eye – how it regenerates and the cells which aid in its repair. • Advances in stem cell technology has seen the use of stem cell therapy to repair damaged corneal cells. This new technology has changed people's lives and offered hope to people with previously untreatable corneal damage. • Clinical trials are "Clinical trials are research investigations in which people volunteer to test new treatments, interventions or tests as a means to prevent, detect, treat or manage various diseases or medical conditions." https://www.australianclinicaltrials.gov.au/what-clinical-trial • Some clinics offer stem cell treatments which are risky and not clinically proven. It is difficult for the general public to know which therapies are legitimate and which offer false hope. See the Munsie Group for more information on finding credible information about stem cell therapies.	• In the article '*Clearing corneas and restoring vision*,' Stephanie and Nick's teams have transplanted healthy stem cells into patients' damaged eyes. In initial trials the cornea was restored in six out of ten patients and 80 per cent also experienced better vision. They are now improving the treatment and developing protocols so that the procedure can be offered to more patients." • Use the video to find out how the team was able to transplant healthy stem cells into patients'' with damaged eyes. • What is a clinical trial? https://www.australianclinicaltrials.gov.au/what-clinical-trial • The article highlights an issue related to clinics offering risky and not clinically proven therapies to patients. It can be difficult for people to find credible information to make informed decisions. "There are clinics offering stem cell treatments that are risky and not clinically proven… "With stem cells there's a lot of hope but there are also hoaxes. It's important that people considering treatments can easily find credible information to make sure they're part of legitimate trials and are not paying for unproven stem cell treatments," she said.

			• Currently, "Limbal stem cells are one of only three stem cell therapies (treatments utilising blood stem cells and skin stem cells being the other two) that are available through healthcare providers in Europe." https://www.eurostemcell.org/what-diseases-and-conditions-can-be-treated-stem-cells	• Where can people go to find credible information? People usually look for information via the internet. What are some characteristics of legitimate websites, particularly when it comes to medical issues? • Navigate to the Stem Cells Australia website and read the page on Eye Disease and Vision loss. https://stemcellsaustralia.edu.au/conditions/explore/vision-loss-and-eye-disease/ • Identify if stem cell therapies are currently approved as a treatment, where, and for which specific condition?
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE228/230	• See red (SHE) section above related to funding. Funding tends to be distributed to research projects which table large scale, topical or wide reading issues. These areas can sometimes be valued more so than lesser known or lower impact issues.	• See red (SHE) section above related to funding.
Australian Curriculum: Science understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain systems of organs carrying out specialised functions that	• The eye consists of different groups of specialised cells organised into tissues. • Sight, along with other sensory organs and system enable multicellular organisms to perceive the world around them. • The following site has a range of resources for teaching about the structure of the eye and how the eye receives light: https://www.teachengineering.org/lessons/view/clem_waves_lesson05	• They eye is a fascinating organ. It enables us to see the world around us. Learn more about the structure of the eye and how it works: • https://www.eurostemcell.org/eye-and-stem-cells-path-treating-blindness • Draw a diagram of the eye and label the following parts: cornea, lens, retina, optic nerve, retinal pigment. • Explain how the eye works – what is the function of each part of the eye? • There are different kinds of cells in the eye. Name 2 cell types and explain how they enable sight. • What might happen if these corneal cells were damaged Can the corneal cells regenerate or repair? • What happens if the limbal stem cells are damaged? • How have stem cells been used to repair cornea damaged?

		enable them to survive and reproduce (ACSSU150		• What causes blindness? How might stem cells be used in the future to repair eye injury or blindness? • Use in conjunction with ACSHE134 above
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of the eye as an important sensory organ.	• See ACSSU150 above as a context for students to explain the different parts of the eye and to predict what might happen if specialised cells associated with the eye did not function.
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	Unit 2	Working like a scientist AND Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. • See section above (red) to draw attention to aspects of working as a scientist, such as the riskiness of science and the need to have a Plan B when a roadblock arises.	• See the SHE (RED) section above related to collaboration and the nature of science.
	Unit 2	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039)	• See section ACSHE135 above. • This case offers the opportunity to highlight the interdisciplinary nature of scientific research – it relies on understanding the context in which the scientific knowledge would be applied (in this case the needs of the patient and the current range of treatment options) and understanding the technological possibilities and limitations.	• See section ACSHE135 above.

	Unit 2	The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)	• See section ACSHE160/194 above • This is an opportunity to highlight the nature of clinical trials as a way of investigating the usefulness and limitations of new treatments of therapies.	• See section ACSHE160/194 above
Senior Biology Australian Curriculum – Science Understanding (SU)	11 (Unit 2)	• The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• The article and video highlight the use of stem cells to treat corneal damage and can be used a context through which to highlight limbal stem cell therapy as only one of three current stem cell treatments. • https://www.eurostemcell.org/what-diseases-and-conditions-can-be-treated-stem-cells	• There are different kinds of cells in the eye. Name 2 cell types and explain how they are specialised to enable sight. • What might happen if these cells were damaged? Can the cells regenerate or repair? • How does the body repair the cornea? What happens if the limbal stem cells are damaged? How have stem cells been used to repair cornea damaged?

3.3 The O'Connor Group: Micro-lenses bring new cataract treatments in sight

Associate Professor Michael O'Connor and Dr Rachel Shparberg

Regenerative Medicine Research Laboratory at Western Sydney University

Billions of dollars are spent each year around the world on cataract surgery, and hundreds of millions more treating resulting complications. Finding drugs to treat cataracts or slow cataract development would be a significant improvement.

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Micro-lenses bring new cataract treatments in* sight' or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the O'Connor Group research?

- Improving drug research using micro-lenses (similar to the ones in the human eye) which are created in the laboratory using stem cells. This development of micro-lenses will reduce the need for animal lenses.
- Understanding how environmental factors cause cataracts and how the lens responds to try and protect itself.
- Finding ways to avoid current complications of cataract treatment.
- The O'Connor lab aims to develop knowledge about how to treat cataracts through better understanding of how they form and how cataracts can be prevented. The lab has a particular focus on cataract prevention in children, as cataract formation and treatment during childhood has lifelong consequences for the individual, as current treatment options are not optimal.

What is the science?

- Cataracts affect the lens, which is the part of the eye that transmits light onto the retina. The lens enables the eye to focus between near and far objects. When a cataract forms, the lens becomes opaque and the light is unable to move through the eye.
- Creating a human eye lens in the laboratory can take seven to eight weeks. Creating these lenses involves complex multi-step processes, which require daily attention. A team of scientists is required to ensure somebody is present each day of the week to manage the stem cell growth protocol.
- The O'Connor lab was the first group in the world to show that human pluripotent stem cells could be used to generate light focusing human lenses in the laboratory.
- Cataracts affect vision and lifestyle activities and are more common in older adults.

- Cataracts can form in children either at birth or during childhood. The cause of most childhood cataract development is unknown. Some cases of cataracts are inherited, other cases arise due to injury, infection during pregnancy, drugs and other childhood illness.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Collaboration: Collaboration is essential for scientific endeavour and advancement. In this case, the O'Connor group is working with Megan Prictor from Cataract Kids Australia to develop possible treatments for children suffering from cataracts.
    - The O'Connor group has also partnered with eye surgeons and the patient group Cataract Kids Australia as well as drug companies to try and work together in order to achieve these goals.
    - To treat cataracts more effectively, scientists collaborate and partner with drug companies and clinicians to create new knowledge and techniques which may lead to possible treatments. This development can lead to clinical trials which test the usefulness of the proposed treatment method.
    - Need: Stem cell technology enables the creation of specific tissue models, such as the human eye lens, to develop and test treatments for cataract.
    - Lab structure and pathways: Science laboratories consist of a diverse mix of people at different stages of their careers, such as post-doctoral researchers (who can also be referred to as early career researchers if they are within 5 years post PhD). You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.
    - Working in a science research laboratory requires teamwork, especially as the experimental protocol requires complex steps or frequent interventions. This may require teams to work around the clock, sometimes even on weekends.
    - Interest and agency: Scientists are often driven by passion and interest, such as a desire to help people, an interest in developmental biology or just biology itself, strong curiosity and the desire to make discoveries.
    - Social, cultural and economic influences on scientific research and ethical aspects: in this case, growing human eye lenses in the lab reduces the need to harvest lenses from animals (i.e. reduces ethical concerns about animal testing). Focusing on improving cataract treatment outcomes for children can enhance quality of life by improving eyesight quality and reducing the need for on-going expensive and invasive treatments (i.e. reducing social and economic impacts)

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/ s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Structure of scientific laboratories and staff (this is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, ECR, associate professor etc.)	• This video features Associate Professor Michael O'Connor and Dr Rachel Shparberg. • Research laboratories consist of a range of people (younger and more senior) from a variety of career stages. Post-doctoral researchers are important in laboratory settings as they conduct much of the hands-on lab-based work. • Dr Rachel Shparberg is a postdoctoral researcher (post-doc). A post-doc is a person who has already completed a PhD and is now working on new research. In her role as a post-doc, Rachel would do much of the 'hands on' work in the lab. She would be mentored through her career by more senior researchers. • Using Rachel's journey into research as an example, teachers can help students identify characteristics which have helped guide scientists into their current career pathways (see specific question indicated by %). Examples might include curiosity or fascination about the human body and how it works, questioning, a continued need to	• In the video Dr Rachel Shparberg talks about her journey into stem cell research. What were the stages of her transition from high school to her current role? • What prompted Rachel to pursue her current career? What was Rachel fascinated about that helped her find her current career path? Why is stem cell research a good 'fit' for Rachel? • In the video Michael says, "The desire to help people, an interest in developmental biology or just biology itself, strong curiosity and the desire to make discoveries, all of those things can be packaged together through experience to create opportunities and lead to careers." What does Michael mean by this statement? • When have you felt the desire to help people? How have you felt when you have helped people? • What do you have a strong interest or curiosity about? If you could make a discovery, what would it be and why? • Why might Michael has said these desired are 'packaged through experience? What might be mean by that? How does experience help you? A famous education researcher, John Dewey, wrote a lot about reflective practice. He said that we don't learn from experience, we learn by reflecting on experience. Why might this be the case? How can you

			know or find out more, a desire to help people etc. These characteristics are common in people who pursue careers in science and can been compared with other cases in this series (e.g. Polo Group (9.1) and the Pébay Group (4.1)). Science offers an outlet for people to investigate their questions and develop new knowledge about areas we don't know much about. • Michael talks about interest being an intrinsic motivator which can lead to new opportunities.	capitalise on learning through experience through reflection? What might this look like in practice? • How might experiences and passion/ interest for something help create opportunities for you? • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.
		Working like a scientist involves working as a team and collaborating with other people.	• In the video Michael emphasises the role of collaboration and partnerships, such as working with drug companies, clinicians and partnering with Megan Prictor from Cataract Kids Australia to better understand the needs of patients and the realities of the clinical setting. • In the video, Michael also highlights the role of teamwork in science laboratories. Working as a team means that jobs can be shared, and tasks can be managed. Working as a scientist may require working flexible hours. This flexibility can be seen as an opportunity.	• In the video Michael talks about partnering with drug companies, support groups (Such as Cataract Kids Australia) and clinicians (e.g. doctors who work with people who suffer from cataracts). What value is there in forming these partnerships? Identify what each partner might bring to the partnership. • In the video, Michael highlights the role of teamwork in science laboratories. In this case, the stem cell technology to develop micro-lenses. The technique requires daily attention over seven to eight weeks. This requires the team to share the load so that the experimental materials can to be tended to every day of the week (including weekends). Do you know of other jobs that require flexibility? How do people who work in those jobs manage? Do they work less hours during the week? What are some benefits and limitations of having flexible working hours? • When in your life have you needed to be flexible with working hours? How do you manage your time? What were the benefits and limitations (internal factors) for you? What were some opportunities and challenges (external factors) you experienced as a consequence?

Australian Curriculum: Science as a Human endeavour (SHE)	8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• The article '*Micro-lenses bring new cataract treatments in sight*' highlights the challenges faced when working to treat cataracts in children. Use the quotes to simulate discussion about how research by the O'Connor lab might generate new knowledge and hypothesise about how our existing knowledge might change in the future as new evidence becomes available in this area. • Use the creative writing scenario to have students apply their knowledge and create hypothetical 'new knowledge' which could arise from the work the O'Connor lab is doing. Consider the three broad aims of the Group: drug development, lens regeneration and avoiding complications of current cataract treatments. Use these three areas to create a context for students to base their hypothetical scenario. • This stimulus offers the opportunity to have students **create** new ideas based on their existing knowledge, the information given in the article and from the video. Although their ideas may not necessarily align with how the research may develop in reality, the idea here is for them to think creatively about possibilities and develop creative thinking skills. • Creative thinking requires inquiry (asking questions) to make connections with other knowledge. Student can use empathy, observations and draw on past experiences.	• In the article, Michael says, "Treating kids with cataracts is much more challenging than treating adults… Surgery is more difficult. It takes longer to complete the treatment— up to 10 years—and the vision outcomes are often much worse." Megan from Cataract Kids Australia went on to say, "We see multiple surgeries and very challenging care regimes post- surgery and often the vision outcomes are poor. Treatment methods for congenital cataract haven't changed in years. We urgently need new approaches." • How might the micro-lenses created by Michael's group, in the lab, be useful for developing new knowledge about cataracts in children? • Imagine you have travelled 10 years into the future. You are a journalist who is writing an article for Science News for Students about a new breakthrough from the O'Connor group. Write a news article which outlines the new knowledge which led to the breakthrough in one of the three focus areas of the O'Connor Group (i.e. a. drug development, b. lens regeneration or c. avoiding complications of current cataract treatments.). Pick one area and create a hypothetical research outcome from the lab related to your chosen area. • The article should describe what you think might be a possible research breakthrough. What was the new knowledge created by the Group which led to the breakthrough? • The research outcome can be creative, but should be plausible. That is, it needs to align with our current understanding about the eye, but can also advance this understanding. • To get started, you will need to find out what is already known, the main issues for cataract treatment in children (for more details see resources on Cataract Kids

			They can make connections to other concepts and disciplines to think in different ways, with fresh perspectives. • Creative thinking involves imagination to seek and generate new ideas. This can include playing with unusual, risky and radical ideas. Hypothetical scenarios reduce boundaries, but in doing so, creates uncertainty and discomfort for the learner. • Creative thinking requires reflection on the novelty of chosen solution. Use a peer review method to have students offer feedback about the plausibility of their creative response.	Australia – see link below) and what the current needs are. This will help you identify what you need to learn more about. • Peer review - Once you have written your article, create small groups and consider each person's article. Offer feedback to each person using the frame '2 stars and a wish'. That is – two things which are strengths of the hypothetical research outcome and 1 idea which may help the person think critically about their response. Make any changes to your response based on the feedback you have received. How is this feedback process modelling the nature of scientific endeavour and peer review? • How might new knowledge enhance the quality of life for children who suffer from cataract?
		Science knowledge can develop through collaboration across disciplines of science and the contributions of people from a range of cultures ACSHE226	Cataract Kids Australia is an organisation that aims to support people impacted by cataracts in children (i.e. children, parents, families, carers etc.) and those who seek to support them. Exploring the website for this organisation offers a number of opportunities to draw out the nature of collaboration for the advancement of science, such as: • Science and other knowledge develop through collaboration. This website highlights the collaborative nature or human endeavour. In particular, students can explore the different people who support the organisation. • Students can explore the information on the site, making inferences about the purpose and value of the information and how it might support its patrons.	• The not-for profit organisation Cataract Kids Australia was established to "improve support for children with cataracts and their families, to enhance clinical care and to build connections with research across Australia". • Navigate to the Cataract Kids Australia website to find out more about this organisation and why it was established: http://www.cataractkids.org.au/ • Not-for profit organisations, like Cataract Kids Australia, will usually have an aim or mission statement, which highlights why they exist and what they aim to provide. This kind of statement is a way for you to understand the intentions and values of the organisation. Can you locate the goals or mission statement? (Hint – click on the tab 'About us' at the top of the page) • What is a charity organisation? What does not-for profit mean? Why are charity organisations valuable for the community? • What resources does Cataracts Kids Australia provide for people with cataract disorders?

			• Looking at the mission statement above, the organisation aims to build connections with research across Australia. This demonstrates how scientific knowledge develops through collaboration. • The organisation, through sharing stories and connecting people, builds knowledge about how cataract disease may impact peoples' lives. This can support and guide research. • Organisations, like Cataract Kids Australia, can connect with international partners to facilitate the sharing of knowledge and support in the future. • The research tab on the website offers the opportunity to showcase the nature of science – in particular how findings from science research do not always agree. Hence the need for critical thinking to consider why findings might be different due to different experimental approaches, different kinds of analysis, different participants, different research approaches and perspectives etc. This does not mean that scientific research cannot be trusted, it simply means that critical thinking needs to be applied when engaging with data and outcomes of research. For medical research, this can include understanding the nature of clinical trials, looking at cohort sizes, the types of data being collected etc. At this level, it can be enough to highlight the following aspects of medical research: • Clinical trials are a way of testing new treatments. There are strict conditions which	• How does the Cataract Kids Australia website illustrate partnerships with other organisations to support its patrons? What is the nature of these organisations and/or partners? • How does the Cataract Kids Australia website demonstrate collaboration between organisations to support research into cataract prevention and cure? • How might this organisation support the development of scientific knowledge? What sorts of knowledge development might be supported? • Why might the organisation need donations and financial support? How might the money be used? • How does the organisation support people who are directly impacted by cataracts? • Navigate to 'Information' tab, and then 'Cataracts and their treatment' Find out more about cataracts – how the might form and the current treatment options. http://www.cataractkids.org.au/ Navigate to the "Research" Tab: http://www.cataractkids.org.au/research.html • Explore some of the partner organisations listed. What is the purpose of these related organisations? How might they support: Patrons of the site? Other researchers? Doctors and clinicians? • In the research tab there is the following statement: "Research findings can disagree on things like: the incidence of childhood cataract in Australia; the optimal timing for cataract removal and IOL implantation; and the likelihood of complications such as glaucoma occurring after cataract removal surgery." • Why might there be disagreement between the research findings of the areas listed? Pick one are of contentions and outline why disagreement might occur.

			guide the use of clinical trials. Ethical approval and ethical behaviour throughout the process is imperative. • The use of data as evidence to support claims. When data in articles and media related to research outcomes is lacking or is weak, it is beneficial to exercise scepticism and critical thinking. • The need to include peer-review and different perspectives to critically reflect on research findings. • Values influencing research. Who has the greatest vested interest in the research outcomes?	• What does this kind of disagreement indicate about the nature of science? • You may like to refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells.
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSH E135	• In science research, models are used to test hypotheses and run investigations to test new ideas for disease treatment. Development of stem cell technologies has enabled scientists to create models of human tissue by reprograming cells and growing those cells into cells of interest. In this case, micro-lenses which are grown from human lens tissue and can be used to test potential treatments for diseases which affect the action of the lens. • Modelling enables scientists like Michael and his team to study how eye disease occurs and also test novel interventions, like drugs, to treat vision loss via cataracts. This case offers the opportunity to explore the nature of such models with students to understand how stem cell technology enables modelling of tissue to better understand cataract	• Developing new knowledge about treatment for cataract requires modelling to find out the impact of new drug treatments without testing on animals or obtaining tissue from animals. • Creation of models for testing new drug therapies is a common practice in scientific research. Stem cells offer flexibility when it comes to growing viable models in the lab. The O'Connor group has developed a technique to grow "hundreds of thousands of micro-lenses" in the laboratory, which can be used to test new drug treatments. • Having watched the video and read the article (Micro-lenses bring new cataract treatments in sight (page 30-31 of At the frontier of tomorrow's medicine) explain how the O'Connor group might be using stem cells to create human lens tissue. • In the past, lenses from the eye were derived from animals. Explain how stem cell technologies have reduced the need to source lenses from animals. What might this mean in terms of ethical implications for the Group?

			development and treatments, rather than being used directly for treatment. • The article *Micro-lenses bring new cataract treatments in sight* (pages 30-31 of *At the frontier of tomorrow's medicine*) describes how the O'Connor lab has created hundreds of thousands of micro-lenses similar to the ones in the human eye for testing cataract treatments. The new stem cell technology has enabled the lab to create large quantities of lens tissue. This article offers the opportunity to explore the interdisciplinary nature of scientific research – which relies heavily on technological and engineering advancement to conduct scientific research. • The development of the micro-lenses has reduced the need for obtaining lens tissue from other animals. Animals testing has ethical implications.	• There are a number of ethical considerations around using any animals in scientific research. Refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells, for more information. • Why do stem cell models offer flexibility for the Group's research? • From the video – which kind of stem cells does this group use and why?
	9 & 10	Scientific understanding, including **models** and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157/191	• See section above (ACSHE135) related to the use of stem cells for creating model lens tissue to explore the nature and action of drugs for cataract treatments.	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research and stem cells offer flexibility when it comes to growing viable models in the lab.
	9 & 10	Advances in scientific understanding often rely on technological advances and are	• Advances in technology and science have seen the O'Connor group create human micro-lenses in the laboratory (See ACSHE 135 above)	• See also section above - ACSHE134 above related to change in scientific knowledge and ACSHE135 advances in technology

		often linked to scientific discoveries ACSHE158/192	• Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life. (See ACSHE134 above). This speculative writing task allows students to develop and illustrate creative thinking skills (see above).	• In the article Micro-lenses bring new cataract treatments in sight (page 30-31 of At the frontier of tomorrow's medicine), Michael says "There is a lot of interest in furthering this technology. Industry and the community can clearly see the benefits". Describe the technology he is referring to and how might it benefit patients, industry and the community? • The article outlines the possibility of growing lens tissue for transplantation in the future. Imagine you have travelled 10 years into the future. You are a journalist who is writing an article for Science News for Students about a hypothetical new breakthrough from the O'Connor group – they have been able to grow and transplant human sized lenses into patients to restore eye transparency. Write a hypothetical news article which outlines new knowledge that has been developed by the group which enabled the growth and transplant of the human sized lenses. (See support guidelines in ACSHE134 above) • Develop a peer review method (see ACSHE134 above for an example) to have students offer feedback to each other and reflect on their own writing.
Australian Curriculum: **Science understanding (SU)**	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain	• The eye consists of different groups of specialised cells organised into tissues. • Sight, along with other sensory organs and system enable multicellular organisms to perceive the world around them.	• They eye is a fascinating organ. It enables us to see the world around us. Learn more about the structure of the eye and how it works: • https://www.eurostemcell.org/eye-and-stem-cells-path-treating-blindness • https://www.nei.nih.gov/learn-about-eye-health/nei-for-kids/about-eye • Draw a diagram of the eye and label the following parts: cornea, lens, retina, optic nerve, retinal pigment.

		systems of organs carrying out specialised functions that enable them to survive and reproduce ACSSU150		• Explain how the eye works – what is the function of each part of the eye? • There are different kinds of cells in the eye. Name 2 cell types and explain how they enable sight. • Cataract is a disease which can cause blindness. Learn more about cataract see the following websites: • Cataract Kids Australia: http://www.cataractkids.org.au/cataracts-and-their-treatment.html • Stanford Children's Health https://www.stanfordchildrens.org/en/topic/default?id=cataracts-in-children-90-P02105 • What causes cataract in children? • Use in conjunction with ACSHE134 above Cataract in older people is common. Learn more about adult cataract at Vision Australia: https://www.visionaustralia.org/information/eye-conditions/cataracts And, The National Eye Institute (international site): https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/cataracts • What causes cataract in adults? • What are some recommended prevention techniques? • How is cataract treated in older people? • How do cataract symptoms, treatment options and success rates differ in children compared to adults? • Create a Venn diagram to compare the similarities and differences.
	9	Multi-cellular organisms rely on coordinated and	• This video offers the opportunity to consider the nature of the eye as an important sensory organ.	• See ACSSU150 above as a context for students to explain the different parts of the eye and to predict what might happen

		interdependent internal systems to respond to changes to their environment (ACSSU175	• Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells, like skin cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	if particular specialised cells associated with the eye did not function. • What are induced pluripotent stem cells? Hint: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	11 (Unit 2)	• Working like a scientist And • Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to aspects of working as a scientist, such as interest, passion, fascination and a curiosity to know. • Find out what interests you and you will work hard. Working hard leads to new opportunities. • This video offers the opportunity to draw attention to pathways into scientific research as a career (e.g. Rachel Shparberg as a post doc) and what drives people to pursue a career in science.	• See the SHE (RED) section above related to collaboration and lab structure for resources. • In the video Michael said, "The desire to help people, an interest in developmental biology or just biology itself, strong curiosity and the desire to make discoveries, all of those things can be packaged together through experience to create opportunities and lead to careers." As you have chosen to study biology at the VCE level, what is it about biology that excites and interests you? Which area of biology interest you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/ sound like you and which aspects do not interest you/ do not sound like you? • Which dispositions related to 'working like a scientist' can you relate to the most? In this series, scientists have said things like feeling a sense of passion, curiosity, a desire to help people, the freedom to ask questions, doing puzzles etc. Which of these dispositions do you identify with the most and why?
	Unit 2 and 3	• Development of complex models and/or theories often requires a wide range of	• See sections above (ACSHE135 and ACSHE157) related to the use of stem cells for creating model lens tissue to explore the nature and action of drugs for cataract treatments. Use the work of the O'Connor	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling

		evidence from multiple individuals and across disciplines (ACSBL038)	group as a context for unpacking the use of stem cells to develop models for research.	is a common practice in scientific research and stem cells offer flexibility when it comes to growing viable models in the lab.
Senior Biology Australian Curriculum – Science Understanding (SU)	11 (Unit 2)	• The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• The article and video highlight the use of stem cells to create micro-lenses to act as a biological model to test new drugs therapies. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	• Induced pluripotent stem cells can grow into any cell type in the body under the right conditions. Find out what these cells are why they have been useful for the O'Connor group for creating micro-lenses. https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/

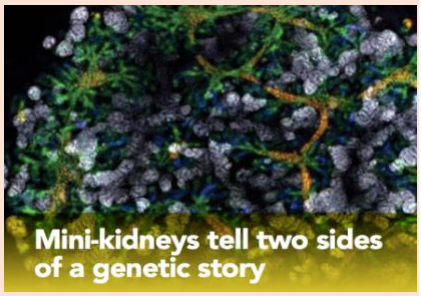
4. The Kidney

4.1 The Little Group: Mini-kidneys tell two sides of a genetic story

Professor Melissa Little and Drs Sara Howden and Tom Forbes

Murdoch Children's Research Institute

Chronic kidney disease costs Australia's economy $4.1 billion each year and is one of our biggest killers. In many cases the cause is genetic. It is estimated that one in ten Australians will show evidence of chronic kidney disease by 2020, but only one in four patients will receive a transplant.



Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Mini-kidneys tell two sides of a genetic story'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Little Group research?

- Developmental biology of the kidney and kidney disease research
- The lab is studying the effects of Mainzer-Saldino, a rare disease which leads to kidney damage.
- The Little lab have grown kidney organoids from patient derived stem cells. Some organoids are made from diseased cells and others from cells which have undergone gene editing to correct a mutation.
- The Little Group wants to better understand how the disease develops so that they can develop personalised treatment options using stem cells.

What is the science?

- Mainzer-Saldino syndrome is a rare disease involving a single defective gene which causes life-threatening kidney damage.
- The defective gene causes malformation of cilia (finger-like cell projections that detect movement of liquid past the surface of the cell) which are vital for the normal function of kidney cells.
- Researchers from the Little group took skin cells from a patient, turned them into stem cells, then used CRISPR gene-editing technology to correct the mutation which causes the condition.
- Reprogrammed stem cells from a patient contains the patient's genetic fingerprint.
- Kidney biopsies in the advanced stages of a disease do not necessarily offer beneficial information for doctors. Regenerating a kidney from scratch is a way of 'winding back the clock' to better understand the impact on the kidney in the early stages of the disease.
- Kidney organoids – diseased and non-diseased – can be used as a model to better understand kidney function in both scenarios and to develop possible treatments, which are specific to the patient.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Nature of science: Science is a creative endeavour which involves the freedom to ask questions and choose the direction that interests you. Science is an artistic process.
    - Science laboratories consist of a diverse mix of people at different stages of their careers.
    - Discoveries and breakthroughs in science create new knowledge and technology.
    - Advances in scientific knowledge often rely on technological advances. Advances in one field can influence other areas of science, technology and engineering. Advances in one area of science can influence and lead to advances in other areas. For example, technology around the growth of kidney organoids can be used for researchers around the world who are conducting research into kidney disease.
    - Collaboration: Collaboration is essential for scientific endeavour and advancement.
    - Social, cultural and economic influences on scientific research and ethical aspects: in this case, the moral imperative of developing better treatments for kidney disease to enhance survival.
    - Gene editing involves ethical considerations.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Structure of scientific laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, ECR, associate professor etc.)	• This video features Professor Melissa Little and Drs Sara Howden and Tom Forbes. • Dr Tom Forbes is a clinician (paediatric nephrologist) and is currently undertaking a PhD. • Research laboratories consist of a range of people, from a variety of career stages (beginning students to experienced researchers). Pathways into science research are often non-linear. People come to science research via different pathways, and at different stages of their lives. • Science involves having a vision, asking questions, working in teams to share expertise, and offers the freedom to pursue research that is of interest. • Creating new knowledge requires thinking in different and creative ways. This can be called thinking laterally, thinking outside the box etc. • Science is an artistic process. Science involves answering questions to which there are not yet answers. Developing new knowledge requires creativity and	• Dr Tom Forbes is currently undertaking a PhD yet is already called Doctor in the video! Tom is a paediatric nephrologist (a medical doctor who specialises in kidney issues in children) (see http://www.melbournepaediatricspecialists.com.au/profile/dr-tom-forbes/) and a PhD student (https://www.mcri.edu.au/users/tom-forbes). How might his experiences as a medical doctor inform and benefit his PhD research? How might his prior experience present challenges for him in his new role? • If Tom is already a doctor (medical) and when he completes a PhD, would he be called Dr Dr James Forbes? What do you think the conventions might be for James' salutation or the way he introduces himself professionally? • Many of the scientists in this video series have highlighted the value of having experienced and beginning scientists (i.e. Honours, Masters and PhD students) as part of the lab team. List some qualities you think students and experienced staff bring to the team. What could members of the team do to learn from one another? What are some characteristics of effective mentoring partnerships? • In the video Professor Little says "I think being a scientist is one of the most fascinating careers that you can have

			imagination. It is a creative and artistic process.	because there are very few jobs where you have the freedom to actually ask a question and go in a direction that you choose to go." Why might scientific research offer such freedom? If you went into scientific research, in which area would you focus? Which questions would you like to see answered? • In the video Professor Little says, "Unless you can think laterally, then you won't actually be adding new understanding, you'll just be relooking at the same thing again and again." What does Melissa mean by thinking laterally? Why is this important when developing new knowledge? Think of an example when you have thought laterally to solve of problem. • In the video Professor Little says "And so I think in many ways a career as a scientist is probably most similar to a career as an artist. It's a very artistic process." Explain how science can be considered an artistic process. How might creativity be important in scientific research?
Australian Curriculum: Science as a Human endeavour (SHE)	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becom es available ACSHE134	• In the article '*Mini-kidneys tell two sides of a genetic story*' there is a quote: "The ability to make a stem cell from any other cell type is something that has only been defined in the last just over 10 years." This quote highlights the nature of scientific knowledge development. New evidence influences scientific discourse. As new evidence becomes available (through new research and changes in technology), new insights are offered which advances knowledge and technology capacity. This is	• The article '*Mini-kidneys tell two sides of a genetic story*' mentions the disease Mainzer-Saldino. • Find out more about Mainzer-Saldino. See for example: https://ghr.nlm.nih.gov/condition/mainzer-saldino-syndrome • What is Mainzer-Saldino syndrome? • What region of the kidney does it affect? How does this influence the routine function of the kidney? • What are the causes? • What are the symptoms? • How can it be treated? • What are the long-term implications for living with this condition?

			an example of science knowledge being tentative, yet durable. • (NB Use in conjunction with ACSSU149 below – although Mainzer-Saldino is mentioned in the article, teachers could choose from different inherited kidney disorders as there is a lack of age appropriate information readily available related to kidney cilia. Other disorders which impact on more prominent aspects of the kidney may be easier to research.)	• Why might the Little Group be conducting research on this disorder? • What are the possible benefits of their research?
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226 AND People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity	• In the video Professor Little talks about science as a "team sport". This is an opportunity to showcase the diversity of workplaces (see red section above) and how scientific endeavour is conducted collaboratively, drawing on the expertise of a range of people. For example, in the video/ article, Melissa brings a wealth of expertise in kidney research (she is a Professor, which is a position that requires years of research experience to achieve promotion). • Sara heads a gene editing facility and would offer expertise around CRISPR (gene editing technology). Dr Tom Forbes is a practicing paediatric nephrologist (kidney doctor for kids), and understands the needs of patients, so he has the capacity to bridge the gate between the lab and the clinic.	• In the video, Professor Melissa Little talks about science as a "team sport". Why might science be like a team sport for Melissa? Why might having a shared vision be important for a 'team'? What other benefits are there to working as part of a team? How can teams function effectively together? Think of a time you have worked well as part of a team. What made it work well? What were challenges that made it not work well? • What expertise does Dr Tom Forbes bring to the lab? • What expertise does Dr Sarah Howden bring to the lab? • Draw on the article and video to support you. • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher. • Compare the work of Dr Tom Forbes to other clinician researchers (i.e. Dr Chong and Dr Watson). Outline the similarities and differences between the three examples of clinicians also working in research. How do their experiences as doctors support and enhance their work as researchers? And vice versa?

		ACSHE121/136	• These are examples of how scientists work collaboratively, usually across disciplines to share knowledge and expertise to advance scientific endeavour. • This case also offers the opportunity to consider how a doctor researcher, like Dr Tom Forbes, uses science skills and knowledge in their occupations.	• This case offers an example of how people develop skills, knowledge and expertise in one area and then apply them to another. Standard science degrees teach general content and generalised skills. Scientists then have to undertake specialised training (usually on the job) in certain areas of research. Different labs have different equipment, protocols and are working with different specialised knowledge. • This is also an example of how knowledge and skills developed through engaging with science are transferable and are often common to other disciplines. For example, historical analysis involves asking questions, being curious and gathering data to use as evidence for claims. Think about the skills and knowledge you have developed in the traditional 'school disciplines' (i.e. science, history, maths, art etc.) and consider which skills and knowledge are transferable? That is, have you used maths in a science class? Have you used maths outside the maths classroom? Have you ever been curious about something in your everyday life? Have you asked questions and maybe even done a little experiment to test your hypothesis? These are examples of how you develop knowledge and skills which transcend 'school-based disciplines.' It just takes a bit of noticing to see how they might be useful! The knowledge and skills you develop are useful for making sense of the world around you every day.
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may	• In science research, models are used to test hypotheses and run investigations to test new ideas. The Little Group has grown kidney organoids in the laboratory to act as models for research. This has been an internationally ground-breaking advance in the area of kidney research.	• Developing new knowledge about diseases requires modelling to test hypotheses. Scientists have a number of options, such as animal models, computer modelling and growing diseases and tissues in a laboratory. Use a Venn diagram to compare and contrast the benefits and limitations of these different model types.

		involve ethical considerations ACSHE 135	• Many of the groups in this series are using stem cells to develop specialised tissue for two broad purposes: modelling or drug/ treatment development. • The lab has also used CRISPR gene-editing technology to edit the single gene mutation which leads to Mainzer-Saldino syndrome. Gene editing technology is not without controversy. You may like to refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells for more information.	• The Little Lab, like many other groups in this series, use stem cells to develop specialised tissue for two main purposes: to model specific tissue and to test new drugs and treatment options. Using the article and video, explain how this group is using stem cell technology in the area of kidney research. List two ways in which they Little Group is using stem cells and what they hope to be able to achieve/ or new knowledge they hope to develop. • In the article, it says "If these diseases can be detected through genetic testing and addressed before symptoms appear, it can save patients a lot of suffering and reduce the costs to our healthcare system." Explain what this quote means. How might advances in the Little lab impact other areas of society?
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157/191	• See section above (ACSHE135) related to the use of stem cells for modelling kidney tissue to explore the nature and action of kidney disease. • In this case, the Little Group are growing kidney tissue to better understand the effects of Mainzer-Saldino syndrome. In people with this disease, the mutated form of the gene leads to the malformation of cilia, which are vital for normal function of kidney cells. The team are using the two models to compare how the disease develops and behaves in cells from a particular patient.	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research and stem cells offer flexibility when it comes to growing viable models in the lab. • Having watched the video and read the article *Mini-kidneys tell two sides of a genetic story'*) explain how the Little Lab are using stem cells as a model for kidney disease. Why do stem cell models offer flexibility for the group's research? Explain how the model tissue is grown in the lab. What kind of stem cells does this group use and why? • In the video, Tom says "The ability of being able to regenerate a patient's kidney from scratch is that you can

				sort of wind back the clock for them and start to look at what their kidneys might have been doing in the early stages of their disease. Previously, I would have had to do a biopsy of a patient's kidney in order to really get the information that we're now seeking to get from using these regenerated kidney organoids. And I think that's a really exciting way of approaching this sort of problem." What is the problem? Why is taking a biopsy of the kidney less informative? What does Tom mean by 'winding back the clock'? Why would knowing how the kidney behaves in the early stages of disease be informative for researchers? • The Little group is specifically focusing on Mainzer-Saldino syndrome. Explain why the group is growing kidney tissue with the gene mutation and tissue without? What do they hope to examine by comparing the two tissue types? Why might the lab want to examine the mutated tissue and mutation-removed tissue from individuals?
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192 And People use scientific knowledge to evaluate whether they accept claims,	• See ACSHE135 above • Advances in technology and science have led to greater understanding of the kidney, such as how it can be repaired. The group has been one of the word leaders in developing kidney organoids in the lab. • Developing new technologies requires creativity and imagination to advance our knowledge and requires advances in technology to bring creative ideas to life. It also requires scientists to draw on developing technologies and adapt them to suit their particular needs and areas of research interest. CRISPR is an example of	• The Little Group has been able to grow kidney organoids in the laboratory. See the 2015 press release from ABC news: Kidneys in a dish: Scientists reprogram adult skin cells to make mini kidneys https://www.abc.net.au/news/science/2015-10-08/proto-kidney-grown-in-a-dish/6833882 • What kinds of stem cells have the Little group used in their research into growing kidney tissue? Has the type of stem cell used changed over the years? If so, how has it changed? • Using the ABC article, explain how the Group's understanding about how to grow the kidney organoids has developed and evolved over time.

		explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities ACSHE160/194	such technology. Gene-editing technology is advancing at a rapid date. CRISPR is being used in human stem cell research, see, for example, the Pébay Group. • Gene editing, such as CRISPR, has opened the door to ethical discussions about editing the genome of living things. The video and article offer an opportunity to discuss the ethical considerations of gene editing when teaching about genetics. • Find out more about CRISPR on the NIH website: Genome Unlocking life's code: https://unlockinglifescode.org/crispr-teaching-tools • The website has links to other sites and lesson plans related to CRISPR technology.	• Why might this 'discovery' have been newsworthy in 2015? • You may like to refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells • The article outlines a new 'invention' developed by Dr Sara Howden. What is her invention and how might it be significant for research into kidney disease? How have advances in technology supported Sara's invention? What kinds of technology is she using? • What is gene editing? Why is the Little group be interested in gene editing? What is CRISPR? How might this technology affect people's lives in the future? • Navigate to the NIH website: Genome Unlocking life's code website to learn more about CRISPR: https://unlockinglifescode.org/crispron-teaching-tools • What is the NIH? What is the purpose of this organisation? • More information about CRISPR-Cas9: https://ghr.nlm.nih.gov/primer/genomicresearch/genomeediting
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research ACSHE228/230	• The article '*Mini-kidneys tell two sides of a genetic story*' states, "Chronic kidney disease costs Australia's economy $4.1 billion each year and is one of our biggest killers. In many cases the cause is genetic. It is estimated that one in ten Australians will show evidence of chronic kidney disease by 2020, but only one in four patients will receive a transplant." • The Little Group case offers an opportunity to explore how values guide research. The	• In the article, Tom says ""If these diseases can be detected through genetic testing and addressed before symptoms appear, it can save patients a lot of suffering and reduce the costs to our healthcare system." • How much does kidney disease cost the Australian economy each year? How many people are impacted? • How is the Little Group using research to create social impact? (i.e. think about what advances might cause long term changes to people's health and changes which might impact the health system)? What are the group's long term aims and what do these say about what they value?

			article raises an issue which impacts a number of Australians, and effects the economy. When so many people are affected, and the costs to supporting people is so high, research tends to be focused in these areas as a way of reducing social and financial impact. • Support organisations, such as Kidney Health Australia exist to support people suffering from kidney related issues. Such organisations convey the value placed on treating and supporting the whole person and their families, not just the disease.	• Navigate to the Kidney Health Australia site: https://kidney.org.au/ How is Kidney Health Australia supporting kidney health? • What is the role of the organisation? What is their mission statement? What services do they provide? What do these elements say about what is being valued? Why is support valuable for people with kidney related issues? Is this a reputable website? How can you tell?
Australian Curriculum: **Science understanding (SU)**	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce ACSSU150	• The excretory system consists of regenerative and non-regenerative tissues and cells. Some cells of the excretory system can regenerate and repair acute damage or injury, such as blockage of the ureter. If a blockage exists and is removed, the cells can be remodelled, and repair is possible. However, the main structure of the kidney, in particular the areas containing nephrons are permanent and once formed are unable to regenerate. In particular, damage to the glomerulus and tubule structures are non-reversible. Once these structures are damaged, kidney function is compromised. • The kidney and other structures of the excretory system are responsible for removing metabolic waste from the body.	• The kidney is an integral organ in the excretory system. To learn more about the structure of the kidney and its role in excretion go to the Kidney Health Australia website and click on “What your kidneys do”: https://kidney.org.au/ • Click on “Keeping your kidneys healthy” to see how you can maintain good kidney health. • While the kidney, like many organs in the body, can undergo some cellular repair after it is damaged, it is largely composed of tissue which is permanent (i.e. the nephrons, which are formed via nephrogenesis), which do not regenerate once damaged. What would happen to the excretory process if the kidney stopped working due to damage? • Use the context of Mainzer-Saldino syndrome or chronic kidney disease more generally to examine how the kidney works and what happens when it is damaged.)

			• See the section about (ACSHE134) on Mainzer-Saldino. Use this condition as a context for teaching about the excretory system, in particular, what happens when the kidney does not work properly.	• Chronic kidney disease can lead to kidney failure. Navigate to the Euro stem cell website to learn more about kidney diseases and how stem cells might be able to help: https://www.eurostemcell.org/kidney-disease-how-could-stem-cells-help • Create (or download) a diagram of the human kidney. Explain what each part of the kidney does using one colour. • Going back to each part you labelled, using a different colour, explain what could happen (or not happen) in each part of the kidney in people with one of the following kidney diseases: • Alport syndrome: https://ghr.nlm.nih.gov/condition/alport-syndrome# • Polycystic kidney disease: https://ghr.nlm.nih.gov/condition/polycystic-kidney-disease# • Dent disease: https://ghr.nlm.nih.gov/condition/dent-disease# • Medullary cystic kidney disease type 1: https://ghr.nlm.nih.gov/condition/medullary-cystic-kidney-disease-type-1
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment ACSSU175	• This video offers the opportunity to consider the nature of the kidney in terms of the specialised tissue (which is part of a complex body system – the excretory system). • Use the context of kidney disease (see examples above) to have students explain how the kidney and excretory system would function differently if each of these areas were not working.	• (See resources listed in ACSSU149 above in relation to permanent tissues/ cells and kidney disease examples) • The kidney is an integral organ in the excretory system. Create a flow chart to explain how the excretory system works. Include how the excretory system is linked to other systems in the body. • Support site: Kidney Health Australia website and click on “What your kidneys do”: https://kidney.org.au/

			• As kidney tissue consists of non-regenerative cells (permanent tissue), once created, these cells do not regenerate or repair if damaged. New regenerative medicine approaches may offer hope in the future through heart therapies. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	• Draw a diagram of the kidney. Label the respective parts. Explain what each part does. In a different colour explain what would happen to the bodies capacity to remove waste if each part you labelled was damaged and did not work properly. • What are induced pluripotent stem cells? https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • Why would these cells be beneficial for growing kidney cells? • (Use in conjunction with ACSHE resources above to explore the excretory system in context)
Senior Biology Australian Curriculum – Science as a Human Endeavour (SHE)	Unit 2	• Working like a scientist And • Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to aspects of working as a scientist, such as agency, shared vision, science being an artistic process, science as a 'team sport' and drawing on expertise from across disciplines. • This video offers the opportunity to draw attention to pathways into scientific research as a career (e.g. Tom Forbes is a clinician who is doing a PhD).	• See the SHE (RED) section above related to collaboration and lab structure for resources.
		• Development of complex models and/or theories often requires a wide range of	• The article and video highlight the use of stem cells for creating model kidney tissue to explore the nature and action of kidney	• New knowledge about diseases can be developed through modelling, to directly observe and investigate how tissues respond to disease. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before it

		evidence from multiple individuals and across disciplines (ACSBL038)	disease and for the development of treatment options. • In this case, the Little Group are growing kidney tissue to better understand the effects of Mainzer-Saldino syndrome. In people with this disease, the mutated form of the gene leads to the malformation of cilia, which are vital for normal function of kidney cells. The team are using the two models to compare how the disease develops and behaves in cells from a particular patient.	leads to permanent damage. Modelling is a common practice in scientific research and stem cells offers flexibility when it comes to growing viable models in the lab. • Having watched the video and read the article '*Mini-kidneys tell two sides of a genetic story*' explain how the Little Lab are using stem cells as a model for kidney disease. Why do stem cell models offer flexibility for the Group's research? Explain how the model tissue is grown in the lab. What kind of stem cells does this group use and why?
	Unit 2	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) AND The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)	• In the article '*Mini-kidneys tell two sides of a genetic story*' there is a quote: "The ability to make a stem cell from any other cell type is something that has only been defined in the last just over 10 years." This quote highlights the nature of scientific knowledge development. New evidence influences scientific discourse. As new evidence becomes available (through new research and changes in technology), new insights are offered which advances knowledge and technology capacity. This is an example of science knowledge being tentative, yet durable**.** NB See section (ACSHE134 above for more details.) • The aim of one day growing fully functioning kidneys in the lab, derived from a patient's own stem cells, is an admirable goal for science. This possibility can be used as a context to draw out benefits and limitations	• Advances in understanding of kidney tissue, in particular technology related to growing kidney organoids has developed rapidly. • In 2015, Professor Little and her team were the focus of an ABC news article: Scientists reprogram adult skin cells to make mini kidneys https://www.abc.net.au/news/science/2015-10-08/proto-kidney-grown-in-a-dish/6833882 • Advances in the growth of kidney organoids has come a long way (see for example - Nishinakamura (2019) Human kidney organoids: progress and remaining challenges https://www.nature.com/articles/s41581-019-0176-x • Summarise any differences between the 2015 and 2019 articles in terms of how knowledge or technology has evolved and developed. • How has the growth of kidney organoids in the lab changed the nature of kidney research? What are two advances outline in the article? Why are the advances

			of developing this kind of technology, especially in relation to social, ethical, cultural and economic considerations. • This case could also be used as a context to highlight how technology like CRISPR has developed and evolved and is now being applied to human models.	significant? How might these advances be used in other areas of research, for example, heart or eye research? • Imagine a time where scientists were able to grow a fully functioning kidney in the lab – as Professor Little outlines as an aim of their research. Create a Plus, Minus, Interesting chart to outline some benefits, issues and interesting ideas that would be raised with the emergence of such technology.
	Unit 2 and 3	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL043 AND ACSB074)	• Gene editing technology (e.g. CRISPR) offers the potential to alter genetic codes to change health outcomes for patients. • New technologies and advances, such as those from the Little and Pébay/Hewitt groups are developing very important foundation knowledge, which may have social and economic impact. However, the possibility of gene editing is not without controversy. This article offers an opportunity to explore gene-editing technology, such as CRISPR in context.	• Consider the current uses of CRISPR technology. Read the following articles and explain how CRISPR is being used and the current state of CRISPR use in human gene editing: • https://www.abc.net.au/news/2017-08-03/how-mutant-genes-are-deleted-repaired-replaced/8769288 • https://www.abc.net.au/news/science/2016-04-07/crispr-gene-editing-technology-explainer/7217782 • Why might altering genetic codes to change health outcomes be controversial? • **Create a debate** arguing for or against the use of CRISPR technology to alter human embryos before implantation. • You may like to refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells, for more information.
Senior Biology Australian Curriculum – Science Understanding (SU)	11 (	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and	• Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	Induced pluripotent stem cells can grow into any cell type in the body under the right conditions. Find out what these cells are why they might be beneficial for the Little group. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/

		cell specialisation (ACSBL055) AND In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of capillaries) (ACSBL058) In particular, the excretory system	• This case offers an opportunity to explore the excretory system in context. Research related to cardiac tissue has focused on ways to regenerate heart tissue for injury repair AND the use of stem cells to develop models for testing drugs. Students can use these contexts as a way of learning more about the nature of cells and how cells develop into tissues and organs. • See also the resources above related to kidney development and structure	• See ACSSU150 and ACSSU175 above about using kidney disease as a context for students explaining the different parts of the kidney and excretory system what happens when they are not working. • Advances in the growth of kidney organoids has come a long way (see for example - Nishinakamura (2019) Human kidney organoids: progress and remaining challenges https://www.nature.com/articles/s41581-019-0176-x • Some criticism of growing organoids has been the lack of vascularisation – that is, the lack of blood flow into and out of the kidney organoids to observe whether the kidney tissue can carry out the role of filtering blood. See for example: https://www.genengnews.com/news/kidney-organoid-method-might-just-stir-the-blood/ • Using your knowledge of the kidney and its role in excretion, explain why vascularisation of the kidney organoid would be helpful. • This article may be useful – it offers background information on organoid development. Koning, et al., (2019) Stem cell-derived kidney organoids: engineering the vasculature https://link.springer.com/article/10.1007/s00018-019-03401-0 • Injury to the kidney can be defined as acute (e.g. a sudden injury due to trauma) or chronic (e.g. prolonged and repetitive). Research suggests that some cells in the kidney may recover from acute damage, however,

				nephrons, once damaged, have not been shown to regenerate in adult kidney tissue. The kidney responds to chronic tissue damage through scarring and irreversible function loss. The kidney ceases to function properly is the glomerulus and tubules are damaged. • Using your knowledge of the kidney and how it works, explain why scarring would inhibit kidney function. Why would damage to the glomerulus and/or tubules lead to kidney malfunction? What role do these structures play?
	Unit 3, year 12	Biotechnology can involve the use of bacterial enzymes, plasmids as vectors, and techniques including gel electrophoresis, bacterial transformations and PCR (ACSBL087)	• This video provides a context for discussing how gene-editing technology (e.g. CRISPR) can alter the genome, which in turn would alter gene expression. There are a number of unknowns when considering altering the human genome, such as the impact on other genes and gene expression, impact on other areas of the body and implications on subsequent generations if these genetic changes are inherited.	• Learn about CRISPR as a form of biotechnology, which enables gene editing. Use the following sites: • https://www.pbslearningmedia.org/resource/lesson-plan-gene-editing-and-crispr/lesson-plan-gene-editing-and-crispr/ • https://unlockinglifescode.org/crispr-teaching-tools • https://ghr.nlm.nih.gov/primer/genomicresearch/genomeediting • Read the following article from 2016 - https://www.abc.net.au/news/science/2016-04-07/crispr-gene-editing-technology-explainer/7217782 • And 2017 • https://www.abc.net.au/news/2017-08-03/how-mutant-genes-are-deleted-repaired-replaced/8769288 • How has understanding and advances in CRISPR technology changes since this article was written? • Explain two reasons why the CRSPR technology is considered controversial.

5. The Blood

5.1 The Elefanty, Stanley and Ng Group: Making the right cells from stem cells

Professors Andrew Elefanty and Ed Stanley and Dr Elizabeth Ng

Murdoch Children's Research Institute and the University of Melbourne

A powerhouse trio of laboratories is refining the way of making blood and heart cells, bringing future therapies closer to reality.

Accompanying Resources:
Refer to the Stem Cells Australia web page: *'Making the right cells from stem cells'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

Dr Elizabeth Ng and Professor Andrew Elefanty

What is the focus of the Elefanty, Stanley and Ng Group's research?

- Developing ways of differentiating pluripotent stem cells into blood cells.
- Understanding how blood is formed during development of an embryo.
- Understanding cellular signals which lead to the differentiation of particular blood cells.
- Studying the process or modelling diseases, such as leukaemia, thalassemia, Type 1 diabetes.
- Gaining a better understanding of and developing screening processes for hypertrophic cardiomyopathy.
- One day these teams hope to produce lab grown blood cells which can be personalised for individuals and used for transfusions and treatment of blood diseases.
- Collaboration between the Elefanty, Stanley and Ng groups as well as collaboration with Dr David Elliott's team.

What is the science?

- The immune and circulatory systems consist of a range of blood cells, broadly consisting of red and white blood cells.
- During early human development, blood stem cells differentiate to form specialised blood cell types.
- Pluripotent stem cells are cells which can give rise to a range of different cell types, depending on specific molecular cues.
- The Elefanty group are able to make cells in the laboratory which are similar to real stem cells in the blood.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:

- Need: Stem cell technology enables the creation of specific blood cells, which can be used to support research in a range of different areas, such as blood and heart cell research.
- Interest: Scientists are often driven by passion and interest, such as a desire to help people, an interest in developmental biology or just biology itself, strong curiosity and the desire to make discoveries. Scientists working in this group have a strong desire to better understand blood cell development processes so that in the future, scientists might be able to re-create these processes to develop treatments, model disease and potentially create human blood products for treatments in sustainable and ethical ways.
- Collaboration: Collaboration is essential for scientific endeavour and advancement. In this case, the Elefanty, Stanley, Elliott and Ng groups are working closely together to develop knowledge related to pluripotent blood stem cells.
- Social, cultural and economic influences on scientific research and ethical aspects: in this case, growing blood stem cells with a view to model disease and eventually grow blood cells for individual transplants. Specialised blood transfusions may reduce graft-host rejection, which would reduce the need for on-going expensive or invasive treatments

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves working as a team and collaborating with other people.	• In the video Andrew emphasises the role of collaboration, such as his working relationship with Ed Stanley and Elizabeth Ng. • Scientists have values and develop a sense of agency, which guide their work. In this case, Andrew Elefanty is interested in understanding how to grow blood cells in culture which are similar to real stem cells in the blood. Elizabeth Ng has a strong interest in knowing more about the developmental process of blood cells, so that scientists can better study disease in dishes, such as better understanding the nature of leukaemia. Ed Stanley has a strong interest in better understanding the nature of how to develop stem cells to replace cells killed off by the immune system, such as cell death in Type 1 diabetes. His area of research focuses on disease in children.	• In the video Andrew talks about collaborating with Ed Stanley and Elizabeth Ng. What value is there in forming these collaborations? Using the article and the video, identify what each partner brings to the partnership. • Andrew mentioned that he trained as a physician – he is a medical oncologist. What is a medical oncologist? What might have been his role in this previous job? Why might Andrew of chosen to leave this job and become a researcher? What skills would Andrew bring to his job as a researcher? • Values and agency: Scientists have values which influences where they choose to channel their research. Listen to the way Andrew, Elizabeth and Ed talk about their work in the video. Identify what they are working on and suggest what their areas of research might say about what they value.
	8	Science knowledge can develop through collaboration across disciplines of science	The article *'Making the right cells from stem cells'* explains how Professor Elefanty has been working closely with Professor Stanley, Dr Ng and Dr Elliott. This is an example of how scientists	○ Read the article: *'Making the right cells from stem cells'*). What are some of the advances or new knowledge these lab groups have produced by working together? What does each lab group bring in terms of expertise and knowledge? Use a

		and the contributions of people from a range of cultures ACSHE226	work collaboratively, usually across disciplines, to share knowledge and expertise to advance scientific endeavour.	Venn diagram to highlight what is individual to each group and what they might have in common. • Compare the collaboration of the Elefanty and colleagues to the Pébay and Hewitt (see the Pébay Group) or the Porrello and Hudson Group (See the Porrello group) or the collaborations of the Palpant and Powell groups (see the Palpant Group). How are the collaborations similar or different? What are some common characteristics of collaborative relationships?
Australian Curriculum: Science as a Human endeavour (SHE)	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE 135	• In scientific research, models are used to test hypotheses and run investigations to test new ideas for disease treatment. Development of stem cell technologies has enabled scientists to create models of human tissue by reprograming cells and growing those cells into cells of interest. • This case offers the opportunity to explore the nature of developing and using such models with students to understand how stem cell technology enables better understand human development. In this case, how blood stem cells develop and how blood cells develop from these blood stem cells. • Developing new knowledge about how blood cells develop requires modelling. Blood stem cells develop during embryo development. It is implausible to investigate blood cell development during these early stages of embryo development. • Understanding blood cell formation during early human development offers insights into blood diseases.	• Developing new knowledge about how blood cells develop requires modelling. • Having watched the video and read the article *'Making the right cells from stem cells'* explain how the Elefanty, Stanley and Ng groups are using stem cells as a model for blood cell development. Why do stem cell models offer flexibility for the Group's research? • In the video, Andrew Elefanty mentioned spending 20 years trying to differentiate human pluripotent stem cells toward blood cells. He mentioned trying to grow human embryonic stem cells to retain their potential to be 'essentially immortal'. What does Andrew mean by 'immortal' in this case? In recent years, human pluripotent stem cells have offered research scientists flexibility. How are embryonic stem cells and pluripotent stems cells similar and different? Use the Stem Cells Australia website to support your thinking: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • Why might the team have moved to using human pluripotent stem cells instead of embryonic stem cells? Use the CER (Claim, Evidence, Reasoning model) to create 2 claims and support your claims with evidence and reasoning.

				• How would knowledge about the first blood stem cells be valuable for scientists when trying to understand blood disorders like thalassemia and leukaemia?
	9 & 10	Scientific understanding, including **models** and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157/191	• See also ACSHE135 above • Models are an important part of scientific endeavour. It is often implausible to do experimentation in situ (see example to the right). In addition, controlled experimentation is just one way in which knowledge can be developed. • Models of systems, such as blood cell development in the body, offer scientists a way to explore the nature and development of cells under different conditions without hurting people. • This is a good example to draw student attention to the use of biological models in science.	• Developing new knowledge about how the body develops requires modelling**.** Scientists are unable to perform experiments within people's bodies to understand how blood cells are created and differentiated into the range of blood cell types that exist within the body. It would be unethical and impractical to perform such investigations on a developing embryo. Models, such as using stem cell derived blood cells, provides a platform for this kind of investigatory work. • Suggest 2 reasons why a derived stem cell made in a lab is more ethical than using an embryo. • Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research and stem cells offer flexibility when it comes to growing viable models in the lab.
Australian Curriculum: Science Understanding (**SU**)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain systems of organs carrying out	• This video offers the opportunity to consider the nature of the blood and the circulatory system, using the video and use of blood stem cells as a context. To know more about the work these scientists are doing, students may need to learn more about blood, such as what blood consists of and why blood is important to the human body. Use this section to support student learning about these concepts so that they can engage with the work of the scientists.	Find out more about blood and the circulatory system: • https://kidshealth.org/en/kids/blood.html • What is blood made up of? • What role do each of these components play? • Blood travels around the body via the circulatory system. Find out more about this system. • How does blood travel around the body? Name the two types of vessels and name 2 characteristics of each type of vessel. • What is a blood type? Do you know your blood type?

		specialised functions that enable them to survive and reproduce (ACSSU150	• The blood consists of different types of cells and other materials. • The circulatory system, of which blood is a vital component, enables multicellular organisms to circulate essential materials around the body. For example, the blood enables the movement of reactants for cellular respiration to every cell in the body. The blood also transports the oxygen and carbon dioxide from and to the lungs. • Blood also consists of platelets, which are valuable for wound repair, and white blood cells, which support immunity. • Students have many alternate conceptions about blood and the circulatory system. Find out more about these alternate conceptions and ideas for teaching about this system via the Science Continuum archive website: https://www.education.vic.gov.au/school/teachers/teachingresources/discipline/science/continuum/Pages/circulatory.aspx	
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of blood and the circulatory system, using the video and use of blood stem cells as a context. To know more about the work these scientists are doing, students may need to learn more about blood, such as what blood consists of and why blood is important to the human body. Use this section to support student learning about these concepts so that they can engage with the work of the scientists.	• See ACSSU150 above as a context for students to learn about blood. In particular red blood cells and the variety of white blood cells. What else does blood consist of? What role does blood play? • Use the diseases suggested in the video and article (e.g. Type 1 diabetes, leukaemia, thalassemia, hypertrophic cardiomyopathy) as a context for learning about body systems by exploring what happens to the body when specific systems or cells do not function as normal. • Predict what might happen within the body if red and white blood cells did not function as normal.

			• Work 'backwards' to learn about systems and cells within the body. Start with a disorder and work backwards to support students as they learn about the body system/cells and as they discover what happens when these body systems/cells do not function as normal. • Make connections to other systems, such as links to the: - Respiratory system: blood is the transport medium for oxygen and carbon dioxide and these molecules are exchanged in the lungs. - Excretory system: blood is filtered in the kidneys, which regulates water levels in the body. - Immune system: White blood cells are essential for fighting invading pathogens. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells, like skin cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions. See https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/	• Draw a concept map to show how blood cells are related to each of the main body systems (e.g. circulatory, respiratory, excretory, immune etc.). • In recent years, human pluripotent stem cells have offered research scientists flexibility. How are embryonic stem cells and pluripotent stems cells similar and different? Use the Stem Cells Australia website to support your thinking: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/
	11 (Unit 2)	• Working like a scientist And • Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to how the work of scientists is influenced by what scientists value, such as caring about	• See the SHE (RED) section above related to collaboration and lab structure for resources. • See the SHE (Red) section above related to values and agency. You have chosen to study biology at the VCE level. What is it about biology that excites and interests you? Which area of biology interest you the most? Would you consider pursuing a career as a research scientist? Why, why

			disease prevalence in children (see Ed Stanley's work on diabetes in children).	not? Which aspects of the job interested you/ sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why?
Australian Curriculum: Science understanding (SU)	Unit 2 and 3	• Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	• See sections above (ACSHE135 and ACSHE157) related to the use of stem cells for creating models. • Models of systems, such as blood cell development in the body, offer scientists a way to explore the nature and development of cells under different conditions without hurting people and without the need for taking multiple blood and tissue samples from people. • Use the work of the Elefanty, Ng and Stanley groups as a context for highlighting how stem cells can be used as models to better understand the nature of blood cell development and for modelling disease.	• Developing new knowledge about diseases requires modelling to find out more about how disease affects body tissues. Knowing more about the action of diseases can help scientists work out how to intervene and overcome or stop the action of diseases before they cause damage. Modelling is a common practice in scientific research - and stem cells offer flexibility when it comes to growing viable models in the lab. • Using the article and video, explain how the scientists are using stem cells as models for disease.
	11 (Unit 2)	• The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• See resources above (ACSSU150 and ACSSU175) related to specialised blood cells. • The article and video highlight the use of stem cells to create blood cells to act as a biological models to understand blood cell development, to test new drug therapies and to model disease. • Induced pluripotent stem cells (iPSCs) can be generated by reprogramming somatic cells. iPSCs are very similar to embryonic stem cells and can grow into any cell type in the body under the right conditions.	• See ACSSU150 and ACSSU175 above as a context for students to learn more about blood cells and to predict what might happen if specialised blood cells did not function. • Induced pluripotent stem cells can grow into any cell type in the body under the right conditions. Find out what these cells are, and why they have been useful for the Elefanty, Ng and Stanley groups for creating blood cells. See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/

5.2 The Nilsson Group: Expanding horizons for stem cell transplants

Professor Susie Nilsson and Dr Ben Cao

Australian Regenerative Medicine Institute at Monash University and CSIRO

A new blood simulation procedure may provide a faster, pain-free way for stem cell donors to help save lives of cancer patients.

Accompanying Resources:
Refer to the Stem Cells Australia web page: *'Expanding horizons for stem cell transplants*, or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

Professor Susie Nilsson

What is the focus of the Nilsson Group research?

- Hematopoietic stem cells (HSCs) are responsible for making all the types of cells in the blood.
- HSC transplants from donors have been used successfully over the last 30 years to treat various forms of blood cancer, such as leukaemia.
- HSC donation is not without risk and better methods for donation are required. A focus of the Nilsson group is to develop faster and safer methods for collecting HSCs.

What is the science?

- Hematopoietic stem cells (HSCs) are responsible for making all the types of cells in the blood. These stem cells remain mostly dormant within the bone marrow but when they are active, they are responsible for regulating blood cell production.
- HSC proliferation needs to be controlled. If HSCs are dividing constantly, there would be too many cells within the blood. If stem cells don't divide enough, there would not be enough circulating blood cells.
- The body needs 1 million blood cells to be produced every second to maintain normal blood cells in circulation.
- One transplanted HSC has the potential to completely reconstitute the entire blood system.
- HSC transplants are used to treat leukaemia. After a patient has had chemotherapy, HSCs can be transplanted into the bloodstream to support blood cell development.
- Donating HSCs requires a donor to be given multiple injections over several days of a drug which stimulates the release of stem cells from the bone marrow into the blood for harvest. The drug regime is not always successful at producing sufficient stem cells.
- A new molecule, BOP, combined with drug regime, has resulted in HSCs being mobilised into the bloodstream of a donor within an hour, rather than 5-6 days. BOP targets bone marrow stem cells and forces these cells to exit the marrow into the blood stream.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:

- Value: 70,000 HSC transplants are conducted globally each year, with 1000 of these transplants occurring in Australia. The Nilsson team is dedicated to developing faster and safer methods of HSC collection.
- Need: Donation of HSCs involves risk. Donors may experience side effectives, such as swelling and rupturing of the spleen. There is a need to develop faster and safer methods for HSC harvesting and donation. Scientists identify areas of need and strive to meet those needs by developing new knowledge and technologies. In this case, The Nilsson lab has a strong desire to refine HSC donation processes to ensure the impact on donors is minimised, to encourage more people to donate and to ensure the donated process is successful in terms of the number of harvested HSCs.
- Interest: Scientists are often exited by and interested in solving problems or discovering new things.
- The new HSC harvesting method, which includes BOP, has led to new technology which could lead to faster and safer donation of HSCs.
- Collaboration: Research groups, like the Nilsson group, consist of many people, including PhD and Master's students and early career researchers (ECRs).
- Productive failure: Mistakes are part of scientific endeavour and are responsible for many scientific discoveries and advancements.
- Science communication: Nilsson and her group made headlines worldwide when they published their findings in a peer reviewed science journal called Nature Communications in 2016. Scientists publish their findings in journals. When findings have significant social impact, mainstream media outlets can pick up and publish articles related to research. This can increase the profile of scientists, which can have flow-on effects in terms of their impact, influence and standing within the scientific community. For example, it may impact their profile when applying for grants.
- Clinical trials are a way for the scientific community to test new drug treatments and processes in controlled ways to minimise adverse effects on people involved.
- Social, cultural and economic influences on scientific research and ethical aspects – in this case, developing a faster and safer method for HSC donation would affect 70,000 people globally. Developing faster and safer methods for HSC donation may lead to increased donor numbers, which could in turn support treatment for more people with blood disorders.

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/ s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves qualities, such as fascination with the unknown which drives action. And Working as part of a team of different people.	• In the video Ben highlights his fascination with 'the unknown' and his interest in discovering new things. This offers an opportunity to help students identify that scientists are often excited by solving problems and developing new knowledge. Use this as an opportunity to have students consider what excites and interest them. They may share Ben's interest and fascination. • Ben talks about mistakes being an important part of scientific endeavour. *A useful resource here is the book Brilliant Blunders by Mario Livio. See for example https://www.sciencefriday.com/articles/brilliant-blunders/ * See also the Merson Group resources for additional articles related to failure in science. • Ben and Susie highlight the collaborative nature of the laboratory environment. There are many different people, at different stages of their careers, working together. Ben talks about PhD and Master's students. These are career pathways to become a scientist. See	• In the video, Ben says "I am fascinated by the unknown and being able to identify a mechanism that is new and novel really excites me." What fascinates and excites you? Do you like discovering new things? Or do you like solving problems? If you could be a research scientist, what would you want to know more about? Where would you focus your research? • Mistakes are part of learning, yet we are not always allowed to fail productively. Failure is really important in science, as it is unexpected and unplanned. Failure often results in new discoveries and new knowledge. It is a really important part of the learning process. Research or recall from memory any examples when scientists have made mistakes and learned from them. What happened? What did they learn? How did it impact on our understanding? • Closer to home, think about when you have made a mistake and learned from it. What happened? What did you learn? • Why would it be beneficial for labs to be made up of a variety of people, at different stages of their careers? • List qualities that PhD, Master's and ECR's would bring to a science research group. Draw up a list of benefits and challenges See accompanying resource regarding the hierarchy in the lab. • Learn more about early career researchers in the Pébay and Laslett group videos.

			accompanying resource regarding the hierarchy in the lab. • In the video, Susie talks about the importance of early-career researchers. ECR's bring new ideas and enthusiasm into research labs. They are the next generation of researchers. For examples of ECR's in this series, see the Dr Grace Lidgerwood in the Pébay Group, Dr Jacob Goodwin in the Laslett Group. • Scientists have values and develop a sense of agency, which guides their work. In this case, Professor Susie Nilsson and her team value minimising the impact on HSC donors to make the process more efficient and to encourage more people to become donors.	• Values and agency feature frequently in the videos. What is being valued by the Nilsson group in this video and article? How might these values impact on their work?
Australian Curriculum: Science as a Human endeavour (SHE)	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135	• Scientific research can lead to new technologies, such as hematopoietic stem cell (HSC) donation and transplantation. HSCs are responsible for making all types of cells in the blood. • Development of HSC transplantation has helped thousands of leukaemia sufferers regrow healthy blood cells after chemotherapy. This is an example of a stem cell technology which has been researched, reported, refined, and subjected to clinical trial. This treatment option has been used for the last 30 years. The article highlights that 70,000 people per year are treated with stem cell blood transplants. • Students can learn more about this technology, which has been use for some	• Blood transfusion is an established medical treatment used for many years to treat disease and trauma. Blood donation from members of the community is essential for maintaining blood supply stocks. Collecting blood stem cells is different to regular blood cell collection. Compare the two blood cell collection processes. Use a Venn diagram (square or round) to compare these two processes. Use the following websites to learn more about each process: • Blood stem cell collection: https://www.cancer.org/treatment/treatments-and-side-effects/treatment-types/stem-cell-transplant/donors.html • Blood, plasma and platelet collection: https://www.donateblood.com.au/learn#how-your-blood-is-used • For each of the processes, find out the following: ○ What is the blood used for?

			time, as compared to many other developing stem cell technologies showcased in this series, which are not yet at a stage where they are used for treatment. It is valuable to make the distinction between proposed and developing treatment technologies and established treatment technologies. • Blood stem cell transfers, skin grafting, and eye stem cell technologies are the only currently utilised stem cell technologies. • To explore the state of these technologies, have students compare and contrast blood collection and stem cell collection techniques. A next step in this sequence could be to look at the advances in donation techniques made by the Nilsson group.	○ What is collected? (e.g. blood, plasma and platelets for blood donation and bone marrow, peripheral blood cells and cord blood for stem cell donation) ○ How are the samples collected? ○ What is each blood component used for? • The Nilsson group are developing new technologies which makes donation simpler and faster for donors and recipients. • Read the following is a press release about the Nilsson group and compare the new technology to the current technology for stem cell donation: https://www.csiro.au/en/News/News-releases/2016/New-way-to-harvest-stem-cells-better-for-donors • This is an example of how technology and scientific knowledge changes over time.
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157/191	• See also ACSHE135 above • Communication of research findings is an important aspect of scientific endeavour. Scientists are expected to communicate their research in scientific peer reviewed journals (i.e. journals which publish scientific articles only after they have been reviewed by other scientists). Some science research is also picked up and reported in mainstream media, such as newspapers, news sites and other print and online media to communicate science to a wider, audience with a non-science background. This variety of communication is important for science as it helps to communicate the nature of science to a wider audience.	• Compare different blood and stem cell collection methods (see ACSHE135 above) • Scientific understanding is refined over time and communicated via media outlets, such as journals and mainstream news outlets. In 2016, Professor Susie Nilsson and her collaborators had a journal article published, which communicated their improved HSC donor collection technique. The following is a media release, which communicated this publication to a wider, lay audience. • https://www.csiro.au/en/News/News-releases/2016/New-way-to-harvest-stem-cells-better-for-donors • The associated journal article for this press release can be found via a link in the press release. Navigate to the website. What do you notice about the article? Make a list of at least 5 things you notice about this article. • Combine student lists and draw attention to the following:

			• For example, the 2016 breakthrough by the Nilsson group could impact a number of people who are considering donating HSCs or people who are waiting for HSC donations. It also communicates the current state of technology in relation to donations of HSCs so that people are aware of what is possible and what is not. • Communication of research findings also increases the profile of scientists, as the work is communicated to a wider audience. This can have other flow in effects in terms of collaborations, grant applications and job prospects.	• How many authors are there? Which intuitions are they from? (This is an example of collaboration). • When was the article published? (This is important as technology changes over time) • How many times has the article been accessed? Cited? (This is an example of collaboration within the scientific community when scientists use and cite another scientist's work) • Style of writing, use of language etc – Who is the intended audience? (This is written to communicate the science and so there is a lot of jargon etc. Notice things like use of abbreviations – the first time the abbreviation is used it is elaborated, and then the abbreviation is used. E.g. HSC. This is a writing convention in many professional formats. Also look at reference to molecules and genes, e.g. BOP.) • Look at the structure of the paper – it has subheadings which are consistent with scientific writing. E.g. introduction, method, results, discussion and conclusion. What is the purpose of each of these sections? NB Students do not need to understand the article to analyse the structure and conventions. E.g. the results section has lots of tables and graphs. In the introduction, the authors cite other literature and provide a context for the research. • NB The way the article is written does not reflect how the science was done. This is an important point to make as it helps students realise that there is no single 'scientific method'. The process of developing the new knowledge was not necessarily linear and did not start with an 'introduction' and proceed through the method and results to a well-developed discussion and conclusion. Doing the experimentation to develop this knowledge was probably planned, but would have been, in reality, laced with uncertainty and failure; it would have been messy, iterative

				and developed over time and through the work of many people. The process would have been strictly linear.
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158/192)	• In the article, the author mentions that the new regime for donation developed by the Nilsson group is ready for phase 1 clinical trials. • Clinical trials are a way for testing the safety and efficacy of a new treatment regime. • Students can learn about clinical trials to understand how they aid in the development of new technologies and how they are linked to scientific discoveries.	• Clinical trials are conducted to test the safety and efficacy of new treatment regimes. Learn more about clinical trials by navigating to the Australian Government website: https://www.australianclinicaltrials.gov.au/what-clinical-trial Answer the following questions: • What is a clinical trial? What are they necessary? • How do clinical trials work? What are the clinical trial phases? • What is a control group? What is a placebo? Explain the placebo effect. • What is a trial protocol? How are clinical trials funded? What are some ethical guidelines for clinical trials? • What happens at the end of a clinical trial? How are results disseminated? • Explain what the Nilsson group clinical trial might entail.
Australian Curriculum: Science Understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149) AND Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce (ACSSU150	• This video offers the opportunity to consider the nature of blood and how blood is made. • Suggested sequence – Use the Elefanty, Ng and Stanley group video to established what blood is and use this video as a context to explore how blood is made. • Teachers could use the context of leukaemia and work backwards, exploring how blood is made by examining what happens when this process does not work. • NB – many people are impacted by cancer and so this approach may cause anxiety for some students if they have a loved one who has experienced cancer.	Context: Leukaemia is a disease that disrupts the normal function of blood cells, in particular white blood cells. Find out more about blood and what leukaemia does to the blood. Teachers could use real stories as a context for this: See for example https://childrenscancerfoundation.com.au/about-us/impact-stories To find out more about blood and why it is important. Navigate to the following website and respond to the questions: https://kidshealth.org/en/kids/blood.html • What does blood consist of? • What role do each of the components of blood play? • Blood travels around the body via the circulatory system. Find out more about this system.

				• How does blood travel around the body? Name the two types of vessels and name 2 characteristics of each type of vessel. • What is a blood type? Do you know your blood type? How is blood made? Navigate to the following website and respond to the following questions. https://www.leukaemia.org.au/blood-cancer-information/types-of-blood-cancer/understanding-your-blood/bone-marrow-and-blood-formation/ • How and where is blood produced? • Which stem cells are involved? What role do the stem cells play? • What are growth factors? • What is the lymphatic system? What role does it play in keeping your healthy? • What happens to the process of blood formation when a person has leukaemia?
	9/10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of blood and the circulatory system, using the video and blood stem cells as a context. To know more about the work these scientists are doing, students may need to learn more about blood, such as what blood consists of and why blood is important to the human body. Use this section to support student learning about these concepts so that they can engage with the work of the scientists. See ACSSU150. • Hematopoietic stem cells (HSCs) are responsible for making all types of cells in the blood. Students can learn more about these	• See ACSSU149/150 above as a context for students to learn about blood. In particular how blood cells are formed and the variety of white blood cells. What else does blood consist of? What role does blood play? • Find out about how blood cells are formed by learning about Hematopoietic stem cells (HSCs). Use the websites below to answer the following questions: https://stemcells.nih.gov/info/2001report/chapter5.htm • When were blood forming stem cells first noticed? What were the circumstances that led to them being noticed? • What are two key characteristics of HSCs? • Identify two sources of HSCs from the body. How, traditionally, have these cells be accessed?

			important cells. The following are sites which may be useful:	• Using the article *'Expanding horizons for stem cell transplants*, compare the common HSC collection technique to the new technique developed by Nilsson and her team. • Create a Venn diagram to compare how the techniques are similar and different. • Use the following article to explain the process developed by the Nilsson group, including their use of BOP. https://www.csiro.au/en/News/News-releases/2016/New-way-to-harvest-stem-cells-better-for-donors
Australian Curriculum: Science as a Human Endeavour (SHE)	Unit 2	Working like a scientist And Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to how the work of scientists is influenced by what scientists value, and the role of failure in the process of scientific endeavour.	• See the SHE (RED) section above related to collaboration and lab structure for resources. • See the SHE (Red) section above related to values and agency. You have chosen to study biology at the VCE level. What is it about biology that excites and interests you? Which area of biology interest you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/ sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why? • If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience.
	Unit 2 and 3	Science is a global enterprise that relies on clear communication, international conventions, peer review and	• See ACSHE157/191 to unpack the nature of scientific communication, such as peer review and publication of scientific findings in journals. • Use activities under ACSHE158/192 to unpack the nature of clinical trials for developing new treatment regimes.	• See activities in ACSHE157/191 and ACSHE158/192 above • Focus on the nature of science communication, peer review and conventions for both. E.g. communication of scientific findings can be via journals, edited books, conference presentations, but can also be disseminated in more mainstream outlets, such as press releases, blogs and news outlets.

		reproducibility (ACSBL037) AND Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)		• Peer review is common for quality and high ranked journals. Peer review is a blinded process, so the reviewers do not know who the authors are. Multiple blind reviewing of the same article is often done to help the editors of the journal make a decision about whether to accept or reject the paper for publication in the journal. • Journals have editorial boards, to share the load between multiple editors. • Clinical trials are common for medical sciences where the outcomes of research, such as drugs and treatment methods may impact the health and wellbeing of people. This is a strict process and offers the opportunity to talk about ethical considerations when working with humans and animals. • You may like to refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells for more information about research using both humans and animals.
	Unit 2 and 3	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL043)	• The article and video offer the opportunity to consider the efficacy and sustainability of a medical process – such as the collection of donor stem cells. • The lack of stem cell donors is an issue for medical practitioners seeking to support people suffering from blood cell disorders. Stem cells aid in the regeneration of the blood after chemotherapy. • Traditionally, the collection of stem cells was painful for the donor, leading to a lack of donors. Practitioners had to rely on friends and family offering to undergo the invasive techniques to help their loved one (see for example the movie – My Sister's Keeper which tackles the issue of designer babies to	• Refining medical collection procedures, such as stem cell collection, can lead to streamlining and enhancing the sustainability of such methods. The Nilsson group are seeking to refine the stem cell collection method to reduce discomfort for donors and hopefully encourage more people to donate, if the process is risk reduced. • Explain the social and economic benefits of the Nilsson group research. • How might the Nilsson group be making blood stem cell donation more sustainable?

			support sibling treatment). However, new technologies have seen the process refined.	
Australian Curriculum: **Science understanding (SU)**	11 (Unit 2)	• The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• The article and video highlight the collection and use of HSCs to replenish blood cells after leukaemia treatment. • Use the need for blood stem cell donations for cancer treatment as a context for learning about blood structure and formation. This is also a rich context for learning about the lymphatic system and as a prelude/ support context when learning about the immune response. •	• See the materials above as a context for students to learn more about blood cells and how they are made. Use the context of predicting what might happen if particular specialised blood cells did not form properly or did not function as needed. • Focus on HSCs as stem cells which can give rise to all of the blood cell types. This is a versatile form of stem cells. Have students explain why this type of stem cell is of interest to scientists like the Nilsson group. • Students can explain the general process of how the HSCs might differentiate into specific blood cell types. •
	Unit 4	Hormones alter the metabolism of target cells, tissues or organs by increasing or decreasing their activity; in animals, most hormones are produced in endocrine glands as a result of nervous or chemical stimulation, and travel via the circulatory or lymph system to the target cells, tissues or organs (ACSBL113)	• Use the Nilsson group research as a context for learning about the lymphatic system and production of white blood cells from stem cells.	• See ACSSU149/150 and ACSSU175 above related to blood cell production and the lymphatic system.

6. The Gut

6.1 The Abud Group: Having the guts to make a difference

Professor Helen Abud and Dr Thierry Jarde

Monash Biomedicine Discovery Institute at Monash University

In 2018, 1.8 million new cases of colorectal cancer were diagnosed globally. Colorectal cancer is the third most common cancer worldwide. (https://www.wcrf.org/dietandcancer/cancer-trends/colorectal-cancer-statistics)

Accompanying resources:
Refer to the Stem Cells Australia web page: *'Having the guts to make a difference' or* scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Abud Group research?

- Colorectal cancer occurs when there is an overabundance of cells in the colon lining. Stem cells regulate the proliferation of cells in the colon lining. When the stem cells divide strongly, it can lead to an uncontrolled growth, or cancer.
- The Abud group is interested in understanding how to regulate the proliferation of stem cells. The group is working with a molecule called Neuregulin 1, which could be used to block the way cancer cells divide and limit the growth of tumours.
- The group have been able to grow 'mini-gut' organoids in the lab, which can be used to better understand the signals which control cell division.

What is the science?

- The cell layer that lines the bowel has two roles. One role is to prevent bacteria and by-products from entering the body and the other is to absorb nutrients from the food that we ingest.
- The intestinal epithelial cells are short lived. More than a billion cells are shed and then replaced every day from the cellular lining. Stem cells are responsible for generating the cellular lining.
- When the bowl lining replacement does not proceed normally, the loss of the layer can lead to inflammatory bowel disease. If the cells regenerate too quickly, this can lead to an overproduction of cells which leads to bowel cancer.
- Neuregulin 1 is a molecule which can block the way colon cancer cells divide and limit the growth of the tumours.
- Colorectal cancer is the fourth most prevalent cancer diagnosed in Australia, after breast cancer, prostate cancer and melanoma. Colorectal cancer is the third most common cancer worldwide, and in 2016, 15, 352 new cases of colorectal cancer were diagnosed in Australia
- Analogy is a way of helping people understand how something works. In the article and video, Helen uses the analogy of a growing plant to explain how cancer grows and how all of

the ‘plant’ needs to be removed, especially the ‘roots’, if the cancer is to be removed from the patient.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Need: Colorectal cancer is the fourth most commonly diagnosed cancer in Australia. To reduce the prevalence of this cancer, we need to better understand how to limit cancer cell growth and division.
    - $252 million in funding has been awarded for cancer research in 2016 to 2018, with the Australian Government providing more than 74% of this amount ($187 million). https://www.canceraustralia.gov.au/research-data/research/cancer-research-australia
    - Value: In 2020, 15,494 Australians were diagnosed with colorectal cancer. Of this number, 8,340 were male and 7,154 were female. This constitutes 11% of all cancer cases diagnosed. In 2020, 5,322 people died from colorectal cancer, which was 11% of all deaths from cancer in 2020. The chance of survival from colorectal cancer is high, with 70% of people surviving at least 5 years (2012-2016). (https://www.canceraustralia.gov.au/affected-cancer/cancer-types/bowel-cancer/bowel-cancer-colorectal-cancer-australia-statistics)
    - Therefore, the chance of recovery is high, but there may be other prolonged issues that remain, even after a person has recovered. This also places stress on the social and emotional wellbeing of the patient and can lead to continued economic implications for the healthcare system. This is an example of the social, cultural and economic implications of disease and how need for scientific research can be identified and how funding awards can be argued and decided.
    - Interest: Scientists are often fascinated by science and enjoy science as a subject in school.
    - Collaboration: Research groups, like the Abud group, consist of many people, including PhD and Master’s students and early career researchers (ECR’s). These labs offer a place for new scientists to learn and develop their skills, while being mentored by other more experienced scientists and staff. Providing a space and forum for the development of the next generation of scientists is highly valued by the profession.
    - Social, cultural and economic influences on scientific research and ethical aspects – in this case, developing understanding how to limit tumour growth could potentially impact the 1.8 million people globally (in 2018) who are diagnosed with colorectal cancer (https://www.wcrf.org/dietandcancer/cancer-trends/colorectal-cancer-statistics). Developing an understanding about the causes of colorectal cancer and better understanding how the tumour develops could reduce the incidence of this cancer worldwide.

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves qualities, such as fascination with science or the unknown. This drives action and influences why people might choose to pursue a career in the STEM disciplines.	• In the video Thierry emphasises his fascination with science and his interest in designing experiments to develop new knowledge. This offers an opportunity to help students identify that scientists are often excited by solving problems and developing new knowledge. Use this as an opportunity to have students consider what excites and interests them. They may share Thierry's interest and fascination. • In the video Thierry talks about designing experiments. Lab based experimental design is just one way that scientists develop new knowledge. This is an excellent example of how experimental science is conceptualised, starting with a question, development of a hypothesis, experimental design and the value of uncertainty and the unexpected. • Helen highlights the collaborative nature of the laboratory environment. Many different people, at different stages of their career, working together. Helen also emphasises the joy she derives from working with beginning staff as they develop their knowledge and	• In the video, Thierry expresses his fascination with science. What fascinates and excites you about science? Do you like discovering new things? Or do you like solving problems? If you could be a research scientist, what would you want to know more about? Where would you focus your research? • In the video Thierry talks about the process of designing a lab-based experiment. This is just one way of doing science. For example, another way of doing science might be to observe a natural phenome in the wild – which cannot be controlled or digging up a dinosaur fossil and trying to determine the species, how it lived and died. Scientific investigation can be broadly and simply categorised as being descriptive, comparative or experimental. The table below outlines the differences between these three types of investigation. • This table is sourced from Corrigan, D., Fitzgerald, A., & Kidman, G. (2018). Science investigations. In A. Fitzgerald & D. Corrigan (Eds.), Science Education for Australian Students: Teaching Science from Foundation to Year 12 (pp. 143-178). Crows Nest, NSW: Allen & Unwin. | | Guided by a | Involves a hypothesis | Involves variables | Key terms |

skills. As a mentor, Helen sees value in educating the next generation of scientists and enjoys watching the process unfold. Mentoring is an important aspect of many professions. When we work in groups and with mentors, we feel supported and nurtured. Other people can help us identify areas for growth and development.

- Scientists have values and develop a sense of agency, which guides their work. In this case, Professor Helen Abud and her team value minimising the impact on colorectal cancer on patients and lowering the incidence of this type of cancer by better understand how tumours develop.

	question		(v) and control (c)	
Descriptive (e.g. making measurements about describing observations)	Can be	No	No	Observe, describe, list, identify
Comparative (e.g. comparing measurements, comparing observation)	Usually	Yes	No	Compare, contrast, similarity and difference, categorise
Experimental (e.g. testing a variable)	Yes	Yes	Yes - V and C	Control group, experimental, variables, controlled variables, constants

- Think back on the practical work you have done in the past in science classes. List some examples of when you have engaged with descriptive, comparative and experimental practical tasks. For each example you list, think about the following:
    - Was there a question involved to guide the practical task? If not, can you think of a question which might have guided the practical task?
    - What were you observing/ describing and why? How did the observation lead to you learn something

				new? Or, what did you do with the observational data? ○ When have you done a comparison task? What did you compare and why? What did you use the data for? ○ When have you done a structured experiment – which had only one variable which was changed, and all other conditions remained the same? What did you learn from this task? • In the video, Thierry says "Well I'm fascinated about science and something that I really like in science is you've got a question, you've got your hypothesis and you design the very exciting experiments. What I like is when you look at the results and whether they match hypotheses or if it's something totally new and unexpected it's also very fascinating." For each of the stages in this kind of inquiry, explain the purpose and value of each stage. How does each stage contribute to developing new knowledge? ○ Noticing phenomena ○ Posing a question to guide inquiry ○ Developing a hypothesis ○ Designing a method for investigation ○ Gathering data ○ Analysing data and comparing to the hypothesis • Uncertainty and the unexpected is common in science. Can you recall an example in the media or in an example you have hear of where scientists have been tentative or expressed uncertainty about their work OR when they have experienced something unexpected? What happened? What did they learn? How did it impact our understanding of the area they were researching? What role does uncertainty and the unexpected play in science?

				• Closer to home, think about a time when you have felt uncertain or experienced something unexpected. What happened? What did you learn? What roles do you think uncertainty and the unexpected play in our lives? Why are they important? Even though uncertainty and the unexpected can sometimes make us feel uneasy, they are valuable for learning. Explain why this might be the case. What role do these experiences play? • Why would it be beneficial for labs to be made up of a variety of people, at different stages of their careers? • List qualities that beginning scientists would bring to a science research group. Draw up a list of benefits and challenges. • Values and agency feature frequently in the videos. What is being valued by the Abud group in this video and article? How might these values impact on their work? What might be driving them to do the research they are doing?
Australian Curriculum: Science as a Human endeavour **(SHE)**	8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134 AND Solutions to contemporary issues that are found using science	• Scientific research can lead to new technologies, such as mini-gut organoids being used for a range of purposes, such as drug and treatment development or to better understand cellular processes of the organ. NB The Herald Sun article featured on the link suggested in the next column is accessible for this year level. Knowledge about body and cellular systems changes as advances in the field are made. This is an example of how knowledge about the proliferation of colon epithelial cells has advanced and the development of mini-gut organoids to understand the organ and conduct drug testing.	• The ground-breaking work of the Abud group, in the field of colon cancer research, has been featured in a number of media platforms. The following website has links to 3 different news reports. https://www.letsbeatbowelcancer.com.au/articles/news/mini-guts-new-organoids-research • Examine one of the media reports in detail. • How are the mini-gut organoids being used by the Abud lab? • How might their research support people who suffer from colorectal disease? • Why are the mini-gut organoids considered 'ground-breaking'? • In the Herald Sun article, what does the author mean by 'taking the guess work out of treatment'?

		and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	• There is an opportunity to compare the development of organoids as a model for research and treatment for disease development by comparing the Little and Abud groups. This is an example of the development of technology which has an impact on other areas of science.	Look at the website: Let's beat bowl cancer: https://www.letsbeatbowelcancer.com.au • Why might this website/ organisation have been created? • What is the purpose of the site? • Why is the target audience? • Who is in a high-risk category for colorectal cancer? • What support services are offered for people on the site? • What kinds of research are showcased on the website? • Compare the work of the Little and Abud groups. Both have produced organoids for use as biological models. The Little group has produced kidney organoids and the Abud group have produced mini gut organoids. Use a Venn diagram to compare and contrast the two models. Consider the following: ○ How is each group using the lab grown organoids? ○ How functional is the organoid?
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158/192)	• See also ACSHE135 above to explore how advances in technology have supported advances in scientific knowledge. • The article highlights the development of 'mini-gut' organoids. The development of organoids was also highlighted in the Little Group, where the group produced kidney organoids. Technological advances in one area of research may be used to help scientists advance in other areas. • This is an example of how scientists work and the knowledge they create and publish can be applied to other areas of science.	• Stem cell technologies have advanced rapidly over the last 20 years. Scientists can draw on the work and knowledge of others and apply their insights to different models and systems within the human body. Even though the target tissue may be different, the processes to discover the cellular signals and the methods for creating organoids may have similarities in knowledge and technology. • Compare the Abud and Little organoid technologies. How are they similar/ different? Compare the development of organoids in the Little and Abud labs. (see ACSHE135 above)

	9 & 10	Values and needs of contemporary society can influence the focus of scientific research. ACSHE228/230	• Colon cancer is the third most common cancer in the world. To reduce the numbers of people being diagnosed with colon cancer, research is focused on modes of prevention and treatment. This is an example of values in science. Where the quality of human life and the strain that cancer treatment can have on the economy and healthcare systems are reasons why research in this area is funded strongly.	• The Cancer Australia website offers an extensive overview of the multiple forms of cancer which impact people in our community. https://www.canceraustralia.gov.au/ • Use the interactive map to locate the various part so the body impacted by cancer. • Look at the 'Cancer statistics' page to see which cancers are the most and least common • Bowel cancer is the fourth most common cancer diagnosed in Australia, but the second most common cancer to result in death. The Bowel cancer site can be accessed here: https://www.canceraustralia.gov.au/affected-cancer/cancer-types/bowel-cancer/ • Explain why there would be a strong value placed on finding treatment and prevention to colon cancer. • Why can colon cancer develop? What are the risk factors? • What are the screening options for detecting colon cancer? • What are the symptoms of colon cancer? • What are the current treatment options? • How would the Abud group research align with the current treatment options? What benefits would the new treatment or prevention options provide?
Australian Curriculum: Science Understanding (SU)	8	Cells are the basic units of living things; they have specialised structures and functions ACSSU149 AND Multi-cellular organisms contain systems of organs carrying out	• This video offers the opportunity to consider the structure of the digestive system, in particular the role of the epithelium in the large intestine. • Cells focus: Teachers could focus on the role cell division and how mitosis and apoptosis (cell death) maintain healthy numbers of cells. Both are required to ensure cell numbers are regulated. • System focus: The colon plays an important role in digestion. It is the site of nutrient and water exchange.	Context: Inflammatory bowel disease and colon cancer are diseases of the colon. The colon is part of the digestive system. The bowl consists of the small and large intestines. • Use this article and video as a context for students to learn about the role of the bowel during digestion. • Where is the bowel located in the digestive system? • What role does the small and large intestine play during digestion? • The article says "The layer of cells that form the inner lining of the gut serves to prevent intestinal bacteria entering the rest of the body and potentially causing disease. It also absorbs useful nutrients." Explain the two

		specialised functions that enable them to survive and reproduce ACSSU150	• Explore the role of the colon through the context of comparing and contrasting Irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD) • NB – many people are impacted by irritable bowl syndrome (IBS) and colon cancer. Some students may be sensitive to discussing this aspect of the human body as they, or a loved one, may suffer from these common ailments. • See support materials such as talking to kids about cancer: https://www.cancer.org.au/cancer-information/types-of-cancer/childhood-cancers/talking-to-kids-about-cancer • Scientists suggest a link between colorectal cancer and high consumption of processed meats. This is a context for drawing attention to this argument and the evidence that scientists use to make these claims. This is also a context for drawing a link to health and the need to eat a variety of foods to maintain gut health.	elements mentioned – 1) Why does the body the need to prevent bacteria entering? How might the epithelium achieve this aim? and 2) Absorption of useful nutrients. What is an example of a 'useful nutrient'? How can the epithelial cells tell the difference between harmful bacteria and useful nutrients? Suggestions for teaching with inflammatory bowel diseases as a context: "Irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD) are two distinct gastrointestinal disorders, though the differences between the two can be confusing for many people." https://www.crohnscolitisfoundation.org/what-is-ibd/ibs-vs-ibd • How are IBS and IBD similar and different? • What are the symptoms? • What is the treatment for both IBD and IBD? • How might the Abud group research support people with IBD? Suggestions for teaching with colon cancer as a context: • What is bowel cancer? • Find out more at Cancer Australia: https://www.canceraustralia.gov.au/affected-cancer/cancer-types/bowel-cancer/types-bowel-cancer • Explore global colorectal cancer statistics. Which countries have higher rates of colon cancer? Are men affected more than women? Why might this be the case? • https://www.wcrf.org/dietandcancer/cancer-trends/colorectal-cancer-statistics

				Scientists suggest healthy eating can lower the chance of colorectal cancer. Use this article from Science News for Student's as a context to draw student attention to scientific findings about the link between eating high levels of processed meats and colorectal cancer. https://www.sciencenewsforstudents.org/article/back-bacon-and-cold-cuts

	9/10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• This video offers the opportunity to consider the nature of cells which line the small and large intestines. This cell layer is very special as it has to ensure that foreign matter does not enter the blood and the circulatory system but also allows nutrients and water to enter the blood stream to supply energy to the body. The intestinal epithelial cells are short lived. More than a billion cells are shed and then replaced every day from the cellular lining. Stem cells are responsible for generating the cellular lining.
			• Use the video and article as a context to teach the following concepts:
			  ○ The process of absorption in the small and large intestines. Role of this part of the digestive system.
			  ○ Mitosis. The cells in the intestinal epithelium are constantly being replaced. Millions per day. This is a context for teaching about mitosis and cell division.
				• See ACSSU149/150 above to make connections to disease and health.
				• Use this article and video as a context for students to learn about the role of the bowel during digestion.
				• Where is the bowel located in the digestive system?
				• What role does the small and large intestine play during digestion?
				• The article says "The layer of cells that form the inner lining of the gut serves to prevent intestinal bacteria entering the rest of the body and potentially causing disease. It also absorbs useful nutrients." Explain the two elements mentioned – 1) Why does the body the need to prevent bacteria entering? How might the epithelium achieve this aim? and 2) Absorption of useful nutrients. What is an example of a 'useful nutrient'? How can the epithelial cells tell the difference between harmful bacteria and useful nutrients?
				• What are some characteristics of the intestinal epithelium?
				
				Live science: https://www.livescience.com/52026-colon-large-intestine.html

			○ What happens when mitosis goes wrong? This is a context for learning about what happens when mitosis is uncontrolled. ○ Extension: Control of cellular growth via signalling molecules, such as Neuregulin 1 (see Unit 2 below)	• Use this article and video as a context for students to learn about **mitosis**. In particular, the epithelial lining of the intestines is continually being replaced. Millions of cells a day are shed in his area of the body. The rate of mitosis in this area of the body is rapid and continuous. • When mitosis does not go to plan, uncontrolled cell growth can occur, and can affect how blood cells are formed and the variety of white blood cells. What else does blood consist of? What role does blood play? • Learn more about the role of the colon by using the context of inflammatory bowl disease and colon cancer. • The video offers an introduction to the role of the colon lining. What are the two roles of the cell lining of the bowel? How do you think the lining might enact both of these roles? •
Australian Curriculum: Science as a Human Endeavour (SHE)	11 (Unit 2)	Working like a scientist And Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to how the work of scientists is influenced by what scientist's value, what interests and fascinates them, and the role of unexpected findings in the process of scientific endeavour.	• See the SHE (RED) section above related to collaboration and lab structure for resources. • See the SHE (Red) section above related to interest and values. You have chosen to study biology at the VCE level. What is it about biology that fascinates and interests you? Which area of biology interests you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/ sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why? • If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience.
	Unit 2 and 3	Advances in science understanding in one field can influence other	• See ACSHE135 & ACSHE158/192 to unpack why understanding how Neuregulin 1 might block colon tumour cell division could lead to this molecule being used as a cancer	• Go to the ScienceDirect website, which has a definition for the molecule Neuregulin 1. https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/neuregulin-1

		areas of science, technology and engineering (ACSBL039) AND The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)	treatment. Treatment of colorectal cancer would reduce the number of people suffering from the disease and possible reduce deaths due to the disease. • Understanding the role or mechanism of Neuregulin 1 on cell division may have applications for tumour research in other areas of the body. Neuregulin 1 is an example of a signalling protein-based molecule. The molecule has been the focus of research for various parts of the body (i.e. neurons and cardiovascular). This implies that the protein is important for cellular growth and repair throughout the body. • This is also a context for unpacking how this molecule might be produced and transported around the body. See also ACSBL079 below • The article and video offer the opportunity to consider the value of being able to remove tumour growth from the colon, using a molecule known to limit tumour growth.	• What type of biomolecule is Neuregulin 1? • Where would this molecule be made within the cell? Why do you think this? • Identify any words in the definition you are unsure about. First, can you infer what the words mean, based on your understanding of other terms in biology? If not, look u the words. What do they mean? What do they mean in the context of this molecule? • Scroll down the page and look at the article which mentions this molecule. A number of body parts are mentioned, which are related to this molecule. • Which areas of the body can you identify from the articles? • What might this diversity imply about the action of this molecule?
Australian Curriculum: Science understanding (SU)	Unit 2	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055) AND	• See resources above (ACSSU149/150 and ACSSU175) related to intestinal cells and the intestine as part of the digestive system. • Cell division. This resource can be used as a context for teaching mitosis. Teachers could focus on the role of cell division and how mitosis and apoptosis (cell death) maintain healthy numbers of cells. Both are required to ensure cell numbers are regulated. • This video offers the opportunity to consider the role of epithelial tissue within the	• See the materials in ACSSU149/150 and ACSSU175 above as a context for students to learn more about the bowel and its role in digestion. • The intestines as a part of the digestive system – See also ACSHE150 and ACSSU175 above for activities • This link is for a peer reviewed article which offers detail about the nature of the intestine structure: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC300863/ • The language may be complex in places, but the article talks about the large surface area in the intestines. Why is a large surface area useful in this area of the body?

		In eukaryotic cells, specialised organelles facilitate biochemical processes of photosynthesis, cellular respiration, the synthesis of complex molecules (including carbohydrates, proteins, lipids and other biomacromolecules) and the removal of cellular products and wastes (ACSBL049)	digestive system, in particular the role of the epithelium in the small and large intestines as a surface which restricts access of foreign matter into the body, but which also acts as a selectively permeable surface across which nutrients and water can move into the body.	• Using the article, what kinds of stem cells are located in the intestinal crypts? • This is also a context for unpacking the role of stem cells for regeneration colon epithelium cells. • The following link is for a peer reviewed journal article about stem cells and how they lead to the proliferation of intestinal epithelium cells in different animals. Read the article abstract. Although the article has complex language, see how many terms you know or can infer based on the words around it, or research the terms of which you are unsure. Using the abstract, explain how stem cells lead to epithelial cells in vertebrates. • https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3873164/ • http://www.vivo.colostate.edu/hbooks/pathphys/digestion/smallgut/lifecycle.html
	Unit 3	Continuity of life requires the replication of genetic material and its transfer to the next generation through processes including binary fission, mitosis, meiosis and fertilisation (ACSBL075)	• See resources above (ACSSU149/150 and ACSSU175) related to cell division • This resource can be used as a context for teaching mitosis. Teachers could focus on the role of cell division and how mitosis and apoptosis (cell death) maintain healthy numbers of cells. Both are required to ensure cell numbers are regulated. • Cellular signalling plays a role in determining what cells do and when. Cellular signals are molecules, such as proteins, which elicit a response in cells.	• See the materials in ACSSU149/150 and ACSSU175 above as a context for students to learn more about mitosis within the context of the intestinal epithelium replacement and what happens which mitosis is not controlled. See ACSSU175 above for activities. • Students can explain the process of mitosis and regulation of cell division in the context of the colon epithelial tissue. • Draw a flow chart to explain how an epithelial cell would be formed via mitosis. • Go to the ScienceDirect website, which has a definition for the molecule Neuregulin 1. https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/neuregulin-1 • What type of biomolecule is Neuregulin 1?

		AND Protein synthesis involves transcription of a gene into messenger RNA in the nucleus, and translation into an amino acid sequence at the ribosome (ACSBL079) Proteins, including enzymes, are essential to cell structure and functioning (ACSBL080)	• Understanding the role or mechanism of Neuregulin 1 on cell division may have applications for tumour research in other areas of the body. Neuregulin 1 is an example of a signalling protein-based molecule. The molecule has been the focus of research for various parts of the body (i.e. neurons and cardiovascular). This implies that the protein is important for cellular growth and repair throughout the body.	• Where would this molecule me made within the cell? Why do you think this? • Explain how this molecule would be produced by a cell from gene to export. • Identify any words in the definition you are unsure about. First, can you infer what the words mean, based on your understanding of other terms in biology? If not, look up the words. What do they mean? What do they mean in the context of this molecule? • Scroll down the page and look at the article which mention this molecule. A number of body parts are mentioned which are related to this molecule. • Which areas of the body can you identify from the articles? • What might this diversity imply about the action of this molecule?

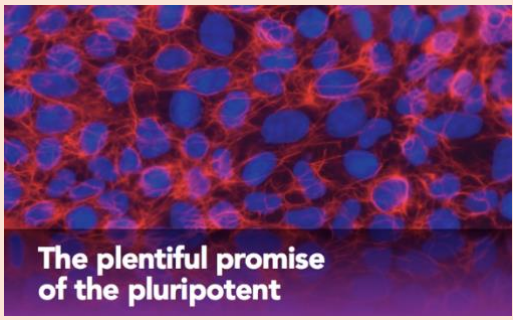
7. Reprogramming and Pluripotency

7.1 The Laslett Group: The plentiful promise of the pluripotent

Associate Professor Andrew Laslett and Dr Jacob Goodwin

CSIRO and the Australian Regenerative Medicine Institute

"Breast cancer is the most frequent cancer among women, impacting 2.1 million women each year, and also causes the greatest number of cancer-related deaths among women. In 2018, it is estimated that 627,000 women died from breast cancer – that is approximately 15% of all cancer deaths among women." World Health Organisation



Accompanying Resources:
Refer to the Stem Cells Australia web page: *'The plentiful promise of the pluripotent,' or* scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

The research:

- Growing a 'disease in a dish' model of breast cancer to use for testing new breast cancer treatments.
- Developing new surfaces to grow induced liver cells in the laboratory. This research is in collaboration with a Chinese research group.
- Develop ways of identifying cell types so that the researchers can identify which cells are present in a culture. This will allow scientists to identify and grow cells that are wanted or remove cells that are not wanted.

The science:

- Working with pluripotent stem cells (i.e. cells which can be induced to grow into any cell type). Click here to find out more: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/
- Breast cancer epithelial cells are cells which make up breast tissue.
- BRACA1 and BRCA2 genes and gene mutation (i.e. Mutations in the BRCA1 and 2 genes have been associated with increased chances of developing breast and ovarian cancers).
- Please note, due to the high incidence of breast cancer, this topic is potentially sensitive. Some children may have a parent, guardian or friend with the BRCA1 or 2 mutations or may have breast cancer. Students may also know they are carriers for the BRCA gene mutation.

Science as a Human Endeavour:

    - Workplace culture: Benefits of working as a scientist (e.g. relaxed dress and international travel)
    - Pathways: What it means to be an Early Career Researcher (ECR) (i.e. a person who is within the first 5 years commencing as a research scientist)
- The nature of scientific endeavour, such as:
    - Agency: The creation and use of models to simulate biological environments as an alternative to animal and human testing of drugs and treatments
    - Collaboration: Collaboration between scientists and research laboratories locally and internationally enhances knowledge development and scientific advancement
    - Values: Sharing research findings advances scientific endeavour
    - Social, cultural and economic influence on scientific research – in this case, the widespread impact of breast cancer, which is globally the most common form of cancer in women (see for example https://www.wcrf.org/dietandcancer/cancer-trends/worldwide-cancer-data)

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)				
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level	Applicable for years 10 - 12

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/ s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-12	Structure of science laboratories and staff (This is related to the hierarchy of science research labs and unpacks how scientists are defined, e.g. doctor, ECR, associate professor etc.)	• This video features Associate Professor Andrew Laslett, head of the Laslett research laboratory located at CSIRO, Melbourne. An Associate Professor is often an experienced researcher (about 7-15 years post commencement). • The video also features Dr Jacob Goodwin who is an early career researcher (ECR) – this means he is within 5 years of commencing his role as a research scientist. Jacob would be mentored by a more senior researcher. • Research laboratories employ scientists of all career stages. ECR's are brought on board and supported as they develop and learn what it takes to become a research scientist. • ** See Support fact sheet about laboratory structures and staff** for more information about how scientific research laboratories can be organised. This information highlights the conditions under which scientists work.	• What might be the difference between a research lab (at CSIRO https://www.csiro.au/) and a research group (at ARMI https://www.armi.org.au/)? • Associate Professor Andrew Laslett is the 'head' of the Laslett Lab – what might his role entail? • Dr Jacob Goodwin described himself as an ECR (Early Career Researcher) – what do you think this means in terms of his career? • What kinds of support might you think is important for an early career researcher to ensure they 'learn the ropes'? • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.

	7-12	Working like a scientist E.g., People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE136	• Scientists often comment that they enjoy solving problems, enjoy planning and conducting their own research and enjoy working collaboratively. • Andrew mentioned that he enjoys his job because of the relaxed dress (i.e. no tie) and the international travel. • Jacob enjoys being a scientist because it allows him to plan and conduct his own research. As he is part of the research group, he will align his research to the group's larger aims, but his specific research allows him a degree of autonomy.	• Associate Professor Laslett talked about why he enjoyed working as a scientist. What were the two main benefits he suggested and how might they compare to a job you might like in the future? • Dr Jacob Goodwin spoke about being able to guide his own research – if you were a biomedical scientist, which aspect of the body (human or other animals) would you focus your research? Is there a disorder or issue on which you might focus? Is there another area of science that you might like to research?
Australian Curriculum: **Science as a Human endeavour (SHE)**	7 & 8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• Mutations in the *BRCA1* gene have been shown to increase the risk of developing breast cancer. This knowledge was developed in the 1990's and has changed the way global monitoring and testing for breast cancer has been conducted. • See: https://www.genome.gov/10000940/brca1brca2-study-faq#al-3 • Please note, due to the high incidence of breast cancer, this topic is potentially sensitive. Some children may have a parent, guardian or friend with the BRCA1 or 2 mutations or may have breast cancer. Students may also know they are carriers for the BRCA gene mutation.	• The first BRCA1 (Breast Cancer gene) was discovered in 1994 and the second, BRCA2 gene was discovered in 1995. These new discoveries have changed the way breast cancer risk is understood and monitored. Around 5% of breast cancers and 15% of ovarian cancers occur due to genetic causes. Since the discovery, new tests have been developed to screen for BRCA 1 and 2 mutations, creating greater awareness among the community about the risk factors associated with breast cancer • Angelina Jolie, a high profile actor, had a double mastectomy (breast removal) and ovary/fallopian tube removal because of her BRCA1 mutation status. See for example: https://canceraustralia.gov.au/about-us/news/angelina-jolies-surgery-reduce-her-risk-ovarian-cancer • Current support site:

				• https://www.cancer.gov/about-cancer/causes-prevention/genetics/brca-fact-sheet#what-are-brca1-and-brca2 • Support site for talking to children about the BRCA gene mutations: https://www.mariekeating.ie/cancer-information/brca/talking-children-teenagers-brca/ • Talking to Children about Maternal BRCA1/2 Genetic Test Results: A Qualitative Study of Parental Perceptions and Advice https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3646977/
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157 See also Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE135	• If pluripotent stem cells from people with the BRAC1 mutation can be stimulated to grow into breast epithelial tissue in a laboratory environment, these cultures can be used as models for testing drugs and treatments without having to test on people or animals. • Growing breast cancer cells in a dish enables scientists to test new drugs and treatments for people with breast cancer and those who are at risk of developing breast cancer	• See questions and activities in the section above • Building tumours in the lab – see https://scienceblog.cancerresearchuk.org/2016/07/04/building-tumours-in-the-lab-a-how-to-guide/ • Create a two columns table to compare the strengths and weakness of using non-human based models (i.e. animal testing) to test breast cancer treatments. • See the PETA website for alternative for animal and human testing (NB there is a sections of this website that discussed simulated surgery models, including a video which may be distressing for some students): https://www.peta.org/issues/animals-used-for-experimentation/alternatives-animal-testing/
		Values and needs of contemporary society can influence the focus of	• See alsoACSHE134 above	• Breast cancer is the most common cancer affecting over 2.1 million women each year. In 2018 it is estimated that 627,000 women died from breast cancer. To improve breast cancer outcomes and

		scientific research (ACS HE230		survival, early detention and effective treatments are vital. (https://www.who.int/activities/preventing-cancer) • See also World Cancer Research Fund website: https://www.wcrf.org/dietandcancer/cancer-trends/worldwide-cancer-data • Based on these statistics and other factors, explain why might research into breast cancer might be a priority.
Australian Curriculum: Science understanding (SU)	8	Year 8 Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce ACSSU150	• Pluripotent stem cells can grow into any cell type in the body under the right conditions. • This team is working with pluripotent stem cells from women with the *BRAC1* mutation. People with this mutation can have an increased chance of developing breast cancer because in women with the BRAC1 gene mutation, an important protein that controls cell growth is not produced. • The aim of the Laslett group is to stimulate the pluripotent stem cells to grow into breast tissue cells. These cells could be cultured in a laboratory and used to test new breast cancer treatment drugs. This would mean scientists can use the lab grown cells for their experiments and would not need to use animals or humans for drug testing.	• Using the video as a stimulus - Explore the different kinds of stem cells. See support resources for students aged 11-15 – Euro stem cell https://www.eurostemcell.org/introducing-stem-cells-presentation-and-classroom-activities • What are pluripotent stem cells and how are they similar and different to tissue-specific stem cells? See: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • There are a lot of different cell, tissue and organ types in the body. What role do stem cells play and why does the body need stem cells?
	10	Transmission of heritable characteristics from one generation to	• Mutations in the *BRCA1* and *BRAC2* genes have been shown to lead to increased chances of developing breast cancer.	• In the Laslett Group example, explain whether the scientists are using embryonic stem cells or induced pluripotent stem cells.

		the next involves DNA and genes ACSSU184		
Senior Biology Australian Curriculum – Science as a Human Endeavour	Units 1-4	Structure of science laboratories and staff	• See red section above	• See red section above
	Units 1-4	Working like a scientist	• See red section above	• See red section above
	Unit 2	Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL037) AND The role of models and modelling in science: Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	• The protocol for differentiating pluripotent stem cells into breast epithelial cells could provide a model for other researchers to use to create breast epithelial cells. • The new protocol adds new knowledge for other scientists to compare and refine protocols for developing other cell types. • New models for research are published via the process of peer review • Use this example as an opportunity to teach students about the process and value of peer review	• The new protocol that the Laslett group are working on will be made publicly available to other scientists via the process of peer review. • Why is it valuable for the Laslett group to share their new protocol for creating epithelial breast tissue cells with the research community? • Why would a 'model' for growing breast epithelial tissue be useful for other researchers? • What is peer review? What is the purpose of blind peer review of research articles? How might peer review provide a level of rigour and accountability when communicating scientific research? Define what these key terms mean before structuring your response. What is reproducibility? Why might it be desirable? When might it is difficult or limiting? • To find out more about the process of peer review see: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4975196/
		The use of scientific knowledge is influenced by social, economic,	Social, cultural, economic and ethical factors: • Breast cancer is one of the most common cancers in Australia affecting 15,934	• The Laslett group has applied for and received funding to conduct their research. Funding agencies need to make decisions about which projects to support that

		cultural and ethical considerations (ACSBL040)	females and 150 males in 2016. The high incidence of breast cancer leads to increased costs for the health system and for individuals and their families in terms of economic, social, cultural and ethical considerations. https://www.bcna.org.au/media/5608/financial-impacts-of-breast-cancer-deloitte-access-economics.pdf	take into account social, cultural and economic factors. Which factors might a funding agency have taken into consideration when funding the Laslett Group research? In a small group, create a concept map to represent your thinking. Compare your concept map with other groups to refine your map. Sharing in this way models how scientists collaborate as a way of understanding different perspectives and ideas. • Testing and experimentation on animals has been the focus of much debate (see for example https://www.abc.net.au/news/health/2016-08-19/animal-testing-could-it-ever-be-banned-completely/7748214 Scientists have tried to create models for drug testing which avoid using animals. The 'disease in a dish' model is one example. • Create a 'Plus, Minus, Interesting' chart to weigh up the benefits and challenges for the 'disease in a dish' model.
	Units 1&2 and 3&4	International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)	• Laboratories collaborate internationally on research projects to increase data sizes and share knowledge. The Laslett group is collaborating with a laboratory in China. • The protocol for differentiating pluripotent stem cells into breast epithelial cells could provide a model for other researchers to use to create breast epithelial cells. • The new protocol adds new knowledge for other scientists to compare and refine protocols for developing other cell types.	• Why might international collaboration benefit scientists and scientific endeavour? Use a 'Plus, Minus, Interesting' chart to consider the benefits, drawbacks and other interesting aspects of local and international collaboration for scientists and the creation of new knowledge.
Senior Biology	Unit 2	The specialised structure and	• Pluripotent stem cells are cells that can grow into any cell type in the body.	• What are pluripotent stem cells and how are they similar and different to tissue-specific stem cells? See:

Australian Curriculum – Science Understanding content		function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)		https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • In the Laslett lab example, explain whether the scientists are using embryonic stem cells or induced pluripotent stem cells.
	Unit 3	Genes include 'coding' and 'non-coding' DNA, and many genes contain information for protein production (ACSBL078) And The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment (ACSBL081) And	• Alterations in the *BRAC1* and *BRAC2* (**Br**east **ca**ncer susceptibility genes 1 and 2) genes lead to non-production of tumour suppressor proteins (TSPs) which help repair damaged DNA. When a mutated form of the BRCA gene is present, the TSPs are not produced, so the chance of developing cancer (most commonly breast or ovarian) increases. • The development of cancer is a complex process and having the genetic mutation is not a guarantee that cancer will develop. As this process is outside the scope of the curriculum, use this context as an opportunity to focus on gene expression, such as the role of the suppressor protein, the dominance pattern of the genes and the process of protein synthesis. • For more information on the role of these proteins within cells please see: https://www.cancer.gov/about-cancer/causes-prevention/genetics/brca-fact-sheet#what-are-brca1-and-brca2	• What is the role of the tumour suppressor proteins in breast epithelial cells? • How might the tumour suppressor protein control cell growth? • Do you think the *BRAC1* and *BRAC2* genes are autosomal dominant or recessive? What information would you need to know to make an informed decision? • Explain how these tumour suppressor protein would be produced - from DNA to the final protein product.

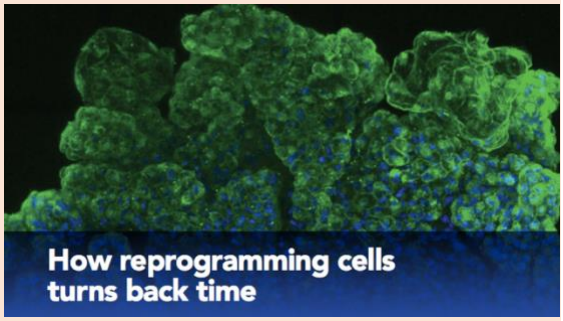
		Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth (ACSBL083) And DNA sequencing enables mapping of species genomes; DNA profiling identifies the unique genetic makeup of individuals (ACSBL086)	• NB it is important to note that while having gene mutations increases susceptibility to developing cancer, it does not guarantee that it will develop. It often takes two steps to develop cancer (see for example Hudson's Two Hit Model). Although genetic inheritance may be the first step, a second (often random) event must occur for the tumour suppressor gene to be no longer functional and cause a cancer to develop. When learning about cancer it is important to understand the random nature of it. This can 'soften the blow' of learning about the BRCA mutation and how it increases the chances of developing breast cancer. This is of note as some students in the class may have these genes. • More detail about the two-hit model: https://www.nature.com/scitable/topicpage/tumor-suppressor-ts-genes-and-the-two-887/	

7.2 Wolvetang Group: How reprogramming cells turns back time

Professor Ernst Wolvetang and Cecilia Gomez

Australian Institute for Bioengineering and Nanotechnology at the University of Queensland

For the past decade scientists have been able to reprogram skin cells, nasal cells and other mature cells to become pluripotent stem cells that can turn into any cell type in the human body. How it works is only starting to become clear.



Accompanying resources:
Refer to the Stem Cells Australia web page: '*How reprogramming cells turns back time*,' *or* scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Wolvetang Group research?

- Professor Ernst Wolvetang is a stem cell biologist and a genome engineer. Once focus of the Wolvetang group is to solve neurodegenerative diseases using human stem cells.
- The Wolvetang group (UQ) works closely with the Polo group (Monash University) and the Lister group (University of Western Australia). Together these lab groups are developing new knowledge about cell reprogramming, in particular they seek to find a consistent reprogramming process in different cell types. Together, this combined team has made a "number of discoveries related to neurodegenerative diseases including leukodystrophies, Rubinstein-Taybi syndrome and Down syndrome, identifying new potential treatments and providing insights into the cell types and processes that underlie Alzheimer's disease".
- "I want to understand how mutations in genes or alterations in gene copy number lead to diseases, especially those that affect the brain, and how a decline in stem cell function contributes to ageing," said Ernst.

What is the science?

- Over the past decade, scientists have been able to reprogram a number of mature cell types, such as skin and nasal cells, to become pluripotent.
- Pluripotent stem cells can become any cell within the body. Stem cell researchers use pluripotent stem cells for research, such as creating model tissues to better understand the nature of diseases, to test drugs or develop treatment regimens for patients.
- Neurodegenerative diseases, such as Alzheimer's disease and Parkinson's disease, impact the brain and peripheral nervous system, resulting in degenerating cognitive and physical function.
- Cellular reprograming has multiple benefits. First, it enables cell types to be grown indefinitely. Second, it also enables genome manipulation (e.g. via CRISPR-Cas9) to correct

or introduce mutations associated with disease. Third, it enables scientists to capture the genetic background of the individual.

- Disease is caused by a combination of mutation and the genetic background of an individual. Knowing about the disease, and the genome of an individual can help scientists determine how best to fight the disease.
- The Wolvetang group is able to produce brain organoids which can be used to represent parts of the brain. These tissue samples can be used for disease investigation, such as mapping cell communication when things go wrong, such as modelling the effects of Alzheimer's disease to understand what is happening at a cellular level.
- Cecilia Gomez, a PhD student in the Wolvetang group is trying to edit the genome of stem cells in order to model diseases and try to figure out ways to cure them.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Need: Understanding how mutations in genes or alterations in gene copy number lead to diseases, especially those that affect the brain. Alzheimer's disease and Parkinson's disease affect thousands of people globally. There is a need to better understand the nature of these diseases.
    - Agency: For scientists, knowing that their work can positively impact peoples' lives instils in them a deep sense of agency and interest. In this case Ernst was passionate about a project which was started because of a sick child. He had a developed sense of agency to support the child and his family. As a result, his team discerned a new disease called HBSL, or **H**ypomyelination with **B**rain stem and **S**pinal cord involvement, and **L**eg spasticity.
    - Interest: Scientists enjoy what they do and feel that they can make a positive contribution to peoples' lives.
    - Collaboration: Research groups like the Wolvetang group collaborate with other groups. In this case the Polo and Wolvetang groups collaborate with Professor Ryan Lister's group. Together they are able to answer questions they would otherwise not be able to do alone.
    - Scientists from various groups bring specialised skills and expertise to teamwork which enables to flow of ideas, co-development of new knowledge and technology. Scientists use and build on the work of other scientists.
    - Social, cultural and economic influences on scientific research and ethical aspects – in this case, developing understanding about how cells function and change during neurodegenerative diseases. This also includes knowing the genes which are involved during disease.
    - Conventions: Scientists apply for funding to support their research. The Medical Research Future Fund (MRFF) grant is an example of this kind of funding.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves qualities, agency, interest and passion. Scientists have values, which influences their work. This drives action and influences why people might choose to pursue a career in the STEM disciplines. Science education offers the opportunity to develop students' scientific literacy. That is, they capacity to engage with science and make informed decisions about the way they live their lives.	• In the video Cecilia Gomez talks about her enjoyment of research and feeling like she is doing something for somebody else. A sense of agency can drive scientists as they feel they can make a positive impact on peoples' lives through the work they do. • In the video Ernst talks about outreach activities as an important part of the work he does. He talks about working with people from other disciplines and engaging with the public to help educate and inform people so that they can make informed decisions as a society. This is an example of how science and scientific education have the opportunity to nurture awareness of issues and development of new technologies to help people make informed decisions about the way they live. • Scientific literacy refers to the capacity to know of and about science so that we can engage with everyday issues, make sense of others' claims, and help us make informed decisions about how we act and live our	• In the video, Ernst talks about an area of his research that he feels passionate about. Cecilia talks about doing "regular molecular biology that I really love". What are you passionate about? What drives you to want to do things or make a change? Are you interested in helping others? • In the video Cecilia talks about being able to find out more about diseases to 'figure out ways to cure them' and to do research 'that will be for somebody maybe in the future'. What does this say about what Cecilia values? • If you could do research to help somebody else, what would you do and why? • In the video, Ernst says "Oh, I wish I was 20 again. At the moment, discoveries are progressing at such a pace that it's hard to follow, actually. And it is this confluence of technologies that I was talking about that that really fuels this discovery process". What does he mean by this statement? • In the video Ernst says "This is a very important part of our public outreach activities and our responsibilities that we have as scientists. By interacting with ethicists, with philosophers, with the public and doing a lot of public engagement, explaining our research to the general public so that we can make informed decisions as a society and as and

			lives. Being curious and interested in the world around us is for everyone. • To find out more about scientific literacy see the NAP document Perspectives and Terms in the National Science Education Standards https://www.nap.edu/read/4962/chapter/4#21 • Or the Australian research by Rennie, Goodrum and Hackling (2001) • https://link.springer.com/article/10.1023/A:1013171905815	also at the government level for where we want to set these barriers." What does he mean by this statement? Why is interacting with other disciplines important for scientists? • Why should scientists communicate their research with the general public? • What kinds of informed decisions is Ernst referring to? • NB See also ACSHE135 below to pursue the idea of interdisciplinary work.
		Scientists need to apply for funding to support their work.	• In the video, Ernst refers to funding from MRFF - Medical Research Future Fund. Students can learn more about the large amount of money which is invested in research. Research funding is a competitive process.	• IN the video Ernst talks about receiving an MRFF grant. Find out more about this grant process – what is this grant? Where does the money come from? • https://www.health.gov.au/initiatives-and-programs/medical-research-future-fund • Locate the latest grant awardees. Look at the titles of the research and the universities/ institutions where the recipients are from. Is there a range of are there commonalities? How much are the awardees granted?
Australian Curriculum: Science as a Human endeavour (SHE)	8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134 AND Solutions to contemporary issues that are found using	• Stem cells are used extensively to create models for research. Models of cells or tissues provides researchers with a platform to test drugs, treatment options and to learn about how diseases work. • One such model are the brain organoids used by the Wolvetang group. Similar examples of organoid models were featured in the Abud and Little groups. • The Wolvetang group is interested in creating brain organoid models because of the issues related to neurodegenerative diseases.	• Scientific knowledge continually changes and advances. As new technologies are developed, scientists work together and push the boundaries of what we know, and develop new knowledge. With new technology, comes new evidence, which advances our understanding. • In the video Ernst explains three reasons why his group uses the technology of cell reprogramming and creation of brain organoids. Explain the three things the group are able to do when they reprogram cells and create mini brain organoids in the lab. • Why might creating cell models of the body benefit researchers and patients? Create a PMI chart for the researchers and the patients.

		science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	• Cellular reprograming has multiple benefits. First, it enables cell types to be grown indefinitely. Second, it also enables genome manipulation (e.g. via CRISPR-Cas9) to correct or introduce mutations associated with disease. Third, it enables scientists to capture the genetic background of the individual. • See the other resources from the groups listed to explore neurodegenerative diseases in more detail. • In the video, Ernst talks about the speed at which stem cell research is moving. This is an example of how fast knowledge can be developed and can change.	• https://www.eurostemcell.org/new-tools-disease-research-reprogrammed-cells-disease-modelling • There are a number of neurodegenerative diseases. Use activities from the other resources to investigate some of these diseases in more detail. For example: • Thompson and Parish Group - Parkinson's disease • Pouton Group – multiple diseases, such as Multiple Sclerosis and Alzheimer's • Merson Group – Multiple Sclerosis • How would the new technology, developed by the Wolvetang group, support researchers who are investigating these diseases? How might it one day help people suffering from these diseases? • In the video, Ernst talks about discovering the disease HPSL. This is an example of the speed at which new knowledge is being developed. • In the video, Ernst says "that has all happened within five years. And I think that shows the power of stem cell research, to take what originally was just a mutation in DNA to screening drugs that might actually make a difference for patients in such a short time. I think that's a paradigm that should be replicated and shows the power of stem cell research for human health." • What does Ernst mean by this statement? Why might stem cell research be advancing so rapidly? • Ernst also says "Oh, I wish I was 20 again. At the moment the discoveries are progressing at such a pace that it's hard to follow, actually. And it is this confluence of technologies that I was talking about that that really fuels this discovery process." • This is an example of how rapidly knowledge can change when so many people are working within the field. What

				does she mean by a 'confluence of technologies'? How is this case an example? • Explain what 'fuels the discovery process'. How can this be nurtured in science? In schools? • Navigate to Ernst's university profile. See: http://researchers.uq.edu.au/researcher/2004. Have a look at his recent grants and publications. What do you notice? • E.g. How many people does he publish with? Does he work with others on grants? etc
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226	• The article '*How reprogramming cells turns back time*,' highlights he collaboration between Ernst Wolvetang, Jose Polo and Ryan Lister. • This is an excellent example of how these three separate and geographically distinct groups work together to advance their research. Together, they are able to do things which would not be possible alone. • This offers the opportunity for students to think about the characteristics of working effectively as part of a group.	• The Wolvetang group article and video illustrates how knowledge can change over time, through collaboration and working with people who have a diversity of expertise. • The article '*How reprogramming cells turns back time*' ,highlights he collaboration between Ernst Wolvetang, Jose Polo and Ryan Lister. Reading the article and having watched the video, what are the skills and expertise that Ernst, Jose and Ryan bring to their collaboration? • In the video Ernst says "So like all science, stem cell science is a collaborative effort. And especially the area that we work in is a confluence of big data science, of genome editing, of stem cells, of imaging. So what we've done is collected a whole bunch of individuals and experts in this area who are working together as a team." • The article also emphasises the notion of collaboration. It says: "Undertaking these complex research projects has only been possible by collaborating," says Jose. "Working together we have answered questions that otherwise would have been impossible or taken far longer to answer." • What do they mean by these comments?

				• Read the section after this quote and in your own words, explain how the groups collaborate with each other. • What makes this collaboration work? • Have you ever worked as part of a team? What made the team work productively and effectively? What made the team work less effective? • If you had to offer advice to somebody working as part of a team, what are your Top 3 tips effectively working as a team?

		People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE136	• In the video Ernst introduces himself as a "stem cell biologist and a genome engineer". This highlights the interdisciplinary nature of scientists work and that the separate subject silos created in schools are not common in the workplace.
			• In the article, have students identify the various technologies which are being used by the Wolvetang group. The group did not create these technologies, but they are using them for their specific research.
			• This could lead to a discussion about the use of technologies for the benefit of a range of people in different disciplines.
			• For example:
			  ○ they are using induced pluripotent stem cells (iPS cells) – see the Polo group for how iPSc's were developed.
			  ○ They have made tissue organoids (see the Little group who pioneered the development of lab grown organoids)
				• In the video Ernst introduces himself as a "stem cell biologist and a genome engineer". Explain what you think each of these elements of his work might involve. What skills would he develop and use?
				• In the video Ernst talks about a boy who had a rare brain disease, HBSL. Why might this example be significant for Ernst? Explain in your own words, the process that Ernst details about how the diseases was discovered to what his group has done to learn more about the disease.
				
				• The other group videos and articles have highlighted similar technologies to those used by the Wolvetang group. Explain similarities between the work of the other labs, and this one.
				• How is the Wolvetang group an example of the use of practices developed in one area being used in another?

			○ They are using CRISPS-Cas9 for gene editing (see the Pébay group) ○ They refer to the database of genes/ mutations (for example, see the Wells group)	
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE191	• See ACSHE134 and 135 above for activities related to models, in particular, the creation of tissue models for research. • Use in conjunction with ACSSU184 (mutations and genes) and ACSSU175 – cells, organs and system, with the neurons being cells which develop tissues which make up the brain and nervous system.	• See activities above ACSHE134/ 135 • In the video Ernst explains three reasons why his group uses the technology of cell reprogramming and creation of brain organoids. Explain the three things the group are able to do when they reprogram cells and create mini brain organoids in the lab. • Create a mind map which outlines these three ideas. Make connections between the ideas and what you have learned about cells, systems, genes and mutations.
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158/192)	• See ACSHE135 and 226 above to explore how significant advances happen, especially when new technologies are developed, and, these advances occur when people collaborate. • See ACSHE136 above. This is an example of how the knowledge and products of science can be applied to other areas of society: in this case, the use of multiple technologies, developed by others, but which are being used in a difference context by the Wolvetang group. • Together, the three research groups in the article have made several discoveries related to neurodegenerative diseases including leukodystrophies, Rubinstein-Taybi syndrome and Down syndrome, identifying new potential treatments and providing insights into the cell types and processes that	• Cell reprogramming technology has advanced rapidly over the last 10 years. Scientists can draw on the work and data of others to use those insights moving forward. The work and knowledge from the past can be used productively to make new advances in the future. This is an example of that kind of sharing and knowledge use in action. • See the activities above related to Ernst talking about the speed at which many advances have taken place and the role of technology and collaboration. • Together, the three research groups in the article have made several discoveries related to neurodegenerative diseases including leukodystrophies, Rubinstein-Taybi syndrome and Down syndrome, identifying new potential treatments and providing insights into the cell types and processes that underlie Alzheimer's disease.

			underlie Alzheimer's disease. Explore these discoveries in the context of understanding the diseases and the impact they have on the body. Use in conjunction with ACSSU175 VCSSU118 and ACSSU184 to connect diseases which have a genetic mode of inheritance.	• Find out more about these diseases and in the process learn about the systems of the body which these disease impact. Consider how stem cells, in particular the work of the Wolvetang group, might support patients with these diseases. • Leukodystrophies: • https://www.chop.edu/centers-programs/leukodystrophy-center/about • Rubinstein-Taybi syndrome: • https://www.cincinnatichildrens.org/service/r/rubinstein-taybi • Down syndrome: • https://globalstemcells.com/down-syndrome-treatment-improvements/ • https://www.sciencedaily.com/releases/2019/05/190523142958.htm • https://www.longdom.org/proceedings/down-syndrome-treatment-with-neural-stem-cells-36570.html#:~:text=Neural%20stem%20cell%20transplantation%20therapy,8%20months%20to%208%20years. • Alzheimer's disease: • https://stemcellsaustralia.edu.au/conditions/explore/alzheimers-disease/
Australian Curriculum: Science Understanding **(SU)**	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149)	• This video offers the opportunity to consider the important role stem cells play in giving rise to different cell types when a human is first created and how stem cells continue to function with the body to regenerate cells as we live.	• Learn about the important role stem cells play in creating different cell types. • Navigate to Stem Cells Australia to learn about stem cells: https://stemcellsaustralia.edu.au/about/about-stem-cells/what-are-stem-cells/ • What are stem cells? • What are induced pluripotent stem (iPS) cells?

			• Euro stem cell – all about stem cells: https://www.eurostemcell.org/all-about-stem-cells-flexible-stem-cell-teaching-tool	• What makes iPS cells so interesting for scientists? • https://www.eurostemcell.org/stem-cell-futures-introduction-ips-cells • How is the Wolvetang group making use of iPS cells?
	9	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175) AND An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by synapses (VCSSU118)	• See ACSHE158/192 to explore the impact that diseases can have on systems of the body • Use the context of these disorders to consider what happens to the body when neurones or other cells do not work as usual. • In particular, what happens when brain cells degenerate or the message between cells degenerates. The context of Alzheimer's disease is particularly relevant for this case, as this was the disease mentioned in the video.	• See ACSHE158/192 to explore the impact that diseases can have on systems of the body.
	9/10	Transmission of heritable characteristics from one generation to the next involves DNA	• This case offers a context for exploring the nature of genetic modification. In this case the use of CRISPR-Cas9 for editing genes in neural tissue grown in the lab.	• In the video, Ernst says "I want to understand how mutations in genes or alterations in gene copy number lead to diseases, especially those that affect the brain, and how a decline in stem cell function contributes to ageing". • Using the video, flow chart to show how the Wolvetang group are growing brain organoids. In your map, use the

		and genes (ACSSU184)		following key terms. You may need to add extra details to explain each step. NB these steps are not in order: ○ Use of an EEG to listen to cell communication ○ Create an iPS stem cell line ○ Growing a brain organoid in a dish ○ Obtain skin cells from the patient ○ Observe cells for signs of degeneration • Once you have created your flow chart, add a section to the chart which explains how the Wolvetang group are using gene editing to learn more about neurodegenerative diseases. Learn more about CRISPR-Cas9 here: • https://www.eurostemcell.org/crispr-changing-gene-editing-landscape https://www.whatisbiotechnology.org/index.php/science/summary/crispr#:~:text=Definition,DNA%20illustration%20by%20Spooky%20Pooka
Australian Curriculum Science - Science as a Human Endeavour (SHE)	11 (Unit 2)	Working like a scientist - interest, curiosity and agency	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • Use the SHE (red) section above to draw attention to how the work of scientists is driven by interest, agency and curiosity.	• See the SHE (Red) section above related to interest, agency and values. • You have chosen to study biology at the senior secondary school level. What is it about biology that fascinates and interests you? Which area of biology interests you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/ sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why? • If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience.
	Unit 2 and 3/4	Development of complex models and/or theories often	• See also ACSHE134 and 191 • Modelling: The Wolvetang group grows brain organoids in the lab to act as models for	• At the start of the video Ernst outlines the process the group takes to create a brain organoid for disease modelling. (see flow chart activity in ACSSU184)

		requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	disease investigation and drug testing. They also use these organoids for genetic modification. Explore, in more detail than is outlined above, how the team use the brain organoid models to learn more about the nature of disease. • Compare this to the use of stem cell created tissues as models in the other cases in this resource. • Collaboration: See section ACSHE above to highlight to collaborative nature of scientists' work. Research groups are made up of a number of different people in various stages of their careers. Research groups work together to share knowledge, equipment, ideas and expertise. Working together means that research can occur at a faster rate than if scientists attempted to work alone. • See also ACSBL041 below	• See other activities above related to creating biological models for research • https://www.eurostemcell.org/new-tools-disease-research-reprogrammed-cells-disease-modelling • Explain why stem cells have changed the landscape of disease modelling. • Look at other examples of disease modelling, such as the Little group (kidney organoids), the Abud group (mini-gut organoids) or the Porrello group (heart tissue). • Stem cells are used throughout the examples from different groups as a means of providing a patient specific model of the disease for exploration in the lab or for testing drug and treatment options. Create a PMI chart to consider the pros and cons of using stem cell created models for disease research.
	Units 2, 3, 4	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) AND ICT and other technologies have dramatically	• See ACSHE226 and 135 to unpack the discoveries and new knowledge advancing the field. • See ACSHE226 above to explore how significant advances can be made when collaborating.	• See activities and links in ACSHE136 • In the article, identify the various technologies being used by the Wolvetang group. They did not necessarily discover these technologies, but they are utilising them for their specific context (i.e. to learn more about neurodegenerative disease). • Brainstorm with a small group of peers and create a list of the technologies you notice in the article and video.

		increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068)		• Explain how the technologies are being used by the team. Identify when the specific technology as first discovered/ developed.
				
				• If students need support, here are some examples:
				  ○ The group is using induced pluripotent stem cells (iPS cells) – see the Polo group for how iPSC's were developed.
				  ○ They have made tissue organoids (see the Little group who pioneered the development of lab grown organoids)
				  ○ They are using CRISPS-Cas9 for gene editing (see the Pébay group)
				  ○ They refer to the database of genes/ mutations (for example, see the Wells group)
				
				• Stem cell technologies have advanced at a rapid rate. Consider the changes that have been made over the last 30 years. The following is a timeline from 1981 – 2014.
				• Explore the timelines and select 5 advances which you think were the most pivotal for stem cell research. Compare your list of 5 with a peer and the whole class. What are the similarities and differences?
				• https://www.newscientist.com/article/dn24970-stem-cell-timeline-the-history-of-a-medical-sensation/
				• https://www.whatisbiotechnology.org/index.php/science/summary/stem/stem-cells-repair-tissues-and-regenerate-cells
				• https://link.springer.com/article/10.1007/s12015-019-09935-x

	Units 2, 3, 4	The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)	• Extension of ACSBL038 above • Genetic alteration on cellular models to find out about brain disease (see also ACSBL039 and 68) • The development of gene editing technologies has been combined with stem cell technologies. Together, these technologies offer a number of possibilities to the creation of new knowledge and ways of fighting disease. Have students explore these technologies and consider how knowledge from one discipline can be used in others (see also ACSBL039/ 68) and how the use of scientists' knowledge can have beneficial and/or harmful and /or unintended consequences. • Consider the ethics of gene editing. What are the arguments for and against editing embryos? You may like to refer to the companion module on the Stem Cells Australia website, Ethics and Stem Cells.	• Use activities from ACSSU184 above. • Using your knowledge of gene editing, explain how the group might use the CRISPR-Cas9 process to edit the genome. • Technology in the area of gene editing, combined with stem cell technologies, as rapidly advanced over the last few years. The following website lists a number of stem cell related examples. • Use your knowledge of biology to see if you can identify some of the term or deduce what the terms might refer to (if you don't know the meaning of some of the terms) • https://www.cell.com/nucleus-crispr-gene-editing-in-stem-cells • What are other possibilities for advances that could arise from the combination of these technologies? Or other technologies featured in this series? • What are some potential benefits or limitations for the combination of gene editing and stem cell technologies? What might be some unintended consequences? Consider social, cultural and economic factors. • This article from Euro stem cells consider the ethics of changing genes in the embryo: https://www.eurostemcell.org/es/ethics-changing-genes-embryo • What are some of the benefits? Drawbacks? Consider the arguments from both sides of the gene editing embryo debate. List and explain arguments for and against. • In 2018, the world's first gene edited babies were born. Read the following article from Euro stem cells. https://www.eurostemcell.org/spotlight-first-gene-edited-babies

Australian Curriculum Science - Science understanding (SU)	11 (Unit 2)	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• See resources above (ACSSU149 and ACSSU175) related to stem cells as valuable cells for development and repair. • Identify how stem cells can lead to specialised cell types.	• Use this context to unpack the nature of cell specialisation and the role that genes would play in that process. In particular, cells which become specialised neurons • Cell fate: Journeys to specialisation: https://www.eurostemcell.org/cell-fate-journeys-specialisation • Cellular differentiation: https://opentextbc.ca/anatomyandphysiology/chapter/3-6-cellular-differentiation/#:~:text=In%20order%20for%20a%20cell,off%E2%80%9D%20is%20through%20transcription%20factors.
	Unit 3	The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment (ACSBL081) AND Mutations in genes and chromosomes can result from errors in DNA replication or cell division, or from damage by physical or chemical factors in the environment (ACSBL082)	• Use in conjunction with ACSBL041 • This case offers an example of gene expression and the influence of mutations • Some diseases are genetic. For example, Down syndrome (featured in ACSHE158/192) is due to an extra chromosome 21. Other diseases can be due to a single gene mutation, such as cystic fibrosis. Explore the variety of genetic mutations and changes which can cause disease.	• "Disease is caused by a combination of mutations and the genetic background." What does Ernst mean by this statement? Explain your thinking using your understanding of gene expression. • In the video Cecilia talks about mutations being a factor in disease expression. Explain what a mutation is and why this might lead to symptoms of a disease. • Find examples of diseases which are genetic. For example, point mutations, chromosomal mutations etc. Compare the mutations, e.g. location, size, type etc. • https://www.nature.com/scitable/topicpage/genetic-mutation-441/ • Add the diseases listed in the article to the categories of mutation.

7.3 The Polo Group: Understanding and controlling cell reprogramming

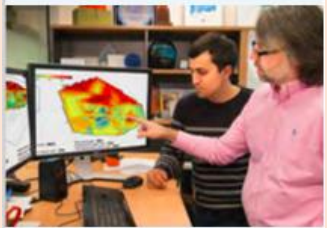
Professor Jose Polo and Dr Anja Knaupp

Australian Regenerative Medicine Institute and Monash University

Associate Professor Jose Polo has made the technicalities of converting one cell type into another vastly more accessible, launching a start-up company in the process

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Understanding and controlling cell reprogramming*,' or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

Associate Professor Jose Polo



What is the focus of the Polo Group research?

- The Nobel-winning discovery of induced pluripotent stem (iPS) cells – in which an adult cell, such as a skin cell, can be reprogrammed back into a stem cell – opened up a wealth of opportunities to better understand and treat disease.
- The Polo group are seeking to advance understanding about cellular reprogramming and ways to accelerate this process.
- The Polo group have created a start-up company – Cell Mogrify – which will commercialise their cellular reprogramming technologies. This will make the new technology accessible and assist medical professionals and researchers when they seek to grow patient-specific, disease-based tissue for disease modelling, drug testing, and treatment design.

What is the science?

- Induced pluripotent stem cells (iPS cell) are created when an adult cell, such as a skin cell, is reprogrammed back into a stem cell. The resultant stem cell can then be reprogrammed into multiple cell types. This type of cellular reprogramming is an example of a new technology.
- Cellular reprogramming was created by Nobel Laureate Shinya Yamanaka in 2006 and relies on use of four genes. When these genes were added to a skin cell, the combination of genes pushed the cell back to a pluripotent state capable of then being coaxed to form any other cell of the body.
- Reprogramming cells from specific patients has the potential for recreating specific tissue in the lab for patient specific disease modelling, drug and treatment development.

- The Polo group have made a number of contributions to the field since the creation of the iPS cell protocol in 2006. There are a number of peer-reviewed articles which showcase how knowledge about iPS cells have developed and advanced over time, often relying on international collaboration.
- The specific cellular signals necessary to turn an iPS cell into any other cell type in the body are being understood as research continues. However, much of this knowledge is yet unknown. Where there is a need and value for iPS cell technology, science will respond and invest in developing new knowledge and technology.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Need: Reprogramming technology offers a way of developing cell-based therapies which can lead to better understanding and treating diseases. There is a continual need for the development of more cost effective and efficacious treatments of disease.
    - Value: Organs for transplantation are in limited supply. Cell reprogramming technology has implications for producing organs which can be used to treat organ damage and failure using patient specific tissue.
    - Interest: Scientists are often interested in science and enjoy science as a subject in school.
    - Collaboration: Research groups, like the Polo group, work with other research groups around the world. This connection of scientists enables to flow of ideas, co-development of new knowledge and technology. Scientists use and build on the work of other scientists.
    - Publish: Scientists publish their work in peer-reviewed journals and present at conferences locally and abroad. The body of knowledge communicated via science-based journals is substantial and lasting. There are conventions for publication in this forum.
    - Social, cultural and economic influences on scientific research and ethical aspects – in this case, developing a company which can bridge the gap between research and industry, such as the creation of the company Cell Mogrify, which has commercialised the Polo group reprogramming technology. This company has the potential to deliver the latest in cell reprogramming technology to make this technology accessible to medical practitioners so they can develop patient-specific, disease-based tissues to test drug treatment models prior to treatment.
    - The iPS cell technology has reduced the need for non-human models and the use of embryonic stem cells, which has reduced the ethical concerns related to using these two types of tissues to research and treatment.

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves qualities, such as interest in science or the unknown. This drives action and influences why people might choose to pursue a career in the STEM disciplines.	• In the video Anja Knaupp talks about being interested in biology at school. • Jose highlights the collaborative nature of research groups.	• In the video, Anja Knaupp talks about being interested in science. What do you find interesting in the world around you? • Which subject at school do you like the most? Why? Would you like to work in that field? • Jose talked about seeing research on TV and wanting to do that kind of research. What have you seen on TV that you might like to do as a job when you are older? • Jose knew that he wanted to do research. How did Jose gain experience in research? How does he describe his journey into research? What was beneficial for him? What was limiting?
Australian Curriculum: Science as a Human endeavour **(SHE)**	8	Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available ACSHE134	• Scientific research can lead to new technologies, such as the development of induced pluripotent stem (iPS) cells. iPS cell technology was first reported by Nobel Laureate Shinya Yamanaka in 2006. Professor Yamanaka was awarded a Nobel Prize in 2007 for this work. • There is an opportunity here to explore how the knowledge about iPS cell has developed over time, through the work of many people.	• Scientific knowledge continually changes and advances. As new technologies are developed, scientists are able to push the boundaries of what we know and develop new knowledge. With new technology comes new evidence, which advances our understanding. The Polo group video and article illustrate how knowledge can change over time, as scientists publish their findings, and other scientists from around the world build on that knowledge to make new advances. • New knowledge is published in journals, using the convention of peer review (this will be unpacked further in

			• The Nobel Prize is the most coveted prize in the science world. This is an opportunity to explore the purpose and value of the Nobel awards and to become more aware of the ground-breaking work of some Nobel laureates.	ACSHE157/191. Significant new advances in knowledge are recognised in the community through awards and prizes, such as the Nobel Prize. • What is the Nobel prize? • If you are a fan of the Big Bang TV series, you may have noticed that in season 12, Sheldon and Amy won a Nobel Prize for physics. "On 27 November 1895, Alfred Nobel signed his last will and testament, giving the largest share of his fortune to a series of prizes in Physics, Chemistry, Physiology or Medicine, Literature and Peace – the Nobel Prizes." https://www.nobelprize.org/prizes/facts/nobel-prize-facts/ • How might the Nobel Prize lead to advances in new knowledge? • How many categories of Nobel prize are there? List the categories. • How many Nobel prizes have been awarded for each category? • Why are people who have received a Nobel Prize called Nobel Laureates? What is the origin of this term? • Look at the list of the youngest Nobel Laureates. Pick one recipient and find out what they won the prize for. • How many Noble Laureates are there? • How many Nobel prizes have been awarded to women? • In 2020, two women were awarded the Nobel prize for their work in chemistry for develop the CRISPR gene editing tool. Learn more about this award here: https://www.abc.net.au/news/2020-10-07/emmanuelle-charpentier-jennifer-doudna-nobel-chemistry-prize/12741596 • See the Pébay and Little group resources for examples of how scientists are using CRISPR technology for stem cell research.

				• In Understanding and controlling cell reprogramming (page 6-7 of At the frontier of tomorrow's medicine), the author mentions another Nobel laureate Shinya Yamanaka. Use the Nobel Prize website to answer the following questions - https://www.nobelprize.org/prizes/medicine/2012/yamanaka/facts/ • When did Professor Yamanaka win the Nobel prize? • Why was he awarded the Nobel Prize? • If Professor Yamanaka developed the protocol for iPS cell in 2006, why might it have taken so long to be awarded the Nobel prize? • Professor Yamanaka works at the Kyoto University in Japan. His profile can be found here: https://www.cira.kyoto-u.ac.jp/e/research/yamanaka_summary.html • When scientists are affiliated with a university, they have a profile page. What information is available about Professor Yamanaka on the website? Why might this information be valuable in an open access forum? • NB If you are interested in learning more about the life and work of other scientists, you can find more information on the website of the organisation where they work. They also have contact details, which is another way you or your class could make contact with scientists to find out more about their work. • More can be read about the Nobel prize at Euro Stem cell: https://www.eurostemcell.org/nobel-prize-goes-stem-cell-pioneers-john-b-gurdon-and-shinya-yamanaka
		People use science understanding and skills in their occupations and	• Much of the knowledge developed by scientists is used to advance the discipline. However, some scientific advances can be used outside the scientific community. An	• The article highlights how the Polo group develops computer program, Mogrify, which would "model how to control the conversion of an adult cell into any other type of cell". This led to the development of a company which could offer this

		these have influenced the development of practices in areas of human activity ACSHE136	objective or idea can be patented, which can then lead to some kind of product or service being produced for use in the wider community. • This is an example of the products of science being available in other areas of human activity. In this case, the Polo group has developed a computer tool to model the signals necessary to develop specific adult cell types. The Jose group has applied for a patent on their program and have created a company which can then offer this program to medical practitioners, outside science, so they too can develop patient-specific, disease-based tissues to treat and select potential drugs for treatment. • Students can learn more about how Mogrify works. That is, a computer program which can help researchers and medical practitioners decide which cell signals to apply to create a specific cell type. This might be useful if they want to create specific patient derived tissues to test possible drug regimes.	computer program to medical practitioners around the world, so that they could work out how to design patient-specific, disease-based tissues to treat and select potential drugs for treatment • Read about the development of the start up company here: https://www.monash.edu/industry/success-stories/mogrify • What was the advance that led to the development of the program Mogrify? • Where did the group obtain funding for their start-up company? • Navigate to the Mogrify website: https://mogrify.co.uk/ • Look at the timeline for development of the technology. What were the main advancements that enabled the scientists to create the company and be able to offer the program as a service for medical practitioners and researchers? • Who are the partners of the company? Why might they need partners?
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE157/191	• This is an example of how scientists work and the knowledge they create is published and shared with the community and beyond through peer reviewed journal publications. • Peer review is a process where scientists submit their work for publication with one of many journals, and the work is blind peer reviewed by other scientists in the field. • A number of articles related to the video and article are offered here. The language in	• The article mentions a number of publications which summarise the development of knowledge about iPS cells and the work of the Polo group over a number of years. • The first article was published by Shinya Yamanaka in a journal called Cell Stem Cell in 2007. https://www.sciencedirect.com/science/article/pii/S1934590907000185 • Look at the conventions in the webpage. Read some of the abstract of the article (i.e. the summary text at the very start

			these journal articles is advanced, but there are many terms which students may recognise. The key idea here is to help students appreciate that journals and the process of peer review exists. • Notice things about the articles, rather than having students read the text, such as conventions, the number of authors, structure of the articles (there is often a common structure), the layout of the webpage etc. • The development of knowledge is also apparent through looking at the articles – such as the initial development of being able to make iPS cells to the knowledge gained about how this process happens. Use the article "Understanding and controlling cell reprogramming" to help map the developments in simple language. • An overview of Jose Polo's publication list is also interesting and can show students how it takes years to develop new knowledge and how the knowledge becomes specialised. https://research.monash.edu/en/persons/jose-polo/publications/	of the article). Which words can you make out? Can you work out what the article is about, based on words you know? • The second article was written by Jose Polo and colleagues in 2012 and was published in a journal called Cell. https://www.cell.com/cell/fulltext/S0092-8674(12)01424-9?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0092867412014249%3Fshowall%3Dtrue • How many authors are there on this paper? • Although the abstract has a lot of complex language, do you recognise any terms? What is the main finding from this paper? • The third article was published in Nature Genetics in 2016. https://research.monash.edu/en/persons/jose-polo/publications/ • What is the purpose of this article? • Look at how often this article has been accessed and cited. These are called metrics and are used as a measure of research output quality and impact. Scientists try to publish in journals which have higher metric ratings. This makes the process more competitive. • The last article was published in 2017 in Nature Methods. This was an Open Access article – meaning that scientists do not have to pay or use their university library to access the article. https://www.nature.com/articles/nmeth.4436 • What is the purpose of this article?
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192	• See ACSHE134 above to explore how significant advances in science can result in recognition of scientists ground-breaking work through awards, such as the Nobel Prize. • The video and article highlight how the Polo group have built on the work of Nobel Laureate Shinya Yamanaka. This is an	• See ACSHE134 to learn more about the work of Nobel Laureate Shinya Yamanaka and the scientific discovery he made related to iPS cells. • Stem cell technologies have advanced rapidly over the last 20 years. Scientists can draw on the work and knowledge of others and apply their insights to different models and systems within the human body. Even though the target

			example of how advances in scientific knowledge are often linked to the development of new technologies and the work of other scientists. In this case, Nobel Laureate Shinya Yamanaka was integral for developing a method for cell reprogramming, yet the Polo team have taken that knowledge and have created new knowledge about how this reprogramming happens. • See ACSHE136 above. This is an example of how the knowledge and products of science can be applied to other areas of society. In this case, the development of a computer based program which can support other researchers and medical practitioners to identify the key regulatory switches to create a specific cell type.	tissue may be different, the processes to discover the cellular signals and the methods for creating organoids may have similarities in knowledge and technology. • The work of Nobel Laureate Shinya Yamanaka was integral for developing a method for cell reprogramming, yet the Polo team have taken that knowledge and have created new knowledge about how this reprogramming happens. • Use this in conjunction with ACSHE157/191 above to highlight the advances that the Polo group made over time and how these advances were building new knowledge. • See ACSHE136 above to learn more about the company which has been the product of the Polo group and their colleagues applying for a patent for their Mogrify computer technology. https://mogrify.co.uk/science/#_mogrify
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research. ACSHE228/230	• Values and needs of society influence where scientific research is directed. Organ transplantation is expensive, organs are in short supply, there are long term health implications after a transplantation (i.e. immunosuppressant medication). There are also the values placed on whether somebody becomes an organ donor and what implications that can have to family members. The prospect of being able to grow replacement tissue and organs in a laboratory would reduce the need for donor organs. • Professor Polo mentions how his lab has made advancement in understanding how	• In the article, Jose says "If you go to a mechanic now and your car breaks, your car breaks down and you go to the mechanics and you say: fix it. Imagine if the mechanics didn't have the spare parts - how much could they can do? Not much. The better they can do is to start to take parts of other cars but that is it. That is the state of medicine now. We don't have spare parts, the best we can do is a transplant. What if I tell you that we are now starting to make our parts and these people may have an impact on your life." • What is being valued by Jose in this statement? • Why would making body tissue from iPS cells be preferable to organ transplantation? Make a list of pros and cons. • Use in conjunction with ACSSU175 and explore how complex body organs are and how a knowledge of multiple cell and

			cells develop into specialised tissue. This offers an opportunity for students to think about the complexity of body organs and what it might take to know how to make a fully functioning, mature organ, such as the heart. The process would be extremely complicated, with multiple genes being switched on and off, and the diversity of cellular signals which would lead to a complex organ being built. To consider this complexity, have students consider how a heart might be built in a developing foetus. They can think about this from the perspectives of the broad tissues located in the heart, such as the muscle, blood vessels, valves etc. This is not about knowing exactly how the heart develops, but making an informed, evidence-based series of decisions about a logical sequence which might result in the construction of a mature organ. This is similar to asking students how to build a house – if we think about a house as having a floor, internal and external walls, ceiling, roof, cladding, plumbing etc. You don't need to know how to build a house to be able to predict which structures might need to be built before others. I.e. a strong foundation is • It might be helpful to look at simple heart models to see which elements are present and which of the complex aspects are missing.	tissue types would be required to know how to grow an entire organ. See the Little and Abud groups – who have created organoids. These mini organs represent a major advancement in technology and understanding, but the organoids are limited. Scientists are yet to work out each of the cell signals which would lead to the development of a mature, functioning organ. Use this as a context to pose 'what if…' questions. • For example, "What if scientists did know the cellular signals for creating a functioning human heart in the lab – which tissues and cells of the heart would need to be developed and in which order? Think about how a human heart might be built when it is first developed in utero. Consider the broad tissues of the heart and what might need to come first. For example, would there need to be the heart muscle cells first to develop a shape? When might the values be built? What about valves, the veins and arteries entering and learning the heart and the blood vessels providing blood to the heart muscle itself, connective tissue, etc." Students could be encouraged to look at models of simpler heart structures. • It might be helpful to compare this to an analogy of building a house. Think about the main elements of a house (e.g. floor, walls, plumbing, ceiling etc.). A foundation would need to be built before walls could be constructed. And a ceiling structure would need to be constructed before the roof tiles could be added.
Australian Curriculum:	8	Cells are the basic units of living things; they have specialised	• This video offers the opportunity to consider the important role stem cells play in giving rise to different cell types when a human is	• Learn about the important role stem cells play in creating different cell types.

Science Understanding (SU)		structures and functions (ACSSU149)	first created and how stem cells continue to function within the body to regenerate cells as we live. • See the Stem Cells Australia website for an introduction to stem cells: https://stemcellsaustralia.edu.au/	• Navigate to Stem Cells Australia to learn about stem cells: https://stemcellsaustralia.edu.au/ • What are stem cells? What are induced pluripotent stem (iPS) cells? • What makes iPS cells so interesting for scientists? https://www.eurostemcell.org/stem-cell-futures-introduction-ips-cells
	9/10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175	• Use the Polo resource at the year 9/10 level as a context for considering the nature of systems and what can happen when organs or tissues in the systems do not work properly or are damaged and need to be repaired. • Use resources in ACSSU149 above to teach about the role of stem cells in body systems. Some body tissues are able to regenerate with the use of stem cells, however other tissues, such as heart muscle cells are not able to regenerate. Stem cells technologies may offer hope for the repair of damaged, non-regenerative tissue. See for example, the Ramialison Group for an example of non-regenerative cardiac tissue. See also the Little group who uses stem cells to regenerate kidney tissue.	• See ACSSU149 above to make connections to cells which make up body systems. • See the Palpant and Porrello groups for contexts about heart tissue. • See the Little group for the excretory system.
Australian Curriculum: Science - Science as a Human Endeavour (SHE)	11 (Unit 2)	Working like a scientist And Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • See section above (red) to draw attention to how the work of scientists is influenced by what scientist's value, what interests and fascinates them, and the role of unexpected	• See the SHE (RED) section above related to collaboration and lab structure for resources. • See the SHE (Red) section above related to interest and values. You have chosen to study biology at the VCE level. What is it about biology that fascinates and interests you? Which area of biology interests you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/ sound like you

			findings in the process of scientific endeavour.	and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why? • If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience.
	Unit 2	Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL037)	• See ACSHE157/191 to unpack the nature of peer review, publishing scientific findings in journals and the conventions associated with that process. • Students at this level would benefit from being able to infer meaning of the articles by identifying terms they are familiar with. There is value in grappling with the article abstracts to develop skills of inference, by drawing on terms and ideas we already understand.	• See activities and links in ACSHE157/191 above.
		Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)	• See ACSHE134 above to learn more about the advances made by Professor Yamanaka and the Nobel Prize that was awarded for his development of iPS cells. • Then use ACSHE157/191 to explore the other advances made by teams of scientists, building on the ideas and work of others and collaborating across institutions, around the globe • See ACSHE228/230above which also emphasises advances in the field.	• See activities in ACSHE134, 157/191 and 228/230 above

		Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) AND The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)	• See ACSHE158/192 – in particular the development of Mogrify and the start-up company founded by Polo and his colleagues.	• See ACSHE158/192 above • Navigate to the following site: https://mogrify.co.uk/science/#_mogrify • Read the blurb. Using your knowledge of biology, which words can you identify? What do these terms mean? • Look at the Steps at the bottom of the page. Use your knowledge of gene expression to explain what these steps are. • Explain how and why the Mogrify site and platform would benefit people outside scientific research.
Australian Curriculum: Science - Science understanding (SU)	11 (Unit 2)	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• See resources above (ACSSU149 and ACSSU175) related to stem cells as valuable cells for development and repair. • Identify how stem cells can lead to specialised cell types. • See specific teaching resources above.	• See the materials in ACSSU149 and ACSSU175 above as a context for students to learn about stem cells and the role these cells play in the body. • Use the context of the Polo group and advances in cell reprogramming to explain why iPS cells are consider a major breakthrough for stem cell research.

7.4 The Wells Group: Big data points the way to custom stem cells

Professor Christine Wells and Nadia Rajab

University of Melbourne Centre for Stem Cell systems

Genomic biologist Professor Christine Wells and biostatistician Dr Kim-Anh Le Cao are analysing big data to discover what makes stem cells tick. Already the pair have found new ways to classify stem cells, and they're working to predict the cells' behaviour and even create custom immune cells.

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Big data points the way to custom stem cells*, or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Wells Group research?

- Professor Christine Wells and her team work with Associate Professor Kim-Anh Le Cao who is a statistician at the University of Melbourne. Together Christine and Kin-Anh have developed and maintain the Stemformatics database. An online encyclopaedia of hundreds of high-quality stem cell studies from other researchers.
- The researchers have creatively and rigorously analysed data from the Stemformatics catalogue to look for commonalities between the various data sets. They have developed strategies to predict the molecular signatures of cells, such as mesenchymal stromal cells (MSCs).
- Christine and Kim-Anh's collaboration is slowly revealing the design principles that make specific cells what they are, which raises the possibility of making hybrid stem cells that combine features from different kinds of existing cells.
- The Wells group is currently working on creating lab-made, designer macrophages to perform new functions and deliver medicines.
- The Wells groups is also interested in understanding how cells form from development through to ageing and disease: what makes a cell a cell?

What is the science?

- Pluripotent stem cells can become any cell within the body. Stem cell researchers use pluripotent stem cells for research, using chemical signals to develop a range of tissue types from pluripotent stem cells.
- When creating a cell in a dish, the cell is without a context, so it does not receive the chemical messages to help it differentiate into a specific cell type. Wells calls this an 'identify crisis'.
- The Wells group use big data sets to capture information about the genes a cell uses to differentiate into specialised cell types.

- The Wells group is currently working on lab-made macrophages. With the information gained from analysing large data sets, the lab could develop chemical signals to create designer macrophages which may perform new roles of deliver medicines around the body. This is moving towards a 'designer cell' model.
- Nadia Rajab, a PhD student in the Wells group is working on cells in the immune system. Nadia is trying to understand how immune systems cells gain 'memory' of antigens they encounter, and whether that memory can be altered.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Need: There are rules about how we form, how we interact with the environment, how we age and we just don't know all of those rules yet there is this whole landscape of discovery to be made.
    - There is a lot of data from many stem cell research projects which can be pooled and used to inform future research.
    - Interest: Scientists are often interested in science, curious about the world around them and see a need for new and innovative thinking.
    - Collaboration: Research groups, like the Wells group, work with other research groups around the world. This connection of scientists enables to flow of ideas, co-development of new knowledge and technology. Scientists use and build on the work of other scientists.
    - Social, cultural and economic influences on scientific research and ethical aspects – in this case, developing a database which can be used to support other researchers and industry understand the genes involved in cell specialisation.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves qualities, such as interest in science or the unknown. This drives action and influences why people might choose to pursue a career in the STEM disciplines.	• In the video Christine says "This is the best job you can imagine. You get paid to be curious, the world - the natural world - is so amazing." • This interest and curiosity can translate to pursuing further study in STEM disciplines, but it also may not. A report released by the Office of the Chief Scientist, asserted that "In 2016, there were 11.5 million people in the Australian labour force. 6% of these people had a university stem qualification". Although many students may find science interesting, not all of them will go on to become scientists. So how can we support and create interest in the greater majority of students who may not pursue a career in science? We can still be interested, curious and want to know more about the world around us, without becoming a scientist. So, although it is a characteristic of many scientists highlighted in this resource, it is also common among people who pursue other professions to be curious.	• In the video Christine says, "You get paid to be curious, the world – the natural world - is so amazing." What do you find interesting in the world around you? • Which subject at school do you like the most? Why? Would you like to work in that field? • How do you use science in your everyday life? • Think about the science topic you are studying now, or studies recently. How might the ideas from that topic be relevant to the everyday world around you? Can you see the ideas in action? • Think about the skills you have learned in science. You may have learned how to light a Bunsen burner or use a measuring cylinder or microscope, but you have also developed capabilities, such as critical and creative thinking. These are important skills of science too. • Thinking about your time at school, when might you have developed capabilities like critical and creative thinking? When have you been interested and curious and wanted to know more? Have you done a bit of research to pursue your interest? What did you learn? • Christine talks about how much joy she derives from working with young people and watching them grow and develop. • What were the characteristics she enjoys most when working with beginning scientists?

			• Scientific literacy (https://ro.ecu.edu.au/ecuworks/4687/) refers to the capacity to know of and about science so that we can engage with everyday issues, make sense of the claims people make and help us make informed decisions about how we act and live our lives. Being curious and interested in the world around us is for everyone. • The report can be found here: https://www.chiefscientist.gov.au/sites/default/files/2020-07/australias_stem_workforce_-_final.pdf • Christine highlights the collaborative nature of research groups, including the diversity of people who work in research laboratories. Many different people, at different stages of their career, working together. • Christine also emphasises the joy she derives from working with young students as they develop their knowledge and skills. As a mentor, Christine sees value in educating the next generation of scientists and enjoys watching the process unfold. Mentoring is an important aspect of many professions. When we work in groups and with mentors, we feel supported and nurtured. Other people can help us identify areas for growth and development.	• What does she mean by 'cross-pollination' of ideas?
Australian Curriculum: Science -	8	Science knowledge can develop through collaboration across the	• The article *Big data points the way to custom stem cells*, highlights he collaboration between Christine and	• Scientific knowledge continually changes and advances. As new technologies are developed, scientists work together and push the boundaries of what we know and develop new

Science as a Human endeavour (**SHE**)		disciplines of science and the contributions of people from a range of cultures ACSHE226
		
		AND
		
		Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135
			Associate Professor Kim-Anh Le Cao, a statistician. To this collaboration, Christine brings insights about cellular pathways, such as how cells form and the genetic activity of cells. Kim-Anh is experienced working with large data sets and Christine likes working with large data sets – so this is a shared interest.
			
			• The Wells lab is interested in knowing how cells form from development through to aging and disease. What makes a cell a cell? This is a dearth of knowledge that the Wells group is trying to learn more about.
			• For a non-specialised cell, like a pluripotent cell, to become specialised, a number of genes need to be switched on, to specialise the cell. The Wells lab is interested in finding out the genes which need to be switched on to specialise specific cell types. To do this, Christine and Kin-Anh are using large data sets from scientists around the world to look for trends which may give clues about the chemical and genetic pathways to cell specialisation. This is an example of new knowledge which these scientists are trying to create to benefit others.
			• Stemformatics is an online data base which Christine directs and manages. It is an online encyclopaedia of data from hundreds of stem cell studies. This data base stores genetic information about the stages of cellular development.
				knowledge. With new technology comes new evidence, which advances our understanding. The Wells group video and article illustrates how knowledge can change over time, through collaboration and working with people who have a diversity of expertise.
				• Compare and contrast the skills and expertise that Professor Christine Wells (a stem cell scientist) and Associate Professor Kim-Anh Le Cao (a mathematician) bring to their professional partnership.
				
				• In the video Christine talks about how cells form. Explain what we do and do not know about this process. What is the Wells group interested in knowing more about? Why would the knowledge they want be helpful for other people?
				• The article introduces the Stemformatics data base.
				  ○ What is this database?
				  ○ How is if formed?
				  ○ Where does the data come from?
				  ○ How manages the database?
				  ○ What might the data consist of?
				  ○ Why is the database helpful for other people?
				
				• The Wells group are wanting to make designer cells, such as designer macrophages. In the video Christine describes what a macrophage is. Explain what the cell is and how does she break down the word ‘macrophage’?
				• Why might designer macrophages be helpful for scientists?
				
				• Macrophage can be broken down into ‘macro’ and ‘phage’. How many other terms in science can you find like this? List them and then break down the words into their constituent parts. Here are a couple to get you started:

			• This new knowledge will impact society as it will scientists from around the world working with stem cells. It will help them to be able to create cell lines for drug testing, disease modelling and possibly to create cell lines to one day treat specific diseases and injures. • The article details the current and future work of the Wells group. The group are working on lab-made macrophages – which are cells in the immune system. In the video Christine describes them as "'Macro' meaning big and 'phage' meaning eaters. What a great cell - the big eater of the body. It's the cell that does lots of the housekeeping of the body." • The idea here is that the lab may be able to custom make macrophages to perform descries tasks within the body, such as perform new roles and deliver medicines.	○ Photosynthesis – 'photo' meaning light and 'synthesis' meaning to put together ○ Pluripotent ○ Peristalsis ○ Monocotyledon
		People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity ACSHE136	• See also ACSHE135 above – This case offers an example of the interdisciplinary use of maths and science. • This case is an example of the development of an online data base, which uses mathematical skills to analyse and manage large genetic data sets. Without mathematical skills, the scientists would not be able to use the data effectively. Without the scientific knowledge, the scientists would not know what the data means. Knowledge and skills from both disciplines is needed to make the most of this opportunity.	• The article highlights how the Wells group has developed a data base called Stemformatics. See ACHSE226 above for questions related to this database. • In the Stemformatics database – describe the maths skills needed to maintain this database. Describe the science skills needed to use this database. • Explain why the expertise and skills of a scientist and mathematician are useful when working on this project. • Compare and contrast the Stemformatics database to the Mogrify platform features in the Polo group resource. • The Stemformatics website: https://www.stemformatics.org/ • The Mogrify website: https://mogrify.co.uk/

			• The development of the Stemformatics database is an example of how science can influence other practices, such as providing the instructions medical practitioners needs to grow patient specific tissue for drug testing to see how the patient's body might respond. • This case can be compared to the Polo case, where the Polo lab created the company Mogrify, which hosts a computer program to help researchers and medical practitioners decide which cell signals to apply to create a specific cell type. This is useful if people want to create specific patient derived tissues to test possible drug regimes. • In the video Christine talks about potential uses of stem cells in the future. This is an example of curiosity and wonder in science - realising what could be possible and then working towards that goal.	• Using the articles, videos and websites, explain the purpose of the Stemformatics and Mogrify platforms. Use a Venn diagram to compare and contrast the similarities and differences. • Towards the end of the video, Christine talks about what might be possible for stem cell technologies in the future. Use a PMI (Plus, Minus, Interesting) chart to consider each of her examples. What might be the benefits of the idea? Limitations? And an interesting idea you have about it, which may not be positive or negative, just interesting.
	9 & 10	Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries ACSHE158/192	• See ACSHE226 above to explore how significant advances can be made when collaborating. • See ACSHE136 above. This is an example of how the knowledge and products of science can be applied to other areas of society. In this case, the development of the Stemformatics database which can support other researchers and medical practitioners to identify the key genes responsible for cell specialisation. • In the video Christine talks about potential uses of stem cells in the future. This is an	• Stem cell technologies have advanced rapidly over the last 20 years. Scientists can draw on the work and data of others to use those insights moving forward. The work and knowledge from the past can be used productively to make new advances in the future. This is an example of sharing and using previous knowledge in action. • Towards the end of the video, Christine talks about what might be possible for stem cell technologies in the future. Use a PMI (Plus, Minus, Interesting) chart to consider each of her examples. What might be the benefits of the idea? Limitations? And an interesting idea you have about it, which may not be positive or negative, just interesting.

			example of curiosity and wonder in science. Realising what could be possible and then working towards that goal.	
	9 & 10	Values and needs of contemporary society can influence the focus of scientific research. ACSHE228/230	• The values and needs of society influence where scientific research is directed. • In the article Christine talks about the 'rules' of cell growth which can repair damaged tissue. The scientific community values knowing more about the 'rules' as it can then lead the way for new technologies which are more sustainable and have less impact on the environment. • An example is the issue of organ transplantation – see the Polo group.	• Link to ACSHE158/192 above • In the article, Christine says "There are rules about how we form, how we interact with the environment, how we age, and we just don't know all of those rules yet there is this whole landscape of discovery to be made." • What does Christine mean by rules? • Why do scientists want to know more about these 'rules'? What do they value? • What are the 'rules' Christine is referring to in terms of cell development? • What role to discoveries play in scientific endeavour? • Are scientific discoveries out there somewhere, waiting to be uncovered? Or, is it the scientists who create and construct the ideas?
Australian Curriculum: Science Understanding (**SU**)	8	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149)	• This video offers the opportunity to consider the important role stem cells play in giving rise to different cell types when a human is first created and how stem cells continue to function with the body to regenerate cells as we live. • Resources for teachers which have specific teaching activities for introducing stem cells: https://stemcellsaustralia.edu.au/	• Learn about the important role stem cells play in creating different cell types. • Navigate to Stem Cells Australia to learn about stem cells: https://stemcellsaustralia.edu.au/ • What are stem cells? What are induced pluripotent stem (iPS) cells? What makes iPS cells so interesting for scientists? • https://www.eurostemcell.org/stem-cell-futures-introduction-ips-cells • Use the activities from ACSHE226 and explore the etymology of various scientific words – and their origins. Being able to break down complex words into smaller words is a critical and creative thinking skill.

	9/10	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175)	• Use the Wells resource at the year 9/10 level as a context for considering the nature of macrophages in the immune system. • In the video Nadia talks about the innate immune system and immune memory. This is a simplified version of a complex system. At this level, the general ideas of cellular recognition (i.e. recognising self) and immune memory can be discussed. • This is a context for unpacking the role of inflammation as an immune response - but also, what can happen when inflammation can become chronic.	• In the video Nadia talks about the memory within the immune system. What does she mean by immune memory? How might immune memory help a person fight disease and stay healthy? • What is the innate immune system? What role does it play within the body? • Inflammation is an essential aspect of the immune system. However, it can sometimes become an issue. Find out more about the role of inflammation and what can happen when the inflammatory response does not work as intended. • What is the difference between acute and chronic inflammation? https://www.health.harvard.edu/staying-healthy/understanding-acute-and-chronic-inflammation (NB when scrolling, the add pops up, just keep scrolling) • https://www.health.harvard.edu/staying-healthy/understanding-inflammation • The Wells lab is working on a way to design and make custom-made macrophage cells. In the context of pro- and – anti-inflammation, how might a custom-made macrophages support somebody suffering from chronic inflammation?
Australian Curriculum: Science - **Science as a Human Endeavour (SHE)**	Unit 2	Working like a scientist And Laboratory structure and staff	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skillsets to advance knowledge. • See section above (red) to draw attention to how the work of scientists is driven by interest and curiosity. Research groups are made up of a number of different people are various stages of their careers.	• See the SHE (RED) section above related to collaboration. • See the SHE (Red) section above related to interest and values. • You have chosen to study biology at the VCE level. What is it about biology that fascinates and interests you? Which area of biology interests you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interest you/ sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why?

				• If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience. • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.

	Unit 2 and 3/4	Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039)
		
		AND
		
		ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068)
			• See ACSHE226 and 135 to unpack the discoveries and new knowledge advancing the field.
			• See ACSHE226 above to explore how significant advances can be made when collaborating.
			• See ACSHE136 as example of the development of an online data base, which uses mathematical skills to analyse and manage large genetic data sets. Without mathematical skills, the scientists would not be able to use the data effectively. Without scientific knowledge, the scientists would not know what the data means. Knowledge and skills from both disciplines are needed to make the most of this opportunity.
				• See activities and links in ACSHE226.
				• Add the following questions to the activities related to the Stemformatics database:
				  ○ Explain why an adult stem cell can be common to multiple different cell or tissue types.
				  ○ How might the protein data be different to the genetic data?
				  ○ Why might there be less protein data than genetic data?
				  ○ How might the lab group be able to make hybrid cells, such as macrophages? Describe a generalised process that would make this possible.

Australian Curriculum: Science - **Science understanding (SU)**	Unit 2	The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)	• See resources above (ACSSU149 and ACSSU175) related to stem cells as valuable cells for development and repair. • Identify how stem cells can lead to specialised cell types.	• Use this context to unpack the nature of cell specialisation and the role that genes would play in that process. • See specific teaching resources above (ACSBL039/069) • In the video Christine says “If you create a cell in a dish how do you know that it shares the same characteristics as a cell from your body? Because it lacks all of the instructions of your body. So, there's a bit of an identity crisis for cells that we create in a dish. So, we use big data, data that captures information about the genes used by that cell to help characterize and benchmarking it against the cells of our body.”

				• Explain what Christine is talking about here. • What does she mean by 'identify crisis'? • Why do the cells lack the 'instructions of the body'? • How might big data help scientists in this scenario?
	Unit 4	All plants and animals have innate (general) immune responses to the presence of pathogens; vertebrates also have adaptive immune responses (ACSBL120) Innate responses in animals target pathogens, including through the inflammation response, which involves the actions of phagocytes, defensins and the complement system (ACSBL121)	• See ACSH175 a context for considering the nature of macrophages in the immune system. • This is a context for unpacking the role of the innate immune system and immune memory (i.e. MHC and memory cells). • This is a context for unpacking the role of inflammation as an immune response and what happens when inflammation becomes chronic.	• See the materials in ACSSU175 above • In the example Nadia uses, explain how the macrophage is able to detect the bacteria as non-self. • How might the Wells group 'designer macrophage' be able to shift from a pro-inflammatory response to an anti-inflammatory response? What changes might need to be made to facilitate this? • What is the difference between acute and chronic inflammation? • Outline the inflammatory immune response –draw a flow chart. • In the video Christine says "Maybe we're going to be developing drug factories that sit under our skin that can make the antibiotics or the vaccines that we need on demand. We could really be shaking up the whole face of medicine just by understanding how to program these cells and treat them as devices in their own right." • What advances would need to be made to enable these mini drug factories? Using your knowledge of genes and the immune system, brainstorm ways this idea might become a reality.

7.5 The Mar Group: Discoveries hidden in big data

Associate Professor Jessica Mar and Dr Atefah Fard

Australian Institute for Bioengineering and Nanotechnology at the University of Queensland

For the past decade scientists have been able to reprogram skin cells, nasal cells and other mature cells to become pluripotent stem cells that can turn into any cell type in the human body. How it works is only starting to become clear. (Page 32, How reprogramming cells turns back time, At the frontier of tomorrow's medicine*)*

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*Discoveries hidden in big data,' or* scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Mar Group research?

- Associate Professor Jess Mar is a computational biologist.
- The computational biologists in Jess' team are trying to understand what is going on with different stem cells, such as what is happening to the stem cells at different stages to figure out specifically which genes and pathways are involved in these sorts of phenomena.

What is the science?

- The computational biology groups, led by Jess Mar, uses statistical models to understand big data and figure out what's going on with stem cells.
- Data gathered from stem cell research can consist of large data sets. Computational biology is the use of statistical and computational models to make sense of this biological data.
- Computational biology can be used to build models using different kinds of statistics about cell growth and development and can be used to address biological questions. This work requires the use and development of technology, such as computer software and hardware.
- Big data sets consist of signal data (desired data that can be used to answer questions) and 'noise' (other data which does not directly assist with answering the question). The computational biologists must work to separate the signal data from the noise data.
- Bioinformatics is "the collection, classification, storage, and analysis of biochemical and biological information using computers especially as applied to molecular genetics and genomics" Reference: https://www.merriam-webster.com/dictionary/bioinformatics

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
  - Need: A lot of data is created during stem cell research. This data can be used to better understand what is happening to cells are they develop and specialise into specific cell and tissue types. Computational biologists are needed to support stem cell biologists as they have specialised knowledge about statistics and other mathematical processes and modelling.

- Interest: Scientists are passionate about science. They are curious and working in science means scientists can apply their curiosity to a range of areas to better understand the world around us. In this case, Atefah is curious about knowing more about the ageing process. Her research is about understanding the processes of diseases which lead to unhealthy ageing. She has a strong desire to know this so that the new knowledge can be applied and more people can experience prolonged healthy ageing.
- Models: Scientists use models to make predictions about how things work, such as the Mar group creating models from stem cell data to make predictions about which genes are responsible during various stages of cell specialisation.
- Collaboration: Working together is essential for science to advance. Being able to communicate well and be on the same page is an important element of working collaboratively.
- Social, cultural and economic influences on scientific research – science involves the use of interdisciplinary skills. In this case, the strong prevalence of mathematics as being essential for working with large biological data sets. More people with quantitative and mathematical skills are needed in STEM disciplines.

Links to the curriculum and suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/ s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: Science as a Human endeavour (SHE)	7-10	Working like a scientist involves qualities, such as curiosity and passion. This drives action and influences why people might choose to pursue a career in the STEM disciplines. And Structure of scientific laboratories and staff	• In the video Atefah Fard talks about her curiosity and passion for science and how science offers an outlet for expressing and applying her curiosity to the world around her. • A sense of curiosity and passion can drive scientists as they feel they can make a positive impact on people's lives through the work they do. • In the video Jess talks about research groups needing people, like interns and research assistants. This is an example of how laboratory groups consist of a variety of people, with a range of skills and experiences. • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.	• In the video, Atefah talks about her passion and curiosity as drivers for why she is a scientist. What is it about her work that helps her express her curiosity? Explain the nature of Atefah's work. Who is her research targeting? How might her research help people? What does Atefah value? • What are you curious and passionate about? What drives you to want to do things or make a change? Are you interested in helping others? If so, where would you like to apply your curiosity? • In the video Jess mentions the lab being interested in taking interns and research assistants (RA's). What is an intern? What is a research assistant? Why are these roles valuable in a laboratory group? Create a list of pros and cons for being an intern or RA in a research group. If you were thinking about becoming a scientist, when might be a good time in an education/work journey to be an intern or RA? During university study? After?
Australian Curriculum:	8	Solutions to contemporary issues that are found using	• Many of the examples in this research focus on the use of stem cells to create biological	• Technology, such as computing hardware and software, enables scientists to work with large data sets.

Science as a Human endeavour (**SHE**)		science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	models for research within a dish. Models of cells or tissues provide researchers with a platform to test drugs, treatment options and to learn about how diseases work. There is another kind of modelling which can be highlighted – data modelling. • The nature of different models in science can be unpacked. For example, physical models (often analogies), conceptual models and predictive models (e.g. mathematical models). • Stem cell research generates large amounts of numerical data. This data can be analysed and used to create models about which genes are being expressed during different stages of cell development. • Technology and science work closely in this example as the technology – such as the computers, hardware and software – enable the storage and manipulation of large data sets which may not be possible without the use of technology. • This case offers an opportunity to make connections between what students know about technology software and hardware and the kinds of technology the lab might use. Students won't necessarily know the exact software brands used by the lab, but they can make connections between basic software functions that they have experienced and the purposed for those programs. For example, Excel is a spreadsheet program which stores and displays data. The program has equation	• Using the video and article, explain how the Mar group are using big data sets. What is it they are trying to find out? How might computer hardware and software support their work? • Jess talks about 'modelling'. What type of modelling might she be referring to when she is a computational biologist? • Scientists use different kinds of models: ○ In your classroom, there may be physical models of phenomena (or posters – which act like models) of various things, such as the human body or cells. These models show us things which might otherwise be difficult to see because they are hidden (in the case of the torso model, we cannot see under our skin) or a cell, as the detail is often not clear on a laboratory microscope. These models are often called 'analogies' as they try to demonstrate something by being like it, but they are not exactly the same. ○ A conceptual model is a way of trying to make sense of a phenomenon by linking related concepts. An example of this could be creating a concept map about the water cycle. ○ Another kind of modelling is predictive modelling, where data is used to make predictions about how things might behave, like the weather. Meteorologists use a number of different data sets to make informed predictions about the weather, such as suggesting a weather forecast for the next few days. These are usually quite predictable but are not necessarily 100% accurate. This is another type of modelling. ○ Jess and her team are using data from stem cell research to create models about how cells become specialised. In particular, they are trying to work out

			functionality and graphing capabilities. Computers have data storage and access to the internet, such as cloud storage, online data bases and sharing platforms, or external hard drives.	which genes are responsible for each stage of the cell specialisation process. This is another example of predictive modelling. • List other models which might fall into one of the three categories of models suggested above. How many can you see around you? How many have you used? • Using your knowledge of computer software and hardware, explain the kinds of programs and hardware items you have used which have helped you to work with different kinds of data. Explain how the Mar group might use similar computer functionality and why the computing technologies would assist the group. Think about software and hardware types.
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226 AND People use science understanding and skills in their occupations, and these have influenced the development of practices in areas of human activity ACSHE136	• The article *Discoveries hidden in big data,'* highlights the need for quantitative analysis skills and collaboration to manage large sets of biological data. • Students may not realise that many different areas of biology research involve the use of data (e.g. fieldwork data, such monitoring abiotic and biotic components of ecosystems can consist of numerical data taken over time). This is an example of how biological research can produce large amounts of numerical data. • Other examples of large data sets within this group of resources is the Wells group and the Polo group. The Ramialison group includes the use of bioinformatics. • Data gathered from stem cell research can consist of large data sets. Computational biology is the use of statistical and computational models to make sense of this	• The video and article *Discoveries hidden in big data,'* highlights the use of large data sets. • What is a large data set? What might the data sets consist of? • In your own words, explain what you think 'Computational biology' means. • What does Jess mean by 'signal' data and 'noise' data? Why is the noise data less desirable? • In the video, Jess talks about getting more data from a lot more patients. Why would more data from a variety of patients be useful for the group? • What challenges would more data present to the group – in terms of analysis, personnel, software and hardware challenges? (see also ACSHE135 above) • Jess says "I think what it means is there's going to be a higher demand for people who have skills in coding statistics, all these kinds of quantitative skills. And we need people to engage more with the stem cell biologist to try to figure out what's going on." What does Jess mean by this statement?

			biological data. Computational biology can be used to build models using different kinds of statistics about cell growth and development and can be used to address biological questions. • Big data sets consist of signal data (desired data that can be used to answer questions) and 'noise' (other data which does not directly assist with answering the question). The computational biologists must work to separate the signal data from the noise data. • In the video, Jess talks about characteristics of effective collaboration: good communication and developing trustworthy relationships – which can lead to people feeling as if they are on the 'same page'. This is an opportunity to unpack the characteristics of effective collaboration and teamwork.	• What are quantitative skills? • Do you like working with numerical data? Why/ Why not? • How might the maths you learn in school be useful for working in a lab like the Mar Group? Which maths might be useful in this case? • Have you learned about coding? Why might coding skills be helpful for the Mar group? • How would you encourage more people to pursue a career in computational biology? • In the video Jess says "People often think about science being a highly technical field, and while that's certainly true, a lot of what it comes down to as well as those human factors of being out of communicate with each other, being able to know that we're on the same page." • What does she mean by these comments? • What are some characteristics of collaboration Jess is talking about in this quote? • Outline a time when you have felt like you were working with other people who were 'on the same page'. How did this influence the group productivity and output? • What are other characteristics of effective collaboration? • If you had to offer advice to somebody working as part of a team, what are your Top 3 tips effectively working as a team?
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community	• See ACSHE134 and 135 above for activities related to models, in particular, the use of mathematical models. • Unpack also the use of technology which enables the use and manipulation of large data sets. • Highlight the prevalence of large data sets in science, in particular, biology. This is beneficial as it can show students the value	• See activities above (ACSHE 135) related to different kinds of models in science: physical (analogy), conceptual and predictive. • See also activities related to mathematical modelling and the use of large data sets in biology, such as the kinds of software and hardware needs. • See ACSHE226 above to unpack the kinds of mathematical processes and technology that would be used by the group.

		ACSHE191 AND Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE158/192)	of mathematics for their future career and highlights the interdisciplinary nature of science (i.e. STEM). • Introduce the term bioinformatics - • For ACSHE158/192- See ACSHE135 and 226 above to explore how technology supports advances in science, such as enabling the collection and manipulation of large data sets.	• See also the questions related to connecting these ideas to what students have done in school (i.e. maths, coding, data manipulation and storage) to show the application of mathematical competencies and skills to other disciplines, such as the use of maths in science. • What is bioinformatics? See https://bioinformaticsreview.com/20181229/bioinformatics-and-stem-cell-research-a-mini-review/ • The article (Discoveries hidden in big data) and the website above mention the transcriptome. What is this? Why is it valuable to researchers? • Using the questions above and the article – which hardware and software capabilities might the Mar group be using? • How would you encourage more people to pursue a career in computational biology?
Australian Curriculum: Science - Science Understanding (SU)	9/ 10	Transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)	• See ACSHE191 and 158/192 above when exploring the transcriptome. This is related to the study of genetics. Bioinformatics is the collection and study of large biological data sets, which consist mostly of molecular data	• Use in conjunction with ACSHE191 and 158/192 above when unpacking gene expression and the use of genes to control how cells develop and specialise. i.e. what is the transcriptome? Why might stem cell researchers be interested in this? How does this relate to the study of bioinformatics?
Australian Curriculum: Science - Science as a Human Endeavour (SHE)	11 (Unit 2)	Working like a scientist - passion and curiosity	• Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. • Use the SHE (red) section above to draw attention to how the work of scientists is driven by passion and curiosity.	• See the SHE (Red) section above related to passion and curiosity as ways people make decisions about their future careers. • You have chosen to study biology at the senior secondary school level. What is it about biology that fascinates and interests you? Which area of biology interest you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/

				sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why? • If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience. • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher.
	Unit 2 and 3/4	Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038) AND Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039) AND ICT and other technologies have dramatically increased the size,	• See also ACSHE135 and 191 above related to models in science. • Mathematical modelling compared to stem cell modelling. Compare the modelling in the Mar group to the Modelling in the Wolvetang group. The Mar group uses computer models of genomic data whereas the Wolvetang groups is creating models of human tissue. Compare and contrast these two kinds of scientific modelling. • Compare this to the use of stem cell created tissues as models in the other research groups described in this resource. • Collaboration: See section ACSHE above to highlight to collaborative nature of scientists' work. Research groups are made up of a number of different people in various stages of their careers. Research groups work together to share knowledge, equipment, ideas and expertise. Working together means that research can occur at a faster rate than if scientists attempted to work alone. • This case offers a context to explore bioinformatics and the use of large data sets	• Compare and contrast the different kinds of modelling in the Mar group and the Wolvetang group. The Mar group is using genetic data to create models of gene expression. The Wolvetang group is creating biological tissue models of cells. • Create a Venn diagram to compare and contrast these two kinds of models. • See other activities above related to creating biological models for research • https://www.eurostemcell.org/new-tools-disease-research-reprogrammed-cells-disease-modelling • Explain why stem cells have changed the landscape of disease modelling. • Look at other examples of disease modelling, such as the Little group (kidney organoids), the Abud group (mini-gut organoids) or the Porrello group (heart tissue). Stem cells are used throughout the examples from different groups as a means of providing a patient-specific model of the disease for exploration in the lab or for testing drug and treatment options. Create a PMI chart to consider the pros and cons of using stem cell created models for disease research. • Bioinformatics is the collection and use of large biological data sets. This case offers a context to explore the use and value of bioinformatics.

		accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068)	for modelling. Use in conjunction with ACSBL081 and 83 below – the context of genetics and use of genetic data for modelling. • See ACSHE135 and 136 related to the use of technology. This is also a context to explore how mathematical skills are used frequently in science (see bioinformatics example). • Highlight the need for people with mathematical skills to pursue careers in STEM disciplines.	• The following link is to an article about the use of bioinformatics in stem cell research. (NB: The link only allows access to the abstract (as the article is copyrighted and needs to be accessed through a subscription. This is not an issue, as the abstract itself is useful at this level as an example). The whole article is a review of the literature related to bioinformatics and stem cells. https://link.springer.com/article/10.1007/s40495-018-0143-4#:~:text=The%20development%20of%20bioinformatics%20tools,differentiation%2C%20and%20cell%20type%20conversions. • Using your knowledge of biology, explain in your own words what the key findings are. • What are the benefits and limitations of induced pluripotent stem cells? • In the video Jess says "I run a computational biology group and my group is interested in using statistical models to understand big data and figure out what's going on with stem cells. Computational biology is using statistical and computational models to make sense of biological data." What kind of statistics might Jess and her team use? What other forms of computer modelling might this group be using to make sense of the biological data sets?
Australian Curriculum: Science understanding (SU)	Unit 3	The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the	• See also ACSHE191 • Use in conjunction with ACSBL038 above • Explore the use of the term 'transcriptome' and how it is related to the study of genetics. • Genes and Ageing: Use the Mar group as a context to look at the notion of specific genes being responsible for certain body processes – such as the ageing process or diseases which might occur during the later stages of life.	• See also ACSHE191 – use the video to unpack the notion of the transcriptome. How is that related to transcription and translation? What might the Mar group be looking for in terms of gene expression? • Genes and ageing: In the video Atefah says "With the help of the analysis that we do, we are able to identify the markers that are driving the aging process and essentially it will help us to identify these markers and the ones that may essentially be involve in initiating disease. So if we can find these markers, we would potentially stop those diseases

		environment (ACSBL081) AND Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth (ACSBL083)	• This case offers an example the use of large genetic data sets (i.e. bioinformatics)	from happening, which would be helping us in prolonged healthy ageing in each and every individual in the community." What does Atefah mean by markers? What might be unhealthy ageing compared to healthy ageing? • Using your knowledge of gene expression, explain how unhealthy ageing might occur and what might cause this process. Atefah talks about 'markers'; what might she be referring to? • In the article "Discoveries hidden in big data", Jess says "The aim is to try to understand which genes and pathways are involved in these sorts of phenomena." What does she mean by this? How might bioinformatics assist with this goal? Why would the field value the skills of computational biologists? • In the article the scientists speak about signal data and noise data. Using your knowledge of genetics, explain what the signal data might be and what the noise data might be.

8. Stem cells and Ethics

8.1 The Munsie Group: Who will help me?

Professor Megan Munsie and Saed Fahd

Stem Cells Australia's Engagement, Ethics and Policy Program at the University of Melbourne

People suffering from serious illnesses are turning to unproven and risky stem cell therapies in growing numbers. Researchers are trying to understand why—and how to provide better information and support. (Page 28, Who will help me? At the frontier of tomorrow's medicine*)*

Accompanying Resources:
Refer to the Stem Cells Australia web page: '*"Who will help me?",'* or scroll through the Australian Stem Cell Research video wall to navigate to a video summary.

What is the focus of the Munsie Group research?

- Professor Megan Munsie leads Stem Cells Australia's Engagement, Ethics and Policy Program at the University of Melbourne. Megan is interested in the implications of stem cell science both in the lab and in the community.
- Professor Munsie is interested in how people view and understand stem cell science but also what rules and regulations should be in place to enable that progress in the field occurs ethically and responsibly.

What is the science?

- Stem cells are often viewed by people as a panacea – that they can fix everything. This is not the case.
- Stem cell therapies that are widely used include bone marrow and cord blood transplants treating leukaemia and other blood diseases (see the Nilsson group) and some eye disorders (see the Pébay group). This is the extent of what is currently possible in terms of tangible and tested therapies.
- Stem cell tourism is trending globally as people seek treatment for otherwise incurable diseases. People are committing thousands of dollars for unproven stem cell treatments. There are widespread reports of patient harm, exploitation and confusion related to current and safe stem cell therapies.
- The tensions around stem cell tourism are that that some doctors, clinics and other stakeholders around the world think that the treatments work (but they have not yet proven through rigorous research that this is the case) or claim that stem cell therapies are able to treat certain disorders (again without rigorous research to support these claims). The issue is that many of these claims have not been subjected to rigours testing or clinical trials and any research findings have not been published via the peer review process.
- Another issue for the field is that doctors and other interested stakeholders are not aware of the current state of stem cell technologies. Increasing awareness and easily accessible

information about what is currently possible and emerging technologies on the horizon, is an aim of Stem Cells Australia.

- Saed Fahd is an Honours candidate who has conducted research with general practitioners related to their understanding of current stem cell technologies and how they address inquiries about stem cell treatments. Saed found that many doctors were not able to respond to patient inquires adequately. This raises concerns about the lack of doctor and patient access to up to date and accurate information about stem cell therapies.

Where is the Science as a Human Endeavour?

- The nature of scientific endeavour, such as:
    - Need: Many people would benefit from stem cell therapies, such as people who suffer from MS and motor neurone disease. Yet the process of translating new stem cell technologies from research through to use of new technologies in a clinical setting takes time.
    - Interest: Scientists are excited, interested and fascinated about their work. In this case Megan is excited by the potential of stem cell therapies and to better understand disease.
    - Value: Megan values helping people avoid misinformation about stem cell therapies. She is concerned about stories of patient harm, exploitation and confusion. This has driven her research about stem cell tourism and effectively disseminating information and educating people about the state of stem cell research.
    - Collaboration: Working together is essential for science to advance. Working with people from other disciplines offers the chance to appreciate and learn from different perspectives and ideas. Scientists work with a variety of people, both locally and globally, to diversify their thinking and perspectives and to have access to resources.
    - Social, cultural and economic influences on scientific research – There is a lot of confusion around the state of stem cell technologies and therapies. This has led to patient exploitation, harm and confusion. Some clinics and medical practitioners act unethically when promising stem cells treatments, which have not been proven effective and safe. This raises concerns about ethical behaviour.

Links to the curriculum and Suggested teaching and learning activities:

Key for curriculum links – The highlighted sections contain questions and activities targeted for the respective year level/s. (NB although the sections are colour coded, some questions may still be relevant for other year levels.)			
Years 7 and/or 8	Years 9 and/or 10	Years 11/ 12	Applicable for any year level

Links to curriculum and key knowledge				
Australian Science Curriculum Area	Year level/s	Australian Curriculum: Science Descriptors	Notes for teachers: Elaboration of key knowledge relevant to the video and/or article/s.	Suggested questions/ activities / links / resources (NB Multiple ideas are offered for teachers to choose from)
Australian Curriculum: **Science as a Human endeavour (SHE)**	7-10	Working like a scientist involves qualities, such as interest, excitement and fascination. And Structure of scientific laboratories and staff	• In the video Megan talks about her excitement and fascination with the development of knowledge in the field of stem cells over the last 20 years. • A sense of interest, excitement and fascination can drive scientists as they feel they can make a positive impact on people's lives through the work they do. • In the video Megan talks about working with people from different disciplines. • The case also highlights the diversity of research groups, which consist of people at different stages of their careers. Saed Fahd is Megan's Honours student. An Honours degree is a yearlong research project which follows an undergraduate degree. This is one form of research degree which can lead to a Master's degree or PhD.	• In the video, Megan talks about her interest, excitement and fascination with stem cell technologies. What is it about stem cells that excites her? • Explain what else interests Megan. What does she focus her research? What does this say about what Megan values? • What are you fascinated about or what new technology excites you? What drives you to want to do things or make a change? Are you interested in helping others? If so, where would you like to address your fascination? • In the video Saed mentions that he is an Honours student. In this resource, there are a number of examples of scientists at various stages of their careers (e.g. Honours, Masters, PhD, research assistants, Research Fellows). How might an Honours project align with other research pathways? Why is this a valuable year for the student and for the research group? • You may like to refer to the companion module on the Stem Cells Australia website, Life as a Researcher for more information about the different levels of qualification within the research profession and the hierarchy within a lab.
Australian Curriculum:	8	Scientific knowledge has changed peoples' understanding of the	• Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available. The area of	• Use the text to the left as an introduction to unpacking how advances in scientific knowledge can be disseminated via organisations like Stem Cells Australia.

Science as a Human endeavour (SHE)		world and is refined as new evidence becomes available ACSHE134	stem cell research has developed considerably over the years. As new knowledge is developed and new evidence is disseminated, understanding about the growth and potential use of stem cells also develops. At the rapid pace this research is advancing, it can be difficult for people outside the field to keep up! • When this happens, it is valuable to have organisations, like Stem Cells Australia, which seek to disseminate new knowledge in accessible ways to educate people and help them locate reliable information. This is particularly useful in the area of stem cell therapies, where the research into new uses of stem cells is rapidly advancing, but these new insights are not as readily being translated into actual treatments. • Students can become familiar with the websites of Stem Cells Australia and Euro Stem Cells to become familiar with these organisations, which are established to form a conduit between research, interested stakeholders and the general public. These organisations rely on structures, such as clear governance models, to ensure they continue to align with their mission goals and values. • This case also offers an opportunity to explore other support organisations, such as MS Australia (see also the Merson group) and MND (see the Pouton Group). A number of other support organisations have been profiled in other Group resources. See for example	• Navigate to the Stem Cells Australia website: https://stemcellsaustralia.edu.au/ • What is the purpose or mission of Stem Cells Australia (SCA)? • Which groups or interested parties do they seek to support? • What kinds of support are available on the website? How might this benefit interest stakeholders? • Another example of an organisation which seeks to disseminate complex research is Euro Stem cells. Navigate to their site. How does their purpose/ mission statement compare to SCA? https://www.eurostemcell.org/ • What are some similarities and differences between the SCA and Euro stem cells websites? • What role do organisations like SCA and Euro stem cells play? How should these organisations be funded? • Look at the governance structure of SCA. • What might be the role of each of the various members/ groups of the governance for SCA? You may need to discuss with others about what you think each of the groups are and what they might do. Explain why these branches are important for SCA. • Why is it important to have a clear governance structure? • In the video Megan says “I think it's very important we have information online that easily accessible. It's got to be written a way people understand, that's useful. And I think we can only do that through co-development with patient groups and with other experts.” In the article, the authors note “The team are working with doctors and patient groups such as Musculoskeletal Australia, MS Australia, MND Victoria and the Chronic Illness Alliance to understand how best to support patients. Support might include resources for GPs and other healthcare professionals, as well as tailored

			• Heart kids – The Ramialison Group • Heart foundation – Chong group • Parkinson's, Huntington's and Alzheimer's – see the Pouton Group resource	patient information provided through community groups and via websites and phone services." • Lean more about these kinds of patient support groups. • Select one of the following support organisations. Navigate to the site and respond to the questions below: • MS Australia: https://www.msaustralia.org.au/ • MND Australia: https://www.mndaust.asn.au/Home • The Heart Foundation: https://www.heartfoundation.org.au/ • NB See others in the resources listed to the left OR offer student choice to find a support organisation for a disease they are familiar with. • What is the purpose of this organisation? Who do they seek to support? What support services does the organisation offer? Do they have an area on the site which disseminates the latest research? What are some benefits and limitations of this information? Who does the organisation collaborate with? How is the organisation funded?
	8	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations ACSHE135	• Stem cells offer hope to people who are suffering from diseases which currently have no cure or lack effective treatment options. As outlined above (ACSHE134), it takes time to move new knowledge from the laboratory to the clinic. Although research offers the potential to treat a myriad of diseases, the reality, in terms of clinical options, is quite different. • The Munsie group offers a context for unpacking how research and clinical treatment options are often not aligned. Media outlets often report new and significant research findings, which may one	• Read the article "Who will help me?" • Possible uses of this article: ○ In 1 sentence explain the main point of the article. ○ Unpack the key issues outlined in the article. ○ Why might people be prepared to pay or travel overseas for stem cell therapies? ○ Read the box "What's the harm? - Why might people outlay large amounts of money for stem cell therapies? Why was Alistair frustrated? What is fraud? ○ Why might untested stem cell therapies be dangerous for patients? ○ What is the Munsie group research focus? ○ What does the Munsie group value?

			day lead to treatment options. However, as beneficial as it is to communicate new knowledge, it may cause confusion as to what is actually possible for patients in terms of treatments. • The article "Who will help me?" highlights the real and progressively more common realities of stem cell tourism gone wrong. This offers the opportunity to have discussions about the ethical implications of stem cell research. • This case also highlights the need for regulation in the field of medical research and practice.	○ Why might the Munsie group and organisations like SCA work with patient support groups? ○ What is a strength of interdisciplinary collaboration? • Consider the ethical implications for untested stem cell therapies. Unpack this by first considering the perspectives from each of the stakeholders below. List the benefits and limitations of each position: ○ Patients ○ Parent, partner or child of the patient ○ The patient's GP ○ The clinic offering the stem cell therapy ○ Stem cell scientists • Consider the following scenario: A patient has travelled overseas and paid $25,000 for an untested stem cell therapy. What might the patient say and do if the treatment is successful? What might the patient say or do if the treatment is unsuccessful? What might be implications for each of these positions? • Regulation of stem cell therapies: In the video Megan says "So my research really focuses around how people view and understand stem cell science but also what rules and regulations should be in place to enable progress in the field occur ethically and responsibly." What does Megan mean by 'rules and regulations'? What kinds of rules and regulations do you think would be necessary in the field of stem cell therapies to treat disease? • What is the Therapeutic Goods Administration (TGA)? What is the purpose and role of this organisation? • Before induced pluripotent stem (iPS) cell technology was developed, pluripotent stem cells were derived from excess human embryos, which remained after IVF treatments. iPS cell technology revolutionised the process of obtaining undifferentiated stem cells. Why might embryonic stem cells have been controversial? To find out what was permissible in

				terms of the use of embryonic stem cells, navigate to the Australian Law reform Commission. https://www.alrc.gov.au/publication/genes-and-ingenuity-gene-patenting-and-human-health-alrc-report-99/15-stem-cell-technologies/stem-cell-research-in-australia/ • Read from article 15.20. NB ART = assisted reproductive technology (otherwise known as IVF).
	8	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures ACSHE226	• In the video, Megan talks about the benefits of working with people in other disciplines, such as social sciences. This is an example of how working with people from other disciplines can advance knowledge by offering alternate perspectives. • Collaboration within research labs is important. Use this example to focus on Saed Fahd and his Honours project. See the red (SHE) section above to have students think about collaboration within teams, with a focus on research students.	• In the video Megan says "I've certainly learned a lot from my colleagues in humanities and social sciences. And I found it extremely rewarding and fundamentally it's challenged what I think and how I act. So, it's really changed my practice. And in the process, we've, I think, made some really unique contributions ourselves to the scholarship by combining forces, combining expertise and experience. And I'm really proud of the work that we've been able to achieve." What does Megan mean by these comments? How has collaboration been beneficial for Megan? • What makes the humanities and social science different from the pure sciences? It might help to draw up from strengths and limitations for the HASS (Humanities and Social Sciences) disciplines and then the science disciplines. Think about the nature of the work you do in each of these disciplines at school. What skills do you develop in these subjects at school? How are they different? Similar? • Why might it be beneficial (and limiting) for people from these disciplines to work together? • Teamwork/ collaboration: Outline a time when you have felt like you were working well with other people. What were the conditions when enabled you all to work well together? This could be things like listening, not being judgemental etc. How did this influence the group productivity and output? • What are other characteristics of effective collaboration?

				• If you had to offer advice to somebody working as part of a team, what are your Top 3 tips effectively working as a team?
	9 & 10	Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community ACSHE191 AND People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities ACSHE160/194	• See ACSHE134 above for activities related to change in knowledge over time. • Use this case to highlight the need for regulation around stem cell therapies. This relies on conventions, such as the process of peer review of the research on the effectiveness of clinical trials associated with stem cell therapies. • Issues with authentication of information from clinics and practitioners can arise when there is a lack of regulation and rigorous, published research to support claims made by clinics and medical practitioners about the effectiveness of stem cell treatments. • This is an opportunity to become familiar with the process regulation as a way of minimising risk for patients. • NB The Euro Stem cell cite has a number of pages devoted to ethics and regulation of a variety of stem cell topics. See for example: https://www.eurostemcell.org/regenerative-medicine-society/clinical-translation-and-innovation	• See activities above (ACSHE134) related to knowledge changing as new evidence becomes available. • Navigate to the Euro Stem cells page related to regulation of stem cell therapies: https://www.eurostemcell.org/regenerative-medicine-society/policy-and-regulation • Using the section "Risk V Access": • Clinical trial data has been a common way of judging effectiveness of new treatments. What is a clinical trial and why is it useful? • Why is there a push to move away from relying solely on clinical trial data? • What is meant by 'evidence' in this article? Why is evidence so important in science? In clinical trials? • What are the benefits and limitations of new regulations, according to Dr Hogle? • What are other forms of evidence being considered? Why might these be useful data sets alongside clinical trial data? • How do the new regulations seek to reduce patient risk?
		Values and needs of contemporary society can influence the focus of scientific research ACSHE228/230	• The health and wellbeing of people is highly valued. Laws and guidelines are established to ensure people are treated with respect. This is valued by the community. This case offers an opportunity to explore new regulations which have been introduced	• See ACHSE135 above – the introduction of new regulations for stem cell therapies. (see ACSBL041 below to extend the above activities for year 9 and 10). • Use in conjunction with ACSHE191 above. • In the video Megan says "A really big part of my role is to talk about what we do. It's to not just educate people that to

			around stem cell therapies. This is an example of how research has influenced the creation of guidelines to protect patients from harm, exploitation and confusion. • Megan emphasises that an important part of her role is to listen to patients about their needs and hopes. This shows value for the patient voice.	listen about what they're interested in finding out. I don't think it's enough just to go out there and talk about what we do. I think we have to hear why people perhaps are concerned or why they have their hopes invested in this area and perhaps have a bit of a conversation around where actually at." • What does Megan mean when she says that listening is an important part of her job? What does this say about what she values?
Australian Curriculum: Science as a Human Endeavour (SHE)	11 (Unit 2)	Working like a scientist - interest, fascination and excitement And Pathways to becoming a scientist	• Use the SHE (red) section above to draw attention to how the work of scientists is driven by interest, fascination and excitement. • Scientific endeavour involves collaboration for scientific advancement. It takes a number of different people, each with unique skill sets to advance knowledge. See the section above related to the Honours year as a pathway towards becoming a scientist. • You may like to refer to the companion module on the Stem Cells Australia website, Life as Researcher for further information regarding an Honour's year and other researcher positions and pathways.	• See the SHE (Red) section above related to interest, fascination and excitement as being influential on why people make decisions about their future careers. • You have chosen to study biology at the senior secondary school level. What is it about biology that fascinates and interests you? Which area of biology interests you the most? Would you consider pursuing a career as a research scientist? Why, why not? Which aspects of the job interested you/ sound like you and which aspects do not interest you/ do not sound like you? Which area of research would you be interested in working? Why? • If you wanted to become a scientist, what would your preparation pathway entail? Consider undergraduate and post graduate study and experience. • Compare the benefits and limitations of the three research degrees that can be undertaken to become a scientist: Honours (1 year), Masters (2 years) and a PhD (which can take 3-4 years). List benefits and limitations for each. • Use the following website for more information about these three research pathways. https://www.graduatecareers.com.au/postgraduate-study/ • Why might an Honours year be valuable for a person who wants to become a scientist? • What skills would you associate with science-based research? Why might it take years to develop some of these skills?

	Unit 2	Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL037)	• This is an opportunity to become familiar with the process of regulation as a way of minimising risk for patients. There are conventions related to how science is translated from the lab into the clinic. This process is often time consuming and heavily regulated through research practices and guidelines. This is an opportunity to highlight the nature of this regulation, even if just to help students appreciate that that regulation exists. • See ACSHE191 above • Also see ACSBL041 below	• See activities in ACSHE191 above • See also activities in ACSBL041 below
	Unit 2	The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)	• See also ACSHE135 and 191 above related ethical consideration (use also in conjunction with ACSBL041 and 71 below) • Collaboration: See section ACSHE above to highlight to collaborative nature of scientists' work. Research groups are made up of a number of different people at various stages of their careers. Research groups work together to share knowledge, equipment, ideas and expertise. Working together means that research can occur at a faster rate than if scientists attempted to work alone.	• Before induced pluripotent stem (iPS) cell technology was developed, pluripotent stem cells were derived from excess human embryos, which remained after IVF treatments. iPS cell technology revolutionised the process of obtaining undifferentiated stem cells. Why might embryonic stem cells have been controversial? To find out what was permissible in terms of the use of embryonic stem cells, navigate to the Australian Law reform Commission. https://www.alrc.gov.au/publication/genes-and-ingenuity-gene-patenting-and-human-health-alrc-report-99/15-stem-cell-technologies/stem-cell-research-in-australia/ • Outline what was permissible under the terms of this regulation document. • Why might these guidelines be structured in this way? Who is the regulation aiming to protect and why?

	Unit 2, 3 and 4	The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041) AND People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSBL01)	• The health and wellbeing of people is highly valued. Laws and guidelines are established to ensure people are treated with respect. This is valued by the community. This case offers an opportunity to explore new regulations which have been introduced around stem cell therapies. This is an example of how research has influenced the creation of guidelines to protect patients from harm, exploitation and confusion. • Use this case as a context to explore how scientific knowledge has been applied to the area of stem cell therapies to calculate and reduce risk to patient health and wellbeing. • See examples of patient support groups in ACSHE134 as a way of highlighting how scientific knowledge has been used to create organisations which seek to support people who are affected by disease. These organisations play a very important role in helping to educate and support people to minimise uncertainty, risk and to avoid harmful consequences. • See also ACSHE191 above related to risk and regulations • NB The Euro Stem cell cite has a number of pages devoted to ethics and regulation of a variety of stem cell topics. See for example: https://www.eurostemcell.org/regenerative-medicine-society/clinical-translation-and-innovation	• Changes in stem cell therapy regulations to minimise risk to patients. • Regulation of stem cell therapies: In the video Megan says: "So my research really focuses around how people view and understand stem cell science but also what rules and regulations should be in place to enable progress in the field occur ethically and responsibly." What does Megan mean by 'rules and regulations'? What kinds of rile and regulation do you think would be necessary in the field of stem cell therapies to treat disease? • What is the Therapeutic Goods Administration (TGA)? What is the purpose and role of this organisation? • Use the link in the article to navigate to the site which outlines the specific changes regulation of stem cell products - The Department of Health TGA website: https://www.tga.gov.au/media-release/regulation-autologous-cell-and-tissue-products • Outline the 3 proposed changes to the regulation of autologous cell and tissue products. Why might these changes protect patients and reduce risk? • How has scientific knowledge been applied to create these new regulations?

Appendix: Overview of links to the curriculum

Code	Year Level	Descriptor	The Heart	Ramalison Group	Powell Group	Porrello Group	Palpant Group	Harvey Group	Chong Group	The Neural system	Bourne Group	Pouton Group	Merson Group	Parish and Thompson Group	The Eye	Pebay Group	Watson and Di Girolamo Group	O'Connor Group	The Kindey	Little Group	The Blood	Elefanty Group	Nilsson Group	The Gut	Abud Group	Repogramming and Pluripotency	Laslett Group	Wolvetang Group	Polo Group	Wells Group	Mar Group	Ethics and Stem Cells	Munsie Group
		Lab structure and staff		1				1	1		1	1				1	1	1		1			1				1							
		Interest, agency, passion, value, asking questions, creativity		1	1	1	1		1		1	1	1			1	1	1				1	1		1		1	1	1	1			
134	Year 8 SHE	ACSHE119/134 Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available			1	1	1	1	1		1	1	1	1		1	1	1		1				1		1	1	1					1
226		ACSHE223/226 Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures		1	1	1	1	1			1	1		1		1	1	1		1		1					1		1	1			1
135		ACSHE120/135 Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations		1	1	1		1	1		1	1	1	1		1	1	1		1		1	1		1		1	1		1	1		1
136		ACSHE121/136 People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity		1			1				1	1	1				1			1						1	1	1	1	1			
149	Year 8 SU	Cells are the basic units of living things; they have specialised structures and functions (ACSSU149)			1	1	1	1	1			1	1	1		1	1	1		1		1	1		1			1	1	1			
150		Multi-cellular organisms contain systems of organs carrying out specialised functions that enable them to survive and reproduce (ACSSU150)				1		1	1		1	1				1	1	1		1		1	1		1		1						

157/19	Year 9 and 10 SHE	ACSHE157/191 Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community		1							1	1	1	1		1		1		1		1	1				1	1	1		1		1
158/19		ACSHE158/192 Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries		1	1	1	1	1	1				1			1	1	1		1			1		1				1	1	1	1	
160/19		ACSHE160/194 People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities														1	1			1													1
228/23		ACSHE228/230 Values and needs of contemporary society can influence the focus of scientific research		1	1	1	1	1	1		1	1	1	1		1	1			1					1		1		1	1			1
175	Year 9 and 10 SU	Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (ACSSU175)			1	1	1	1	1		1	1	1	1		1	1	1		1		1	1		1			1	1	1			
118		An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by synapses (VCSSU118)									1	1	1	1													1						
184		Transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)			1		1									1										1					1		
37		Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL037)		1												1					1				1		1				1		

38	Unit 1 and 2 SHE	Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)		1	1		1		1		1	1						1		1		1	1				1	1	1		1				
39		Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039)				1		1									1			1					1				1	1	1	1			
40		The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)								1	1		1														1								1
41		The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)				1		1	1							1			1					1				1	1					1
42		Scientific knowledge can enable scientists to offer reliable explanations and make reliable predictions (ACSBL042)		1																														
43		Scientific knowledge can be used to develop and evaluate project ed economic, social and environmental impacts and to design action for sustainability (ACSBL043)						1	1					1				1			1													
49	Unit 2 SU	In eukaryotic cells, specialised organelles facilitate biochemical processes of photosynthesis, cellular respiration, the synthesis of complex molecules (including carbohydrates, proteins, lipids and other biomacromolecules), and the removal of cellular products and wastes (ACSBL049)																						1										
54		Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs and systems (ACSBL054)								1	1		1																					

55		The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)		1		1	1	1	1		1	1	1	1		1	1	1		1		1	1		1		1	1	1	1			
58		In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of capillaries) (ACSBL058)		1		1	1	1	1											1													
62	SIS	SIS - • Design investigations, including the procedure/s to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics, including animal ethics (ACSBL062)								1																							
68	Unit 3 and 4 SHE	ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068)		1	1	1	1																				1		1	1			
71		People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSBL071)																															1
73		International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)		1	1	1	1																				1						
74		Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL074)														1				1													

75		Continuity of life requires the replication of genetic material and its transfer to the next generation through processes including binary fission, mitosis, meiosis and fertilisation (ACSBL075)																								1									
78	Unit 3 SU	Genes include 'coding' and 'non-coding' DNA, and many genes contain information for protein production (ACSBL078)		1	1		1																				1								
79		Protein synthesis involves transcription of a gene into messenger RNA in the nucleus, and translation into an amino acid sequence at the ribosome (ACSBL079)																								1									
80		Protein structure and function (ACSBL080)						1	1																	1									
81		The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment (ACSBL081)		1				1																				1	1			1				
82		Mutations in genes and chromosomes can result from errors in DNA replication or cell division, or from damage by physical or chemical factors in the environment (ACSBL082)																											1							
83		Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth (ACSBL083)		1																								1				1				
86		DNA sequencing enables mapping of species genomes; DNA profiling identifies the unique genetic makeup of individuals (ACSBL086)			1		1																					1								
87		Biotechnology can involve the use of bacterial enzymes, plasmids as vectors, and techniques including gel electrophoresis, bacterial transformations and PCR (ACSBL087)													1				1																	

110	Unit 4 SU	Homeostasis involves a stimulus-response model in which change in external or internal environmental conditions is detected and appropriate responses occur via negative feedback; in vertebrates, receptors and effectors are linked via a control centre by nervous and/or hormonal pathways (ACSBL110)								1			1																				
112		Neural pathways consist of cells that transport nerve impulses from sensory receptors to neurons and on to effectors; the passage of nerve impulses involves transmission of an action potential along a nerve axon and synaptic transmission by neurotransmitters and signal transduction (ACSBL112)								1			1																				
113		Hormones alter the metabolism of target cells, tissues or organs by increasing or decreasing their activity; in animals, most hormones are produced in endocrine glands as a result of nervous or chemical stimulation, and travel via the circulatory or lymph system to the target cells, tissues or organs (ACSBL113)																				1											
120		All plants and animals have innate (general) immune responses to the presence of pathogens; vertebrates also have adaptive immune responses (ACSBL120)																												1				
121		Innate responses in animals target pathogens, including through the inflammation response, which involves the actions of phagocytes, defensins and the complement system (ACSBL121)																												1				