Regenerative medicine
INTRODUCTION TO THE GUIDE

RiAus PDplus Teacher Notes are a new initiative of RiAus, designed to assist early high school (Years 7–9) teachers engage and involve their students.

The notes supplement a PDplus presentation hosted by RiAus on regenerative medicine, that will allow teachers to have access and put questions to scientists about their research and careers.

See the RiAus website for further details and footage. www.riaus.org.au

OTHER RIAUS PDPLUS TEACHER NOTES


HOW TO USE THE GUIDE

The notes offer both variety and flexibility of use for the differentiated classroom. Teachers and students can choose to use all or any of the five sections – although it is recommended to use them in sequence, and all or a few of the activities within each section.

THE ‘FIVE Es’ MODEL

The guide will employ the ‘Five Es’ instructional model designed by Biological Sciences Curriculum Study, an educational research group in Colorado. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience. Its components are:

- **Engage** Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.
- **Explore** Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.
- **Explain** This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations given to models and theories.
- **Elaborate** Students develop a deeper understanding of sections of the topic.
- **Evaluate** Teacher and students evaluate what they have learned in each section.
Regenerative medicine

It’s been a common theme of science fiction for decades – the lone scientist striving to grow human body parts in the laboratory. But, will new research finally make regenerative medicine a reality?

The development of a complete human from a tiny embryo is undoubtedly one of nature’s most miraculous occurrences. Can scientists apply the same principles to grow replacement human body parts in the laboratory? Welcome to the world of regenerative medicine, a fascinating research area that explores the possibilities of regrowing human body parts. It opens the door to a raft of radically new products and therapies with the potential to transform medicine as we know it.

**WHAT IS REGENERATIVE MEDICINE?**

Regenerative medicine aims to renew or replace cells in human tissues and organs that have been damaged and lost function due to injury or illness. This can be achieved by encouraging the body’s own cells to heal, or by treating a patient with laboratory grown cells and tissues. Potentially, entire organs could be generated for transplantation, making today’s shortage of suitable organ donors a problem of the past.

**HOW DO NEW CELLS GROW?**

All multicellular organisms, including humans, have some capacity for regeneration. In our bodies, new cells grow continuously in many tissues, replacing older cells as they age and die. Cells divide by the process of mitosis, which involves replication of the chromosomes, then division of the cytoplasm to form two identical daughter cells.

**WHAT ARE STEM CELLS?**

Central to the regeneration process are stem cells. These can develop into different kinds of specialised cells. In the human body, there are hundreds of types of specialised cells, all arranged into organs and systems that perform different functions. All of these specialised cells developed originally from stem cells. There are three kinds of stem cells: adult stem cells, embryonic stem cells (ES), and induced pluripotent stem cells (iPS).

**ADULT STEM CELLS**

In an adult, every organ and tissue type has its own adult stem cells. Unlike an embryo’s stem cells, adult stem cells can only develop into organ-specific cells. For example, a kidney adult stem cell can only develop into new kidney cells (of which there are 26 types!). When a body part is injured – for example, skin is burned - adult stem...
cells in that area produce the new cells to replace the damaged tissue. But, if the
damage is too severe and the skin’s adult stem cells are affected, the injury may
be irreparable.

In some organs, such as the gut and bone marrow, stem cells regularly divide
to repair and replace worn-out or damaged tissues. In other organs, such as
the pancreas or heart, stem cells only divide under special conditions. In the
laboratory, adult stem cells have been used to grow specific tissues, such as skin
for grafts, and parts of the bladder.

**EMBRYONIC STEM CELLS**

After conception, a fused egg and sperm evolve into a highly organised group
of cells called the blastocyst that later develops into an embryo. The blastocyst
consists of only a few cells, yet ultimately gives rise to an entire organism. This
means blastocyst cells must have the potential, or potency, to develop into the
hundreds of different cell types that make up the human body. These cells within
the blastocyst, referred to as embryonic stem cells (ES cells), are therefore
described as ‘pluripotent’.

Over a decade ago, scientists successfully isolated ES cells from human embryos
left over from a procedure of artificial insemination and donated for research
purposes. In theory, any human tissue can be grown from ES cells, and so these
cells have enormous scientific and therapeutic potential in the field of regenerative
medicine. However, ethical issues have restricted their use dramatically to date.

**INDUCED PLURIPOTENT STEM CELLS**

The pluripotent nature of a stem cell depends on the presence of a small number
of specific genes. Scientists have recently found a way to insert these genes into
a fully grown adult cell, making it capable of once again of differentiating into any
kind of tissue, just like an embryonic stem cell. These
genetically modified cells are called induced pluripotent
stem cells (iPS cells).

iPS cells constitute a major breakthrough in the field
of regenerative medicine. They are the basic, albeit
artificially created, building block of the human body.
Exposed to certain conditions in the laboratory, iPS
cells can give rise to all cell types, tissues, and in theory
entire organs.

**WHAT CAN REGENERATIVE MEDICINE ACHIEVE?**

Hopes for the medical applications of stem cells are
high. With their ability to develop into any kind of cell
in the body, stem cells hold huge potential to treat a
range of human diseases and conditions, including
heart disease, Alzheimer’s, spinal cord injury, stroke,
burns, diabetes and arthritis.

At present, iPS cells are being used to model diseases
for research and drug development purposes. If a
disease affects a particular cell type, it can be very
accurately modelled by growing exactly this type of
cell from the affected patient’s iPS cells.

In a more futuristic scenario, tissues destroyed due
to degenerative diseases, such as Parkinson’s disease
or juvenile diabetes, could be replaced by growing
the required type of cells from the individual’s own
iPS cells. Where a genetic fault is known as the

human ES cell research: topic
heatedly debated in 2004 and
2008 U.S. presidential elections.

**2007** Key genes identified
that define a stem cell; the finding
generates research to produce
the first induced pluripotent stem
cell (iPS cell) from adult cells,
first in mice and then in humans.
Studying human iPS cells offers
an alternative to ES cells that
avoids many of the surrounding
ethical issues.

**Today** IPS research expanding
rapidly, with numerous diseases
successfully modelled in
laboratories. Questions on future
iPS cell use in patient therapy,
including safety concerns, remain.
cause of a disease, this fault may be corrected in the newly grown cells, not only replacing the damaged tissue, but curing the patient permanently.

Due to their patient-specificity, tissues grown from iPS cells would not be rejected by the body’s immune system, which explains why these cells hold great future promise in the field of organ transplantation.

**LIMITATIONS OF REGENERATIVE MEDICINE**

Due to the considerable ethical restrictions of using ES cells for research, iPS cells are currently considered to be the best available tool in regenerative medicine.

Laboratories around the world are constantly improving techniques for the generation of iPS cells, and attempts to grow different tissues and organs are well under way. However, since iPS cells are genetically modified, thorough investigations regarding their safety are necessary before they can be used for patient therapy in the form of tissue replacement.

There is little doubt that regenerative medicine offers exciting promise for the future. However, significant technical and ethical hurdles remain that will need to be overcome if we are to see it reach its full potential.

**Websites**

**TECHN YOU SCIENCE EDUCATION RESOURCE ON STEM CELLS**


**AUSTRALIAN REGENERATIVE MEDICINE INSTITUTE**


**CALIFORNIA INSTITUTE OF REGENERATIVE MEDICINE**

[www.cirm.ca.gov](http://www.cirm.ca.gov)

**INTERNATIONAL SOCIETY FOR STEM CELL RESEARCH**

Stem cell classroom: [www.isscr.org/stem_cell_classroom.htm](http://www.isscr.org/stem_cell_classroom.htm)

**REGENERATIVE MEDICINE PARTNERSHIP IN EDUCATION (DUQUESNE UNIVERSITY)**

[http://sepa.duq.edu](http://sepa.duq.edu)

**A TEACHER’S GUIDE TO STEM CELLS**

[www.pbs.org/wgbh/nova/teachers/viewing/3209_04_nsn.html](http://www.pbs.org/wgbh/nova/teachers/viewing/3209_04_nsn.html)

**STEM CELLS AUSTRALIA**

[www.stemcellsaustralia.edu.au/](http://www.stemcellsaustralia.edu.au/)

**ETHICAL ACTIVITIES AROUND STEM CELLS**


**ABC TV SHOW ‘CATALYST’ STEM CELL SPECIAL**

[www.abc.net.au/catalyst/stemcells/](http://www.abc.net.au/catalyst/stemcells/)
OUR BODY IS NOT always able to repair major injuries. For example, some large fractures of the bones never heal. In such cases, treatment with stem cells can help the natural body repair system. Stan Gronthos and his colleague Andrew Zannettino, working at the Department of Haematology SA Pathology, developed a method for isolating purified bone-cell progenitors, or adult stem cells, from human bone marrow. This patented technology was developed with their commercial partner, Mesoblast Ltd, to isolate bone cell progenitors from a patient’s own bone marrow, which were then grown in the laboratory and delivered to the fractured bones.

“Over time, we can get the bones fusing together,” said Gronthos. The stem cells not only multiply and differentiate into bone tissue, they also produce molecules that moderate inflammation in the injured limb and, most importantly, stimulate the growth of blood vessels, which can then supply the regenerating tissue.

What makes these cells particularly interesting is the fact that they are also efficient for the treatment of patients suffering from severe heart failure. “We’ve delivered some of these stem cells into the hearts of patients and that’s generated new blood vessel formation, decreased fibrosis and increased heart function,” reported Gronthos. This is possible because of the adult stem cells’ ability to secrete anti-inflammatory and blood-vessel-attracting growth factors, which they retain no matter where they are growing. Importantly they cannot form any other tissue such as bone or cartilage in the heart, because the cells require the right environment and factors to form skeletal tissue.

EVEN MORE FLEXIBLE are embryonic stem cells that have the ability to differentiate into nearly any tissue of the body. While there have been ethical issues associated with the use of these cells, which are taken from developing embryos, researchers are now able to genetically reprogram adult cells to become just like embryonic stem cells. But even these new cells, called ‘inducible pluripotent stem cells’ need to be placed under the right conditions to develop into a specific tissue type.

Trying to find out exactly which signals guide the differentiation of stem cells has been the focus of most intensive research during the last decade, said Gronthos. Some successes have been made in this area and some of the key factors necessary to push the cells towards some general tissue types are now known. But scientists still don’t understand the full details of this process. It is this lack of knowledge that still hampers the use of stem cell therapies. Unlike adult stem cells, which are restricted to developing into certain tissue types only, embryonic and pluripotent stem cells “have the potential to form tumours,” warned Gronthos. “That’s one of the limitations of that technology, trying to convert all the cells into safe, mature cells and not leave any primitive cells around if you’re putting them into someone’s body.”

For the future, Gronthos hopes to be able to use cells from a donor to treat another patient. “When patients come in with some major trauma, a doctor [could] simply go to the freezer, pull out an ampoule of stem cells and treat the patient,” he said. Currently it takes up to six weeks until a patient’s own stem cells are extracted, processed and grown up. Here, too, the secretion of anti-inflammatory and immunosuppressive molecules by the stem cells may be helpful and protect the foreign cells from being rejected by the body. – Achim Eberhart
[Task] Home-grown

Imagine if we could regenerate (grow back) any part of our body. We could have new limbs, new eyes, new lungs and new hearts whenever we needed them. If we had this ability, do you think we would live our lives the same way as we do now? How might it change the way we behave? Do you think some of us might take more risks? Might we have different expectations of life itself? What could be the applications to health and medicine, industry and other areas?

Get into teams of three or four to brainstorm this hypothetical situation. Each team could represent a different group in society, such as:

- doctors
- people with medical conditions, e.g. diabetes, heart or bone conditions
- Government officials such as policy makers
- owners of a company that sells the technology to enable regeneration
- owners of a nursing home
- athletes
- members of an ethics society
- stem cell researchers who use stem cells to grow human skin

1. Brainstorm your group’s attitude to regeneration of human body parts, and how it might be a good or bad thing for them. Record your ideas on a piece of paper to contribute to the class discussion.

2. Come together as a class and record the thoughts and ideas that each group came up with in their brainstorms. Discuss your reactions to these different viewpoints.

3. Move on to a discussion about what you know about regenerative medicine - the reality of what is actually possible today, and what may become possible soon.

4. Make a record in your work book of at least three questions you would like to know the answers to by the end of this unit.
Teacher’s information

The aim of the Explore section is for students to investigate some of the ideas around regenerative medicine. It is intended that the students make their own discoveries as they work around the stations in the room.

The table below lists the materials and preparation required for each station.

<table>
<thead>
<tr>
<th>Station</th>
<th>Materials needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Organs and cells</td>
<td>3-D model of the human body, showing the different organs. Microscopes and prepared slides of human tissues e.g. kidney, brain, heart.</td>
</tr>
<tr>
<td>3. Human spare parts</td>
<td>Current technology, for example a hearing aid, eye glasses, contact lens, and/or artificial limbs and joints if available (try your local hospital).</td>
</tr>
<tr>
<td>4. Making cells</td>
<td>A computer to access: <a href="http://www.ns.umich.edu/stemcells/022706_Intro.html">www.ns.umich.edu/stemcells/022706_Intro.html</a> Plasticine (or equivalent) to make models of the cells.</td>
</tr>
<tr>
<td>5. In the news</td>
<td>[optional] Local newspaper articles related to regenerative medicine, to supplement those supplied.</td>
</tr>
<tr>
<td>6. Regeneration in nature</td>
<td>[optional] Parts of animals that have been shed and re-grown (e.g. snake skin, feathers) to supplement pictures supplied.</td>
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</tbody>
</table>
Explore (student activities)

Station 1

**[Task] Video clips**

Watch these short videos to find out about regenerative medicine and discover the world of possibilities opening up through this field of research. After watching, answer the following questions in your work book.

www.youtube.com/watch?v=QI-S2po5CAM (2 mins 30 secs)

www.wakehealth.edu/Research/WFIRM/Fast-Facts-and-Video/Regenerative-Medicine-101.htm (1 min 45 secs)

www.youtube.com/watch?v=n4gEnpEL_M&feature=player_embedded (4 mins 45 secs)

1. What amazed you when watching these videos?
2. What did you learn that you didn’t know before?
3. Write a question you have after watching these videos, which could help you learn more about regenerative medicine.

Station 2

**[Task] Organs and cells**

Complete the following activities relating to organs and cells of the human body.

Examine each of the prepared slides of human body cells. Fill in the table to record information about each cell type, and make a biological drawing of each (choose a single cell), showing its shape, cell membrane, cytoplasm, nucleus and any other organelles you can identify. Remember to use pencil and provide the magnification (look at the objective lens of the microscope).

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Biological drawing of cell</th>
<th>Organ cell comes from</th>
<th>Function of organ</th>
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</thead>
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<tr>
<td></td>
<td>Magnification:</td>
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1. Look at the model of the human body and locate the organs from where the cells you looked at came from (e.g. if you looked at kidney cells, find the kidneys). Think about the main function(s) each of these organs performs in the human body. Make sure you have recorded this information in the table.

2. Suggest why the cells you examined under the microscope look so different to one another.
Station 3

[Task] Human spare parts

Look at the provided examples of technology we use today when parts of our bodies no longer work properly. (Some of these things could be considered ‘human spare parts’!) Complete the following activities in your work book.

Record some observations about the technology provided, using the table below.

<table>
<thead>
<tr>
<th>Name of technology</th>
<th>Which body part does it relate to?</th>
<th>Purpose of technology</th>
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Do you think the technology we use today when parts of the body don’t work properly is adequate? Does it need to be improved? Why/why not? Don’t forget to use examples in your answer.

Use your imagination to think up one example of a piece of technology that may become available in 10 or 20 years’ time, to replace technology we use today. Describe your idea – include a drawing if it helps you explain what part of the body it assists or replaces.

How does today’s technology compare to what you have imagined might become available? Are there any similarities? What are the main differences?

Station 4

[Task] Making cells

Complete the following activities to learn more about human cells.

Go to www.ns.umich.edu/stemcells/022706_Intro.html and click on the tab ‘Stem Cells Defined’ to find out about stem cells and how they develop into the hundreds of specialised cells of the human body.

Use the provided plasticine (or equivalent material) to model different types of human cells.

a) Take a small, fist-sized lump of plasticine each. This represents an embryo.

b) Divide your lump up into about five evenly sized portions – each of these represents an embryonic stem cell.

c) Decide which type of specialised cells your stem cells will form (e.g. nerve cells, red blood cells, skin cells) then model these cells. Note: If you don’t remember what the different types of cells look like, just make up your own differently shaped cells.

d) Now that your ‘stem cells’ have developed into specialised cells (this process is called cell differentiation), each of these specialised cells will divide to form more of the same type of cell (this is cell division). Take each of the specialised cells you made and divide them in two, doubling the number of each cell type you made. Note: If you have enough plasticine, you can divide each of these new cells into two as well.

e) How many cells has your group ended up with? Another few billion and you could build a human being!
Station 5

[Task] In the news

Read the extracts of news stories provided, then answer the questions that follow.

STEM CELLS REVERSE HEART ATTACK DAMAGE By Tara Francis
Stem cells have been used to re-grow cardiac muscle in heart attack patients for the first time, researchers have reported. A new study published this week has described how patients’ own cardiac stem cells have been used to stimulate the growth of healthy tissue and reduce the scarring caused by heart attacks.

STEM-CELL TRIAL FAILED TO TREAT HEART FAILURE
By Steven Reinberg
An innovative approach using patients’ own bone marrow cells to treat chronic heart failure came up short in terms of effectiveness, researchers report. Use of stem-cell therapy to repair the slow, steady damage done to heart muscle and improve heart function is safe, but has not been shown to improve most measures of heart function, the study authors said.

EUROPEAN COURT RULING ‘THREATENS STEM CELL WORK’ By Helen Briggs
Europe’s highest court says stem cells from human embryos cannot be patented, in a case that could have implications for medical research. Scientists say the Court of Justice decision may impede European research into the use of stem-cell therapies, or drive research abroad. Others have welcomed the news, calling it a victory for human dignity.

SCIENTISTS TURN SKIN INTO BLOOD By Kerry Sheridan
Stem cell researchers have found a way to turn a person’s skin into blood, a process that could be used to treat cancer and other ailments, according to a recent Canadian study. The method uses cells from a patch of a person’s skin and transforms it into blood that is a genetic match, without using human embryonic stem cells. By avoiding the controversial and more complicated processes involved with using human embryonic stem cells to create blood, this approach simplifies the process, researchers said.

HUMAN SPERM MADE FROM BONE MARRROW
Agence France-Presse
Immature sperm cells have been created from stem cells in human bone marrow. The cells might one day lead to treatments for male infertility, according to a new study, outlined in the journal Reproduction: Gamete Biology.

Researchers report however that their work has so far been unable to produce mature sperm and experts caution that much more research would be required before the method could be used to produce viable sperm for fertility treatments.

What sorts of issues or developments are making news in regenerative medicine? Record the headline of each story, together with a one sentence summary of what the news is (what’s the issue/breakthrough?).

What can you tell about regenerative medicine research from reading the articles? For example, is it easy? Make three observations about this type of research.

Is there anything controversial about regenerative medicine? If so, which aspect(s) seem to be most controversial and why?

If you were interviewing an expert for a news story about regenerative medicine, what would you like to ask? List three of your interview questions.
Explore (student activities)

Station 6

[Task] Regeneration in nature

Many animals can regenerate – that is, grow new parts of their bodies to replace those that have been damaged. Study the examples given, then answer the questions that follow.

**FLATWORM**
The flatworm (planarian) can be cut into as many as 32 pieces and each fragment is able to rebuild a miniature flatworm complete with head, tail, eyes, mouth and internal organs. In one experiment, it was found that the smallest piece that could grow into a complete planarian was $\frac{1}{279}$th of a planarian (about 10,000 cells).

**STARFISH**
The starfish has its mouth and digestive organs in the centre part of its body (the central disk). If it loses any or all of its arms, the starfish is able to develop new arms from the central disk.

**LIZARD**
Some lizards have a breaking joint that allows the tail to drop off when seized by a predator. The tail grows back over time. Crabs, lobsters and crayfish also have breaking points that allow them to lose limbs then re-grow them.

**AXOLOTL**
Axolotls (also known as salamanders) are amphibians that can repeatedly regenerate their limbs, tail, spinal cord, external gills and jaws – all without any sign of scarring. Tail and limb regeneration is also found in the larval stages of frogs and toads.

**HUMAN**
Yes, that’s right, we can regenerate too – but in a very limited way. We can heal many of our wounds, mend mildly broken bones, and even re-grow some internal organs (e.g. the liver) if a large enough part remains. If we lose a fingernail, we can grow it back – but if we lose a finger, it’s gone forever.

Why do you think invertebrates such as the flatworm and starfish have a much greater ability to regenerate than mammals such as humans?

Why do you think it is easier for a human to grow back a fingernail than a finger? (Think about what is involved in growing back a finger, and what starts to happen as soon as a digit or limb is lost)

Do you think parts that animals have lost or discarded, such as the skin from a snake or the feathers from a bird, have anything to do with regeneration? Explain your answer.

Do you think plants have the ability to regenerate? Give an example to support your answer.
Teacher’s information student literacy activities

In this section, we delve into the science behind regenerative medicine by asking students to read related articles, and then follow up with discussion topics and activities tailored to the articles.

Each of the articles has a brainstorm activity to get students thinking about the relevant topic as well as its own literacy activities, which include:

GLOSSARY

COMPREHENSION AND SUMMARY

QUESTIONING TOOLKIT

The articles include:

ARTICLE ONE - MEDICINE IN 2030:

The promise of regeneration (first published in the June/July 2010 issue of COSMOS)
Regenerative medicine has the potential to change the face of medicine over the next 20 years. www.cosmosmagazine.com/features/print/3633/the-promise-regeneration

ARTICLE TWO - BRIEF GUIDE TO STEM CELLS

(first published on www.cosmosmagazine.com on 7 March, 2009)
What exactly are stem cells? And why is stem cell research so controversial? www.cosmosmagazine.com/features/online/2610/the-quest-harness-stem-cells

ARTICLE THREE - AUSTRALIANS ACHIEVE KIDNEY STEM CELL WORLD-FIRST

(first published on www.cosmosmagazine.com on 19 May, 2011)
Researchers in Melbourne have produced the world’s first kidney-derived induced pluripotent stem cells, which they hope may be used to treat diseased kidneys. www.cosmosmagazine.com/news/4328/australians-achieve-kidney-stem-cell-world-first?page=0%2C0
The promise of regeneration

Regenerative therapies such as stem cells have the potential to change the face of medicine over the next 20 years.

**NEW PHRASE OF** optimism has entered the global vocabulary over the past two decades: ‘regenerative medicine’. Today, everyone seems to be interested in what life-enhancing products the field might yield.

Expectations are high, but the time frame remains speculative. This is because the term ‘regenerative medicine’ includes an array of projects, some with short and straightforward paths to market, and some with difficult and uncertain roads to success.

The field covers the use of advanced technology to find new drugs, to new biological agents focussed on tissue repair. Importantly, it also includes stem-cell therapies for tissue replacement.

These technologies are evolving rapidly, and predictions that regenerative medicine will quickly become a US$20 billion (A$22.4 billion) industry are common. The U.S. government is tracking 2,496 clinical trials of stem cell medicines, and several biotechnology companies are becoming recognised for their work in the field.

Currently Geron Corp in San Francisco is working with the U.S. Food and Drug Administration to begin the first U.S. clinical trial using cells derived from embryonic stem cells. They will be using oligodendrocytes (a type of cell in the central nervous system) for spinal repair. Geron has also partnered with General Electric to commercialise cellular assay products derived from embryonic stem cells for use in drug discovery, development and toxicity screening.

And biopharmaceutical company Athersys in Cleveland is using a bone marrow-derived product that can control inflammation. The company has partnered with Pfizer for treatment of inflammatory bowel disease. Celgene in New Jersey has used extracts of the human placenta to create cell products that treat Crohn’s disease.

And these examples are just in the United States.

The growth of cell therapeutics has much to do with the vision of scientists working to understand the biology of normal development and the opportunity to study the very early cleavage-stage embryo as a result of research and clinical application of in vitro fertilisation (IVF). The California Institute for Regenerative Medicine (CIRM) was born on the optimism of some of these cell biologists and patient advocates of the therapy, and in spite of the ideological intransigence of former U.S. President George W. Bush. Californian voters, in a citizen-initiated referendum, backed Proposition 71 in 2004 and created CIRM, which now provides US$3 billion (A$3.4 billion) in support of stem cell science and regenerative medicine.

The creation of CIRM galvanised other countries and states to back regenerative medicine. CIRM has strong partners – Britain, Germany, Spain, Japan, Canada, China, and the state of Victoria in Australia as well as the U.S. states of Maryland and New York. The world is now linked in its efforts to deliver a major new medicine.

So what may we expect to happen over the next two decades? Most current clinical trials involve adult autologous (a medical term in which donor and recipient are the same person) cell therapies - using stem cells taken from the patient’s own bone marrow or fat tissue. These are sometimes altered slightly, often expanded in number outside the body and then replaced in the patient.

Also in the pipeline and hopefully headed for clinical trials, are autologous cells corrected using gene therapy or therapies.

This involved induced pluripotent stem (iPS) cells – cells derived from banked embryonic stem cells, or even adult cells, which have been reprogrammed to behave like embryonic cells.

CIRM, like many leading stem cell research centres, is supporting a new cadre of academic–commercial teams, linked as appropriate to the best scientists around the globe and pursuing that next tier of stem-cell-derived therapies. Their goals are emblematic of the field as a whole. They won’t all succeed, but we expect a significant number of these projects to result in clinical trials in two to five years.

World opinion is moving strongly in support of regenerative medicine. In Melbourne, stem cell and immunology scientists are leading the way with the largest number of collaborative projects with California. This is due to the strong innovative vision of the Victorian government and the ambition and status of Melbourne scientists to rise to the occasion and establish collaborations with overseas academics and biotech companies that are at the forefront of the regenerative medicine revolution.

The optimism centred on the field of regenerative medicine is well founded. It just needs to be tempered with a bit of patience and the knowledge that while many paths to therapies will get to their target, most will not be a straight line – and many will require multiple attempts to get to the ultimate therapeutic goal.

**In the pipeline**

Here are some of the breakthroughs that scientists hope to achieve over the next 20 years:

- Genetically modifying haematopoietic (blood) stem cells from HIV/AIDS patients to result in cell-level resistance to HIV infection.
- Targeting sickle cell disease, again using haematopoietic stem cells, modified to have the normal gene inserted instead of the disease-causing gene.
- Using the homing characteristics of neural stem cells to destroy inoperable glioma brain tumours. The neural stem cells can be loaded with cell-killing molecules that target the tumour directly.
- Destruction of cancer stem cells that cannot be destroyed by chemotherapy or radiotherapy. Many of these have protective molecules, and by blocking these molecules scientists could make them vulnerable to treatment.
- Directing embryonic stem cells to differentiate into pancreatic islet cells, so that they can be placed under the skin of Type 1 diabetes sufferers. These cells are glucose responsive and will keep the diabetic patient stable. They are easily imaged and replaced.
- Grow retinal epithelium from embryonic stem cells on appropriate scaffolds and insert these into the eyes of patients with dry macular degeneration.
- Develop neural and glial precursor cells for the treatment of strokes and other conditions. These cells can be derived from embryonic stem cells and delivered to the central nervous system.
- Treat the disease Epidermolysis bullosa that results in the loss of the outer skin layer. Scientists are planning to convert a patient’s skin cells into iPS cells, insert the correct gene and then direct the cells to grow into epidermal sheets that can be transplanted into the patient. – Alan Trounson and Don Gibbons

RiAus PDplus: Regenerative medicine

riaus.org.au/pdplus
Brainstorming

[Task] Brainstorm the topic of regenerative medicine by creating your own mind map. Remember to show how different words or terms you include in your mind map are connected. Below are some terms you might like to include: regeneration, body parts, stem cells, embryos, research, health, treatments, diseases, life span

Glossary

[Task] Define some of the scientific terms used in the article using the table provided.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>regenerative medicine</td>
<td></td>
</tr>
<tr>
<td>tissue repair</td>
<td></td>
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<tr>
<td>biotechnology</td>
<td></td>
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<tr>
<td>embryonic stem cell</td>
<td></td>
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<tr>
<td>cell therapeutics</td>
<td></td>
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<tr>
<td>autologous cells</td>
<td></td>
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<tr>
<td>induced pluripotent stem cells (iPS cells)</td>
<td></td>
</tr>
<tr>
<td>clinical trial</td>
<td></td>
</tr>
<tr>
<td>homing characteristics</td>
<td></td>
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<tr>
<td>genetically modifying</td>
<td></td>
</tr>
<tr>
<td>differentiate</td>
<td></td>
</tr>
</tbody>
</table>
Summarising

[Task] Answer the following questions relating to the article.

What regenerative medicine research is being done? Fill in the table below to show three projects or clinical trials currently underway, and what they are aiming to use stem cells for.

<table>
<thead>
<tr>
<th>Project</th>
<th>Stem cell use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tbody>
</table>

What is Australia’s involvement in this field of research? According to the article, where is most of our research taking place and why?

Draw up a table to show five breakthroughs that scientists hope to achieve over the next 20 years. In one column, show what the scientists are using (e.g. blood stem cells) and in the other column, show what the application is (e.g. resistance to HIV infection).
**Questioning Toolkit**

**[Task]** Below are a series of discussion questions in the form of a questioning toolkit. Choose some or all of the questions, or ask some of your own e.g. the questions you asked in the ‘Engage’ section at the beginning of this unit. [Inspired by Jamie McKenzie’s Questioning Toolkit]

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Your ideas and opinions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Essential questions</strong></td>
<td></td>
</tr>
<tr>
<td>These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer.</td>
<td></td>
</tr>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>1. What is regenerative medicine?</td>
<td></td>
</tr>
<tr>
<td>2. What promise does it hold – what does this field of science have to offer?</td>
<td></td>
</tr>
<tr>
<td><strong>Subsidiary questions</strong></td>
<td></td>
</tr>
<tr>
<td>These questions help us manage our information by finding the most relevant details.</td>
<td></td>
</tr>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>1. What are the most important application(s) of regenerative medicine?</td>
<td></td>
</tr>
<tr>
<td>2. Should this type of research be government funded? Who should pay?</td>
<td></td>
</tr>
<tr>
<td><strong>Hypothetical questions</strong></td>
<td></td>
</tr>
<tr>
<td>Questions that are designed to explore the possibilities (the ‘what ifs?’). They are useful when we want to test our hunches.</td>
<td></td>
</tr>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>1. What if we could use regenerative medicine to extend our life span indefinitely ... would death become obsolete?</td>
<td></td>
</tr>
<tr>
<td>2. What if only some people had access to regeneration ... do you think it would create problems for society?</td>
<td></td>
</tr>
<tr>
<td><strong>Provocative questions</strong></td>
<td></td>
</tr>
<tr>
<td>Questions to challenge convention.</td>
<td></td>
</tr>
<tr>
<td>For example:</td>
<td></td>
</tr>
<tr>
<td>1. If we could live forever, would we bother having babies?</td>
<td></td>
</tr>
<tr>
<td>2. Is regenerative medicine completely safe? Could it harm people?</td>
<td></td>
</tr>
</tbody>
</table>
Explain (article two)

Brief guide to stem cells

The controversial quest to harness the power of embryonic stem cells may be about to enter a new phase in the United States. But what exactly are stem cells?

**Embryonic stem cells** are the primitive cells that grow into the roughly 200 types of cell that comprise the body’s tissues.

Scientists aim to coax these cells into becoming lab-dish replacements for heart, liver, skin, eye, brain, nerve and other cells destroyed by disease, accident, war or normal wear and tear. Parkinson’s disease, Alzheimer’s, Type 1 diabetes, cancer and cardiac degeneration are among the many disorders that, in theory, could be healed by this wonder cure.

Of the two categories of stem cells, the greatest interest by far has been focused on embryonic stem cells. These are so-called pluripotent cells, meaning that they have ability to differentiate, or diversify, into many different tissues.

**Controversy and opposition**

But embryonic stem cell research has been controversial. These master cells are extracted from early embryos that are allowed to grow for five to six days in culture. The harvested stem cells are kept in self-replicating ‘lines’ for study, but the embryos themselves – usually surplus embryos from in-vitro fertilisation (IVF) – are destroyed by the process. American Christian conservatives have long opposed this research, saying that a human embryo equates to a human life.

In August 2001, former president George W. Bush banned all U.S. federal funding for research that required new lines of human embryonic stem cells. That move caused an outcry among U.S. researchers, who warned investment and talent in their field would shift to other countries. In July 2006, an attempt in the senate to lift some restrictions was barred by Bush, wielding his presidential veto for the first time.

President Barack Obama has vowed to scrap the ban, and a White House official said the president would sign an executive order Monday reversing Bush administration restrictions on federal funding for embryonic stem cell research. The official would not divulge the exact wording of the order, but confirmed, on condition of anonymity, that it would be in line with Obama’s campaign vow to restore funding to embryonic stem cell research.

Access to embryonic stem cells in other countries has also been restricted by laws governing the source of the embryos.

**Adult stem cells**

In contrast to embryonic stem cells are so-called adult stem cells, which are genetically programmed to differentiate into a lesser number of specific cell types. Adult stem cells were initially thought to be very small in number, but the tally has been found in many more tissues in recent years. They have now been found in brain, bone marrow, peripheral blood, blood vessels, skeletal muscle, skin and liver.

There are already several types of therapy involving adult stem cells, the best known of which, dating from the 1960s, is the bone marrow transplant. Most, though, are still at experimental or laboratory level.

Compared with embryonic stem cells, adult stem cells are less versatile and are harder to culture in the lab. In 2007, researchers said they had found a way to make pluripotent (and therefore more versatile) adult stem cells by ‘reprograming’ adult stem cells taken from skin, though this has yet to be verified. And in January 2008, a team led by Robert Lanza at Advanced Cell Technology (ACT), a Massachusetts biotech company, announced they had devised a method to create the first human embryonic stem cells without destroying the embryo.

**Stand and deliver**

Biomedical researchers warn that big questions remain to be answered before stem cell research fully delivers. A major challenge is to understand how a stem cell differentiates into specialised cells. Another is how to ensure that transplanted stem cells are not attacked by the immune system.

One area of work is to clone stem cells from a patient’s own cells, so that they carry the DNA of the patient and thus are not treated as foreign by the immune system. Another method would be to induce a patient’s own adult stem cells to become pluripotent and therefore able to turn into as many cell types as embryonic stem cells, but this has yet to be achieved.

– *Agence France-Presse*
Brainstorming

[Task] Where have you seen or heard the term ‘stem cells’ used before? On the TV, in a newspaper or magazine? Fill in the table provided to outline some of the ways you have heard or seen the term used, and explain in what context it was being talked about.

<table>
<thead>
<tr>
<th>Where (e.g. TV news)</th>
<th>Context (e.g. Potential to cure diseases; using human embryos)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

Glossary

[Task] Define some of the scientific terms used in the article using the table provided.

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<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkinson’s disease</td>
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<tr>
<td>Alzheimer’s</td>
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<tr>
<td>pluripotent</td>
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<tr>
<td>cell culture</td>
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<tr>
<td>harvested cells</td>
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<tr>
<td>self-replicating</td>
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<tr>
<td>in-vitro fertilisation</td>
<td></td>
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<tr>
<td>bone marrow transplant</td>
<td></td>
</tr>
</tbody>
</table>
Summarising

[Task] Answer the following questions relating to the article.

What is a stem cell? (Use your own words.)

What are the two categories of stem cells, and where do they come from?

What’s so special about stem cells? Why are they so valuable for medical research?

What do scientists hope to be able to do with stem cells? What are some of the disorders stem cells may be able to heal?

Why is stem cell research controversial?

What has happened in some countries to restrict stem cell research? Give an example.

How do adult stem cells compare with embryonic stem cells?

What are two of the biggest challenges faced by scientists working in stem cell research?
### Questioning Toolkit

**Task** Write down your ideas and opinions relating to the questions presented here. Choose some or all of them, or ask some of your own e.g. the questions you asked at the beginning of this unit.

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Your ideas and opinions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Essential questions</strong></td>
<td></td>
</tr>
<tr>
<td>These are the most important and central questions. For example: 1. What are stem cells? 2. Why is there so much interest in stem cells?</td>
<td></td>
</tr>
</tbody>
</table>

| **Subsidiary questions**  |                         |
| These questions help us manage our information by finding the most relevant details. For example: 1. What could stem cells be used for? 2. What are the benefits of using stem cells over the technology we have available today? 3. What is the controversy over the use of stem cells in research? |                         |

| **Hypothetical questions** |                         |
| Questions that are designed to explore the possibilities (the ‘what ifs?’). For example: 1. What if stem cells end up being able to cure every type of disease and disorder in humans, how valuable will they become? 2. What if stem cells prove to be useless, after billions of dollars have been spent on research, will it be money wasted? |                         |

| **Provocative questions**  |                         |
| Questions to challenge convention. For example: 1. If we could only get stem cells from human embryos, should we still use them for research? 2. Could stem cells be used for evil? Is there a dark side to stem cell research? |                         |
Australians achieve kidney stem cell world-first

With their wizardly power to conjure up any type of body tissue, embryonic stem cells promise spare parts for ailing bodies.

**But It Turns Out** that some cell types are easier to produce than others. Making brain or retina cells, for instance, has been fairly straightforward. Not so for kidney cells: the route to making them seems obstructed by twists and turns.

That’s been frustrating for kidney researchers trying to generate replacement cells for the tens of thousands of patients who suffer terminal kidney failure each year.

Now researchers at Monash Immunology and Stem Cell labs at Melbourne’s Monash University say they have found a detour that may shorten the path to producing kidney cells.

**Winding back the clock**
Instead of starting with embryonic stem cells derived from surplus human embryos, they started with mature human kidney cells and wound back their developmental clock to a more embryonic state.

These cells, known as induced pluripotent stem cells or iPS cells have similar properties to embryonic stem cells – they multiply without limits and produce different types of cells. But the researchers are hoping they will also retain a memory of their origins and find their own way back on the convoluted route to becoming kidney cells.

“We think these kidney iPS cells will be better at making kidney tissue,” says Sharon Ricardo, one of the authors of the paper which was published in this month’s issue of the Journal of the American Society for Nephrology.

When Japanese researchers first reported making iPS cells from human skin cells in 2007, it seemed like an answer to researchers’ prayers. Generating embryonic stem cells from spare embryos is not only technically difficult, researchers faced huge resistance from powerful groups to stymie the research.

By contrast, the iPS cell method produced cells that seemed to have the same power as embryonic stem cells: they appeared to retain a strong ‘epigenetic’ memory of the cell type they originated from. In practice that meant that an iPS cell made from a skin cell would rather turn back into skin than any other tissue.

That was a disappointing result if you want to make different tissues from skin iPS cells. But for Ricardo and co-author Andrew Laslett, it signalled a new opportunity. If they could make iPS cells from kidney cells, they might not only get a cell with the ability to multiply like a stem cell but also one that would, like a homing pigeon, return to its native state.

Ricardo had access to kidney tissue from human biopsies but this tissue was a collage of some 26 different cell types. She had to choose a single type of cell to transform into a stem cell and ultimately settled on the mesangial cell – a cell that plays the key role in filtering wastes and is also the one most often damaged in kidney disease. The researchers’ meticulous work succeeded in producing the world’s first kidney-derived iPS cells.

Now they plan to put them to work. If they can produce copious amounts of healthy mesangial ‘filtering’ cells, they might be able to slot them back into a diseased kidney – rather like replacing the charcoal filter on your water purifier.

**Unmasking causes of disease**
They also plan to make kidney iPS cells from patients with inherited kidney diseases such as polycystic kidney disease and Alport disease. These cells in turn will provide human cell models to unmask how these diseases develop and search for drugs that can derail the process.

Last year researchers at the Salk Institute in San Diego used a similar approach with iPS cells made from the skin cells of children with Rett’s syndrome (a form of autism). When they triggered these cells to form brain cells, they discovered they made sparse connections, a result not seen when iPS cells were produced from healthy children.

Other kidney researchers have welcomed the step forward. “This is an exciting development for this field of medicine. It opens the door to studies that may teach us about the nature of the problem in patients with kidney disease and screening for drugs that might help,” commented Melissa Little at the University of Queensland. – Elizabeth Finkel
**Brainstorming**

**[Task]** What stem cell research is going on in Australia? What do people in Australia know about it? How do they feel about it – are they supportive, or against it? Why/why not?

Find out by interviewing at least five people (e.g. family and friends) using the questions provided here, plus a couple of your own. Make notes on the answers given so you have a record of your interviews.

**Q1.** Can you tell me what you know about stem cell research?

**Q2.** Do you know if any stem cell research is going on in Australia?

**Q3.** How do you feel about this research? Do you support it, oppose it, or neither? Why?

**Q4.** What do you see as the potential benefits/drawbacks of this area of research?

**Q5.** Do you think stem cell research in Australia should be government funded?

**Glossary**

**[Task]** Define some of the scientific terms used in the article using the table provided.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>kidney failure</td>
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<tr>
<td>developmental clock</td>
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<tr>
<td>embryonic</td>
<td></td>
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<tr>
<td>retrovirus</td>
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<tr>
<td>tissue rejection</td>
<td></td>
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<tr>
<td>tissue-matching</td>
<td></td>
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<tr>
<td>anti-rejection drugs</td>
<td></td>
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<tr>
<td>epigenetic</td>
<td></td>
</tr>
<tr>
<td>biopsies</td>
<td></td>
</tr>
</tbody>
</table>
Summarising

[Task] Answer the following questions relating to the article.

What has been frustrating for kidney researchers in the past?

What do researchers at Melbourne’s Monash University think they have been the first in the world to achieve?

What are the researchers using instead of embryonic stem cells?

What method did they use to produce these cells?

What are the two big advantages of using these cells instead of embryonic stem cells?

What do iPS cells have a tendency to do? Is this a problem?

What do researchers plan to do if they can produce lots of these iPS cells?

Why have other researchers welcomed this development?

Questioning Toolkit

[Task] Write down your ideas and opinions relating to the questions presented here. Choose some or all of them, or ask some of your own e.g. the questions you asked at the beginning of this unit.

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Your ideas and opinions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential questions</td>
<td></td>
</tr>
<tr>
<td>These are the most important and central questions. For example:</td>
<td></td>
</tr>
<tr>
<td>1. What are iPS cells?</td>
<td></td>
</tr>
<tr>
<td>2. Why is the development of iPS cells considered a breakthrough?</td>
<td></td>
</tr>
<tr>
<td>Subsidiary questions</td>
<td></td>
</tr>
<tr>
<td>These questions help us manage our information by finding the most relevant details. For example:</td>
<td></td>
</tr>
<tr>
<td>1. What are the benefits of iPS cells over embryonic stem cells?</td>
<td></td>
</tr>
<tr>
<td>2. What are the limitations of iPS cells?</td>
<td></td>
</tr>
<tr>
<td>Hypothetical questions</td>
<td></td>
</tr>
<tr>
<td>Questions that are designed to explore the possibilities (the ‘what ifs?’). For example:</td>
<td></td>
</tr>
<tr>
<td>1. What if iPS cells could be grown at home, could we have ‘DIY’ regeneration?</td>
<td></td>
</tr>
<tr>
<td>2. What if iPS cells were found to increase the risk of cancer, should they still be used?</td>
<td></td>
</tr>
</tbody>
</table>
### Provocative questions
Questions to challenge convention.
For example:
1. Why bother developing iPS cells when embryonic stem cells exist?
2. Would you want to be treated with iPS cells if you had a disease they could treat?

### Bringing it all together

**Task** Complete the following activities to summarise the ‘Explain’ section.

1. Draw a mind map, or other type of diagram, to show the relationship between the three articles.
2. List three big issues that you have learnt about from the articles.
3. Make a list of questions you had that reading the articles helped answer. Outline the answers they provided.
4. List five new questions you have now that you’ve read the articles.
About the COSMOS matrix

What is the COSMOS Science Matrix?
A learning matrix such as the COSMOS Science Matrix is a flexible classroom tool designed to meet the needs of a variety of different learning styles across different levels of capabilities. Students learn in many different ways - some are suited to hands-on activities, others are strong visual learners, some enjoy intellectually challenging, independent hands-off activities, while others need more guidance. The matrix provides a smorgasbord of science learning activities from which teachers and/or students can choose.

Can I use the matrix for one or two lessons, or for a whole unit of study?
Either! The matrix is designed to be time flexible as well as educationally flexible. A time frame for each activity is suggested on the matrix. Choose to complete one activity, or as many as you like.

Is there room for student negotiation?
Yes! Students can be given a copy of the matrix and choose their own activities, or design their own activities in consultation with their classroom teacher.

Can I use the matrix for a class assessment?
Yes! You can set up a point system - perhaps one lesson equals one point. Students can be given a number of points to complete. If they choose less demanding activities, they will have to complete more of them.

What do the row headings mean?

<table>
<thead>
<tr>
<th>Row heading</th>
<th>Description of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific procedure</td>
<td>Hands-on activities that follow the scientific method. Includes experiments and surveys. Great for kinaesthetic and logical learners, as well as budding scientists.</td>
</tr>
<tr>
<td>Science philosophy</td>
<td>Thinking about science and its role in society. Includes discussion of ethical issues, debates and hypothetical situations. An important part of science in the 21st century.</td>
</tr>
<tr>
<td>Being creative with science</td>
<td>For all those imaginative students with a creative flair. Great for visual and musical learners and those who like to be innovative with the written word.</td>
</tr>
<tr>
<td>Science time travel</td>
<td>Here we consider scientific and technological development as a linear process by looking back in time or travelling creatively into the future.</td>
</tr>
<tr>
<td>‘Me’ the scientist</td>
<td>Personalising the science experience in order to engage students more deeply.</td>
</tr>
<tr>
<td>Communicating with graphics</td>
<td>Using images to communicate complex science ideas.</td>
</tr>
<tr>
<td>ICT</td>
<td>Exploring the topic using computers and the Internet.</td>
</tr>
</tbody>
</table>

What do the column headings mean?

<table>
<thead>
<tr>
<th>1. Read and revise</th>
<th>2. Read and relate</th>
<th>3. Read and review</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed to enhance student comprehension of information.</td>
<td>Gives the student the opportunity to apply or transfer their learning into a unique format.</td>
<td>Involves the more challenging tasks of analysing, and/or assessing information in order to create and express new ideas and opinions.</td>
</tr>
</tbody>
</table>
1. Read and revise – one or two lessons

2. Read and relate – three or four lessons

3. Read and review – four or five lessons

Examine cells under the microscope to see cell division (mitosis) taking place – this is the process that enables growth and regeneration.

See Linked Activity 1

How long does it take human hair to regenerate? Measure your hair-length each week for a month and calculate the regeneration rate. For an explanation of how hair regenerates, see ...

See Linked Activity 2

Research the blood cells of the human body, where these cells are made, and the stem cells they are made from. Then go on to examine the bone marrow from fresh chicken bones. (See www.scholastic.com/ash/ashbookletweb.pdf-'What runs through my veins')

Research 'stem cell tourism' to find out what it is and to decide whether or not you think it is ethical. Consider issues like safety, and the need to control the market. What are some of the dangers involved?

Using the information in the articles you read, create a webpage or podcast that promotes regenerative medicine, focusing on the promise this area holds for the future.

Create a graphic of your choice that shows the differences between embryonic stem cells (ES) and induced pluripotent stem cells (iPS cells).

Create a storyboard for a short video about regenerative medicine, designed as a general introduction to this topic for high school students.

Conduct some research and create a graphic that shows: a) where regenerative medicine research is being carried out in the world; b) the number of research projects, and the types of research projects are being done in these places - which diseases are scientists looking to prevent or cure?

Watch these online videos: www.ted.com/talks/anthony_atala_printing_a_human_kidney.html and www.wimp.com/ organregrowth/  ... and comparing the two different ways of making human organs shown in these videos: 3-D printing and scaffolding.

Some medical procedures that were once considered unethical (e.g. IVF), are now commonplace. On the other hand, some ... the nuclear bomb) are now considered unethical by many. Explore the ethics of regenerative medicine.

If you were a scientist studying animals that can regenerate, which animal(s) would you choose to study and why? What ... you investigate? Decide on one experiment you would like to do, and write an outline showing what would be involved.

You have been asked to provide advice to the Australian government on spending in the area of regenerative medicine. Prepare a written report in the form of a presentation or speech, outlining your findings, and calling for an increase in spending on this research by the Australian government.

Revise how cells make copies of themselves through the process of mitosis, to enable regeneration to occur. Then have a go at modelling the process of mitosis in the classroom. (See www.biologylessons.sdsu.edu/classes/lab8/lab8.html)

It is several decades into the future and you have reached 100 years of age – congratulations! Write a journal entry to describe a typical day in your life, and compare this to what was possible for elderly people in today's times.

Imagine you are Sharon Ricardo (the scientist in the kidney stem cell article). Write a journal entry about your newest research, and how you feel about it. What does it make you feel? What hopes do you have for what you might achieve next, and what might ultimately prove possible?

If you were a scientist studying animals that can regenerate, which animal(s) would you choose to study and why? What ... you investigate? Decide on one experiment you would like to do, and write an outline showing what would be involved.

Research the blood cells of the human body, where these cells are made, and the stem cells they are made from. Then go on to examine the bone marrow from fresh chicken bones. (See www.scholastic.com/ash/ashbookletweb.pdf-'What runs through my veins')

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### The Cosmos Science Matrix

<table>
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Activity 1
MITOSIS IN ONION ROOT TIP CELLS

BACKGROUND INFORMATION
Mitosis is the process by which cells divide to form copies of themselves. This is how growth occurs and therefore is central to the process of regeneration.

AIM
To observe different stages of mitosis in onion root tip cells.

MATERIALS
• Onion
• Razor blades
• Microscopes
• Microscope slides and coverslips
• 1M HCl (hydrochloric acid)
• Clothes pegs
• Bunsen burner
• Safety glasses
• Hot gloves
• Paper towel
• 0.5% toluidine blue

RISK ANALYSIS
Complete the risk analysis table below before you begin your experiment.

<table>
<thead>
<tr>
<th>Risk</th>
<th>Precaution</th>
<th>Consequence</th>
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</thead>
<tbody>
<tr>
<td>Heat from Bunsen burner</td>
<td></td>
<td>Could burn skin resulting in damage to skin and/or infection</td>
</tr>
<tr>
<td>Burn from acid</td>
<td>Wear safety glasses and gloves; take care when handling acid</td>
<td></td>
</tr>
<tr>
<td>Staining of skin or clothing by toluidine blue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuts from scalpel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuts from broken glass (e.g. cover slip)</td>
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METHOD
1. Choose an onion bulb that is just beginning to show roots emerging. Cut off a root and lay it on a microscope slide. Cut off the first 1-2mm of the root tip and discard the rest.
2. Cover the root tip with two or three drops of 1M HCl.
   **Note:** BE CAREFUL – this is strong acid. Wear safety glasses and gloves.
3. Using a clothes peg to hold the slide, gently warm it by passing it back-and-forth over the flame of a Bunsen burner for 5 seconds. (If the onion turns brown or if all the liquid boils away, stop and start again.)
4. Use the edge of a paper towel to blot around the root and remove excess HCl. Cover the root tip with 0.5% aqueous toluidine blue.
   **Note:** BE CAREFUL – this stains.
5. Pass the slide over the heat source again, two times, without boiling the liquid. Let the slide stand for 1 minute.
6. Carefully blot around the root to remove excess stain. Add one drop of fresh toluidine blue stain to the slide and then apply a coverslip.
Elaborate

7. Place the slide, coverslip-side-up, between two layers of paper towel on your laboratory bench. Using your finger, firmly but carefully apply an even pressure to the coverslip to squash and spread the root tip.
   **Note:** BE CAREFUL to not break the coverslip!
8. Using your microscope at 10x magnification, locate the meristematic region of the root tip (this is just behind the very tip, and is where most cell division is happening). Change to 40x magnification and look for cells in different stages of mitosis.
9. Study the cells showing the different stages of mitosis: prophase, metaphase, anaphase, telophase and interphase.

**RESULTS**
Record your observations in your exercise book. Make biological drawings of cells undergoing each of the five stages of mitosis, showing the position of the chromosomes in each cell. Make sure that for each drawing, you note the magnification and label the stage of mitosis.

**DISCUSSION**
Complete these activities in your exercise book.

1. How many different stages of mitosis did you identify in your onion cells?
2. Why do you think you couldn’t do this experiment using another part of the onion?
3. What difficulties did you encounter while preparing and examining your slides?
4. Suggest one way to improve this experiment.
5. What did you learn while conducting this experiment?

**CONCLUSION**
In your exercise book, write a conclusion that responds to your aim and summarises your results.
Regenerative medicine has many ethical issues associated with it, making it a controversial area of research. Some of these issues are listed below.

**Issue 1:**
Is it OK to use embryonic stem cells for research?
Can very early stage embryos be considered human beings?
Is it wrong to use an embryo left over from IVF, when it was just going to be discarded anyway?
Who should decide whether scientific research using embryonic stem cells should go ahead - politicians, scientists or the public?

**Issue 2:**
Is it OK to use regenerative medicine to extend the human life span?
Is it wrong to make people live longer, when the world is already over-populated?
Is it ethical to extend the life span of people who are sick and, in natural circumstances, would have died?
Does everyone deserve to live longer, are some people more deserving than others?

**Issue 3:**
How should regenerative medicine techniques and therapies be used?
Is it safe to use techniques and therapies that have not been ‘tried and tested’ over many years? When does it become safe?
Should these techniques and therapies only be used to save lives, or would it be OK to use them to enhance or improve humans?
Who should this new technology be available to? Should the user pay? Or should the government subsidise it so everyone has equal access?

**Task**
Find out what the class thinks of these issues.

Divide the class into small groups of 4 or 5.
In each group, discuss the issues listed above and make a note of the group consensus (if you reach one) on each issue.
Come together as a class to discuss each group’s position on the issues.
As a class, note the points of difference between the various positions held.
Regenerative Medicine DIY quiz

1. Ask each student to call out a word or term that relates to regenerative medicine. Record these on the board.

2. Each student is to pick five words/terms from the board and write a definition for each.

3. Each student is to pick another eight words/terms from the board, and write a paragraph about regenerative medicine that uses as many of these words as possible.

4. Students create their own concept map, or some other type of diagram, to show what they have learnt about regenerative medicine. They are to use as many words/terms from the board as possible, and show the connections between these.

Class debate

1. Choose Issue 1 or Issue 2 in Linked Activity 2 of the Elaborate section to use as the topic for a class debate.

2. Divide the class into two groups. Group 1 will debate the affirmative and Group 2 will debate the opposing view.

3. Appoint an adjudicator to decide which team presented the most compelling argument.

What and where?

1. Look at a 3-D model or picture of the human body – your teacher will be able to find one for you.

2. Choose three parts of the human body – these could be organs, skin or tissues.

3. For each chosen part, write a paragraph explaining in simple terms how regenerative medicine is aiming to help with problems in those areas.
   (For example, if you choose kidneys you could explain that kidney-derived iPS cells are being produced to replace diseased kidney cells with healthy cells, etc.)
### Personal review of unit

<table>
<thead>
<tr>
<th>Personal regenerative medicine summary</th>
<th>Where to now?</th>
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<tbody>
<tr>
<td>Make a dot point summary, or a mind map, of all the things you learnt while completing this unit of work. Highlight those things you found to be the most interesting.</td>
<td>Write at least five new questions that have come up while you have been studying this unit of work.</td>
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Have the questions you had before studying regenerative medicine been answered? List any questions you would like to investigate further.

### Something ethical

<table>
<thead>
<tr>
<th>Something political</th>
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<tr>
<td>List as many ethical issues as you can think of that came up during this unit of work, and propose ways that some of these issues might be addressed.</td>
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