Teacher's Notes

Regenerative Medicine

Overview

The goal of regenerative medicine is to grow replacement tissue or organs for patients who have sustained an injury or have had a disease that permanently damaged their tissue. Researchers are figuring out how to grow some of these replacement tissues from patients' own cells, reducing the need for donor organs and long-term use of immunosuppressant drugs. The Wake Forest Institute for Regenerative Medicine is studying techniques for growing replacement tissues and organs for more than 30 parts of the body, including skin, bladders, livers, kidneys and ears. They have teamed up with the Department of Industrial and Systems Engineering at North Carolina State University to automate manufacturing of regenerative therapies.

The North Carolina Tissue Engineering and Regenerative Medicine Society (http://www.ncterm.org) is another organization working to advance basic research, commercial development and education in the field of regenerative medicine. One of the major goals of NCTERMS is to stimulate academic and corporate interest in regenerative medicine and tissue engineering in North Carolina. It also works to stimulate collaborations between different organizations and between researchers in different disciplines.

Other researchers in North Carolina and around the world are working to understand basic mechanisms regulating cell growth and differentiation, to develop healing therapies for many different ailments and to translate these discoveries into clinical care for patients. Veterinary researchers also are studying regenerative medicine for animals.

The goals of this chapter are to help students understand the science concepts that underlie regenerative medicine and to explore some of the many career possibilities in this exciting new field.

Alignment with Standards

Biology Objectives from the Essential Standards

Bio.1.1: Understand the relationship between the structures and functions of cells and their organelles.

- **Bio.1.1.3:** Explain how instructions in DNA lead to cell differentiation and result in cells specialized to perform specific functions in multicellular organisms.

Teacher's Notes

Regenerative Medicine (continued)

Bio.1.2: Analyze the cell as a living system.

- **Bio.1.2.2:** Analyze how cells grow and reproduce in terms of interphase, mitosis and cytokinesis.

Bio.3.3: Understand the application of DNA technology.

- **Bio.3.3.3:** Evaluate some of the ethical issues surrounding the use of DNA technology (including cloning, genetically modified organisms, stem cell research and the Human Genome Project)

AP Biology Themes and Topics

Themes	Topics
Relationship of Structure to Function	Cells • Cell cycle and its regulation
Science as a Process	Molecular Genetics • Gene regulation
Science, Technology and Society	Structure and Function of Plants and Animals • Reproduction, growth and development

Biomedical Technology Objectives from 2004 Course Blueprint

BT02.00: Analyze biomedical ethics and legal principles.

- **BT02.02:** Analyze the ethical principles of biomedical technology.

Teacher's Notes

Regenerative Medicine (continued)

BT07.00: Examine organ transplantation.
- **BT07.01:** Describe basic facts and organizations related to organ transplantation.
- **BT07.02:** Analyze bioethical issues associated with organ transplants.

BT09.00: Evaluate careers and techniques that use biomedical technology.
- **BT09.01:** Investigate laboratory careers.
- **BT09.02:** Discuss imaging careers and technology.
- **BT09.04:** Outline biotechnology careers and genetics.
- **BT09.05:** Evaluate the importance of biomedical technology in a chosen health career.

BT10.00: Analyze biomedical research.
- **BT10.01:** Discuss biomedical research.
- **BT10.02:** Outline biomedical research methods.
- **BT10.03:** Analyze the benefits of biomedical research.

BT11.00: Analyze challenges to biomedical research.
- **BT11.01:** Interpret personal beliefs about biomedical research.
- **BT11.03:** Evaluate therapeutic versus reproductive cloning.
- **BT11.04:** Debate pros and cons of animal research and animal rights.

BT12.00: Analyze current issues in biomedical technology.

Key Vocabulary

- A **tissue** is a group of similar cells from the same origin performing a specific function (e.g. smooth muscle tissue or connective tissue).
- **Organs**, such as the heart, skin, kidney or stomach, combine two or more tissues that function together.
- A **scaffold** is a support structure. In regenerative medicine, scaffolds serve as a support structure for cells to grow and orient themselves when building replacement tissues and organs.
- The **extracellular matrix** surrounds and supports the cells that form tissues and organs in the body. It is created and maintained by cells.
- **Decellularization** is the process of removing cells from the extracellular matrix.

Teacher's Notes

Regenerative Medicine (continued)

- **Biomaterials** are synthetic or natural biocompatible materials used to replace part of a living system or function in intimate contact with living tissue.
- **Stem cells** are undifferentiated cells that give rise to other cells.
- **Totipotent** stem cells can give rise to all the other tissues needed by the body as well as the extra embryonic tissues (e.g. the placenta).
- **Epigenetics** is the study of heritable changes in gene expression that are not caused by changes in the DNA sequence.
- **Pluripotent** stem cells can give rise to all the other types of body cells.
- **Multipotent** stem cells can give rise to the cell types needed in the tissue from which they are derived but not to other types of cells found in the body.

Regenerative Medicine

Healing Promise

Luke Massella was born with spina bifida, a birth defect involving the spinal column. In 2001 he was seriously ill. He couldn't run around or play outside with his friends. He could barely go to school. In Luke's case, the defect in his spinal column led to a paralyzed bladder. When the bladder does not function properly, urine can back up and cause damage to the kidneys, which are responsible for filtering waste from the blood. When the kidneys don't work, toxins build up. Kidney damage often is life-threatening. Even after 16 surgeries, Luke's kidneys were in danger. He was losing weight and still was unable to live a normal life. Then, Luke received a new bladder grown outside his body using techniques from the new and experimental field of regenerative medicine. This preserved his kidneys and restored his health. He even became captain of his high school wrestling team. In 2012 Luke is enjoying life as a healthy, athletic college student. Luke's doctor for this groundbreaking treatment was Dr. Anthony Atala, Director of the Wake Forest Institute for Regenerative Medicine (WFIRM), in Winston-Salem, N.C. *(See the Resources section later in this chapter for links to TED Talk videos of Dr. Atala explaining his techniques and meeting with Luke 10 years after Luke received a new bladder.)*

Regenerative medicine is still in its infancy. Luke's miraculous story was part of a clinical trial; his treatment won't become routine for several more years. However, research being done today in North Carolina and around the world is solving problems that will lead to new treatments for patients with many different damaged and diseased organs. Damaged and diseased organs are a huge medical challenge. Sometimes doctors can repair or replace damaged organs with artificial parts, but these artificial parts (such as a titanium hip or artificial heart valve) can deteriorate over time and may cause infection or inflammation. Artificial replacement parts are a particular problem for children because they don't grow with the child, so these replacement parts have to be replaced again as the child grows. Human organ transplants from living or dead donors are another way to treat severely damaged organs, but organ transplants pose many issues and are definitely not a cure-all.

In 2011, there were 28,537[1] organ transplants in the United States, 1,042 of which were done in North Carolina. Sadly, this does not begin to meet the need for such transplants. More than 100,000 people in the U.S. are waiting for an organ transplant — the majority for a kidney. An average of 18 people die each

Regenerative Medicine (continued)

day while waiting[2]. Furthermore, even a successful transplant leads to a lifetime of special drugs to keep the body from rejecting the donated organ. The fantastic promise of regenerative medicine is that someday doctors will be able to heal patients with cell and gene therapies and grow replacement tissues and organs from a patient's own cells. If doctors are able to grow replacement tissues from a patient's own cells, the patient's immune system will accept the transplant without powerful immune suppressant drugs, and the patient will be able to live a much more normal life. Let's take a look at some of the science behind this promise.

Background Science

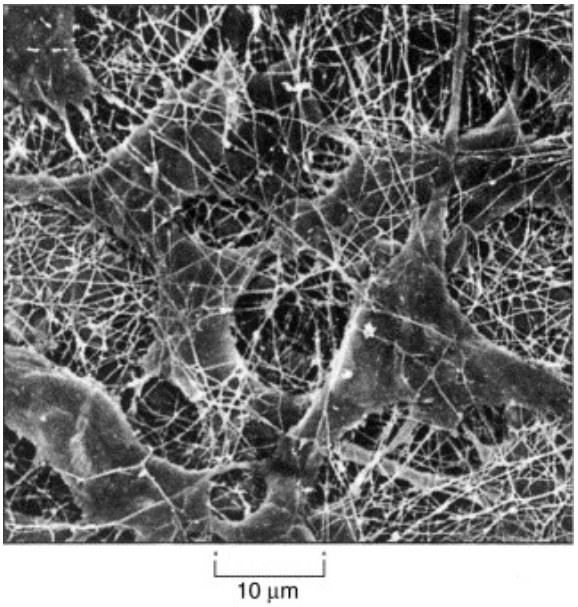
Tissues and Organs

Tissues are groups of similar cells performing a similar function. **Organs** are made up of multiple tissues working together to perform a function. Scientists are researching ways to regenerate more than 30 different tissues and organs, including skin, blood vessels, bladders, bone, kidneys, lungs and livers. Organs range in form and complexity from flat organs (such as skin) to tubes (such as blood vessels or the ureters) to hollow, bag-like organs to complex, solid organs. For example, the bladder is a hollow, bag-shaped organ lined with smooth epithelial tissue on the inside and smooth muscle tissue on the outside. Solid organs such as the kidney and liver are more complex. The kidney has multiple specialized parts to filter waste from the blood and excrete it as urine. So far, regenerative medicine techniques successfully have been used to replace damaged skin, cartilage, the urethra, the bladder and the trachea in human patients. However, all these treatments remain experimental. Many questions about materials, safety and procedure still must be answered before regenerative treatments that replace these organs become standard medical practice. It will be even longer before a complex, solid organ such as the kidney can be regenerated successfully and placed in a human patient.

Regenerative Medicine (continued)

The Extracellular Matrix: A Scaffold for Building New Organs

The first step of building replacement organs is to build a **scaffold**. Simple tissues and complicated organs are similar in that they create and reside in a supportive **extracellular matrix**. This extracellular matrix is outside the cells and consists of proteins and polysaccharides. The polysaccharides are linked to proteins to form a gel-like substance in which other fibrous proteins are embedded. The gel allows diffusion of nutrients, wastes and other chemicals to and from the cells. The fibrous proteins form a strong, resilient scaffold and help organize the cells. Amazingly, tissues and organs can be **decellularized**. In other words, all the cells can be removed, leaving only the extracellular matrix. The matrix forms a scaffold for the cells but is not itself made of living tissue. This matrix then can be used as a scaffold to build a new organ.



A scanning electron micrograph of native extracellular matrix in connective tissue. It is largely composed of collagen fibrils. The hydrogel, composed of proteoglycans and glycosaminoglycans, that normally fills the interstices of this fibrous network has been removed by the processing treatment.

To build a new tissue or organ, researchers place new cells of the desired types in the correct location on the scaffold. Then they grow the cells on the scaffold in a growth medium for several weeks. The scaffold is important not only because it provides support, but also because it influences where and how the cells grow. This helps orient the cells correctly for their function. Scaffolds can come from deceased human donors or animal organs, or they can be built from synthetic **biomaterial**. All of these are much more available than human organs suitable for transplant.

Regenerative Medicine (continued)

Challenges

Researchers studying these scaffolds are working on several challenges. One important challenge is developing biomaterials to build artificial scaffolds. These biomaterials must be nonreactive with the human immune system. They need to have the right texture to signal cells to grow and orient themselves correctly. And they need to be strong enough to last until the new organ creates its own extracellular matrix, then dissolve away like surgical sutures. Researchers also are investigating the effects of embedding various growth factors or anti-inflammatory medications in the scaffolds.

Once the scaffold materials are developed, the next challenge is building the scaffold. Just as 3D printers can make solid objects by laying down layers of plastic, 3D bioprinters are being developed that one day may be able to build human replacement organs. In ink printers, different colors of ink are kept in separate cartridges and printed together to form the exact desired color. Similarly, bioprinters can keep cells and different substances separate until placing them exactly where needed in the new tissue. Dr. Atala and the research team at the WFIRM recently demonstrated how this might work by printing out a model of a kidney with cells. However, much more research is needed before this experimental technique will be ready to build a functional kidney that can be used safely in patients.

The decellularization of animal tissues presents a different challenge: removing all the cells without damaging the function of the scaffold. This is difficult because the scaffold not only needs to have the right structure, but it also must have the right texture and the right chemical properties. Different tissues require different techniques, and these different techniques may affect the structure and composition of the scaffold in different ways. Researchers are experimenting with a variety of detergents and enzymes as well as with different protocols to perfuse the tissue and remove the cells.

Growing new cells on the scaffold and preparing the tissue or organ for its role within the body also is challenging. Growing human cells outside the body was a huge problem. Researchers are finding that many tissues have some undifferentiated cells that will reproduce and grow in the right environment

Regenerative Medicine (continued)

and with the right nutrients in the culture media. Experimentation with growth factors is leading to improved control of cell proliferation and differentiation. Researchers also are designing equipment to simulate the normal environment of the body with hydrostatic pressure, pulsing fluid flow and stretching and compressing tissues. This exercises and conditions the tissues to their environment and helps signal the growing cells to organize themselves correctly. For example, researchers grow a regenerated heart valve in a tube and pump the growth medium through the tube to simulate the rate and pressure of blood flow. Such laboratory devices are referred to as bioreactors. They play a key role in the regenerative medicine process.

Stem Cells

A variety of regenerative therapies, including production of cells to populate the extracellular matrix, depend on stem cells. Stem cells have been extremely controversial in the political arena, yet many people do not understand what they really are or why they may lead to exciting advances in medicine.

Think about your body. It is composed of many different types of cells. You already may be familiar with neurons, red blood cells and muscle cells. All these different cells must be generated from the zygote, a single cell formed by the joining of a single egg and sperm. As multicellular organisms develop from zygotes to adults, they must produce differentiated cells capable of forming all the organism's different tissues and organs. The undifferentiated cells that give rise to other types of cells are called **stem cells**. There are many different types of stem cells found at different stages of development and in different parts of the body. The hope is that these cells can be used to repair tissues and grow new organs — but to do this we must understand how these cells work. Researchers are beginning to learn how development and differentiation are controlled at the molecular level.

When a zygote first begins to grow, it is **totipotent**. This one cell can give rise to all the tissues needed for the body as well as the cell types needed for the extra embryonic tissues, such as the placenta. As the zygote divides and goes through the various stages of development, the cells begin to differentiate. The differentiation is controlled by chemical signals that cause changes in cell epigenetics. In an epigenetic change, the sequence of the nucleotides (ACGT)

Regenerative Medicine (continued)

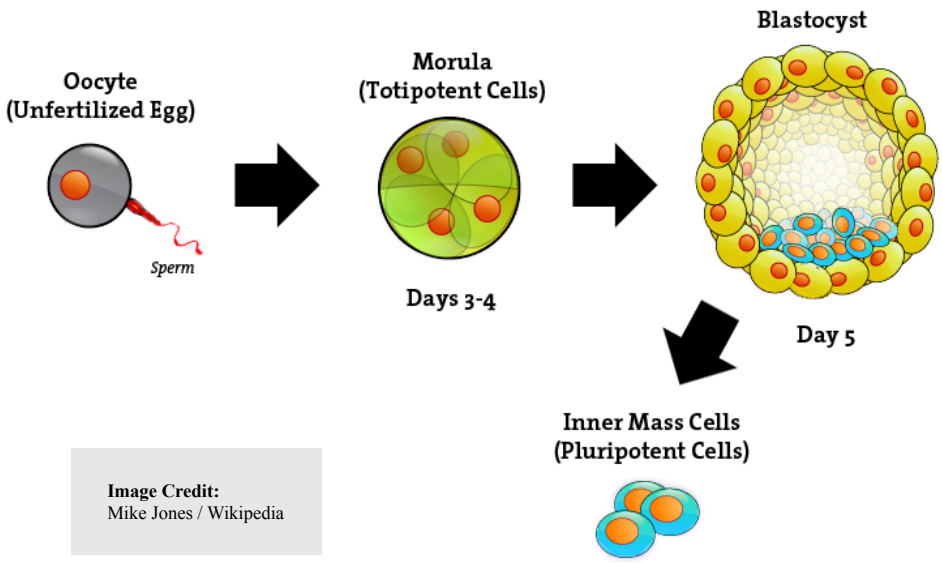


Image Credit:
Mike Jones / Wikipedia

is unchanged, but chemical changes in the chromosome turn on or off particular genes. *(See the Resources section later in this chapter for a link to more about epigenetics.)* These genes then stay on or off even as the cell divides so that the changes are passed on to the daughter cells. This means that normally once a cell has differentiated into one type of cell (a nerve cell, for example) it can't differentiate backward into another type of cell. Therefore, even though each cell in an organism has all the information for all the types of cells found in that organism, only some of this information is available to the cell.

Embryonic stem cells are **pluripotent**. Pluripotent cells can give rise to all the other types of body cells. Human embryonic stem (hES) cells are derived from human embryos created as a part of the *in vitro* fertilization process at fertility clinics. The embryonic stem cell lines come from extra embryos donated for research purposes. The hES cells come from cells taken from the blastocyst stage of the embryos. Because this has the potential to save lives but also destroys these embryos, creation of new embryonic stem cells has been the subject of much ethical and legal debate.

Adult stem cells (also called somatic stem cells) are undifferentiated cells found in differentiated tissues of children and adults. These stem cells are **multipotent**. They can give rise to the multiple cell types needed in the tissue

Regenerative Medicine (continued)

they come from, but due to epigenetic control they are no longer pluripotent. Until the mid-2000s, most types of adult stem cells were difficult to find and work with, and little was known about them. Only stem cells found in the bone marrow (hematopoietic stem cells and bone marrow stromal cells) currently are used in standard medical treatments.

Hematopoietic (blood) stem cells have been used successfully for years to treat various blood disorders such as leukemia and lymphoma. In these cases, stem cells from the patient or donor's bone marrow replace diseased bone marrow cells. Treatments using other types of stem cells are mostly in preclinical stages or early clinical trials. Even the mechanisms by which the stem cells might help are not yet well understood. Stem cells may help replace diseased tissue either by integrating with the tissue and producing new cells or by producing growth factors that cause the patient's cells to regenerate and repair themselves.

Researchers also are experimenting with various approaches to regrowing skin on burn patients. First, skin stem cells are isolated from an unburned area on the patient's own skin. Then, the printer or spray gun is used to place the skin stem cells and other skin cells directly on the burn. A special bandage that provides nutrient fluids and clears wastes supports the healing tissue. The stem cells provide growth factors to the damaged skin so it can regrow rather than integrating with it and becoming part of the new skin. The growth factors promote healing, and although the spray gun has not yet been used in humans, initial results show these types of techniques can promote much faster recovery from serious burns.

Many other researchers also are working to develop new treatments using stem cells. In 2012, there exist clinical trials testing the safety of using retinal cells derived from human embryonic stem cells to treat two progressive eye diseases that usually result in blindness. Other clinical trials are testing the use of stem cells to treat heart disease, diabetes and many other diseases.

In 2006, Japanese researchers published the first report of induced pluripotent stem cells (iPSCs) in mice. In 2007, that group and two others published results indicating they had created pluripotent stem cells from adult cells in humans.

Regenerative Medicine (continued)

They did this by using viruses to insert genes for transcription factors into the DNA of various types of cells. This seemed to reprogram the cells back to an undifferentiated state. The resulting cells then could be cultured and induced to differentiate into adult cells of various types — even beating heart muscle. These induced pluripotent stem cells are exciting because researchers are able to use them to create cultures of tissues from organisms with various diseases, which allows for *in vitro* studies of disease processes and potential drug treatments. They also increase the potential for growing replacement tissues or even organs from a patient's own cells, which reduces the likelihood of rejection. iPSCs already have been successful in treating blood disorders in mice. Unfortunately, the reprogrammed cells are not exactly like embryonic stem cells. They do not always behave in the same way, they have different epigenetic markers and they sometimes lead to tumors in experimental animals. More research is needed to understand how to control the programming of these cells.

Another newly discovered source of stem cells is human amniotic fluid. Amniotic fluid is the fluid that surrounds the developing baby in the womb. Amniotic fluid-derived stem cells come from the amniotic fluid taken in an amniocentesis or naturally produced at birth. Thus, they do not involve destroying an embryo. They are multipotent and can form all sorts of tissues. Unlike embryonic stem cells, they do not form tumors when grown in animals. Scientists are continuing to study the effects of various growth factors on the growth and differentiation of amniotic fluid stem cells when placed into various types of tissues and scaffolds.

Engineering New Bone Tissue

Dr. Elizabeth Loboa and her research team at North Carolina State University's Cell Mechanics Laboratory are doing work that will lead to better understanding of bone and muscle regeneration. This team is studying the effects of the mechanical environment on bone formation. In addition to regulation by transcription factors, stem cells found in bone respond to electrical signals,

Regenerative Medicine (continued)

the physical environment and mechanical signals — including the amount and direction of stress, tensile strain (pulling), compression and hydrostatic pressure. For example, the right amount of tensile strain on these stem cells results in formation of new bone tissue, while greater strain results in scar tissue. Bone cells have a variety of receptor molecules that cross the cell membrane and respond to these changes in the mechanical environment by changing shape. This presents new binding sites and sets off biochemical changes within the cell. (This translation of a mechanical signal to a biochemical signal is called mechanotransduction.) Physical properties of the extracellular membrane, such as fiber diameter, stiffness and the size of niches in which cells can settle, also are important. Researchers are investigating scaffold characteristics and scaffolds that slowly can release medications to speed healing, reduce inflammation and prevent infection. Eventually, this research will lead to new treatments for wounded veterans and others who have lost or damaged bones, as well as for infants born with bone deformities.

Careers in Regenerative Medicine

Regenerative medicine depends on bringing together fundamental research from many areas of medicine and on moving research from basic science to animal trials to clinical trials in humans and patient care. This can be done more efficiently with a large, coordinated team approach than with the more traditional academic departments in which each senior scientist leads an independent research team. At the WFIRM, for example, teams of scientists working together include molecular biologists, cell biologists, physiologists, pharmacologists, biomedical engineers, surgeons, veterinarians and many more.

Focus on Technicians: Jay Barrett

Jay Barrett is a Core Technician at the WFIRM. He supports a large group of researchers. His responsibilities include managing operations and equipment, supplies control, giving tours and keeping records. Because WFIRM researchers share laboratory space and equipment, it is Jay's job to maintain systems that

Regenerative Medicine (continued)

ensure people keep the laboratory clean and organized. He maintains and repairs machines as needed and enjoys experimenting with the electrospinning machine that is used to build scaffolds. Jay's first degree was in business, but he found his career in finance unfulfilling and went back to school to get an Associate degree in biotechnology from Forsyth Technical Community College. At Forsyth Tech, Jay took courses in cell culture, bioprocessing, statistics and aseptic techniques. As part of that program, he was able to do an internship at the WFIRM, where he became hooked on the excitement of the science of regenerative medicine.

Jay's advice to students is to do as well as possible in each subject because this will lead to better opportunities. He thinks it is especially important to study statistics because it is so important to the analysis of data in every field of research. He also thinks it is essential to continue learning. Jay enthusiastically attends all the weekly research seminars at the WFIRM. This gives him the opportunity to learn the latest techniques and findings from world-class researchers.

Focus on Scientists: Elizabeth Loboa

Dr. Elizabeth Loboa is the Associate Chair and an Associate Professor in the Joint Department of Biomedical Engineering at the University of North Carolina at Chapel Hill and North Carolina State University. She also is an Associate Professor in Materials Science and Engineering at NCSU and the founding director of the Cell Mechanics Laboratory in the UNC-CH/NCSU Biomedical Engineering department. Dr. Loboa studies how physical stimuli regulate stem cells. Her research group is studying the mechanical signaling pathways involved in bone regeneration. This can be important for bone healing and creating bone implants. They are studying the effects of tension, pressure and electrical and chemical signals, as well as the effects of various scaffold structures on bone cell growth and differentiation.

Dr. Loboa became interested in engineering at Modesto (California) Junior College. She then took a biology course and became fascinated by the idea of applying a mechanical engineering approach to biological and especially

Regenerative Medicine (continued)

medical problems. She went on to do research as an undergraduate at the University of California, Davis, where she earned a B.S. in Mechanical Engineering. She continued her education at Stanford University, where she earned an MSE in Biomechanical Engineering and a Ph.D. in Mechanical Engineering. Dr. Loboa encourages students to make what they love a part of their careers and to think outside the box when solving important problems. By thinking beyond traditional boundaries she was able to combine biology and mechanical engineering before this was a well-recognized field of study.

Special Thanks To...

Dr. George Christ, Dr. Koudy Williams, Dr. Benjamin Harrison, Jay Barrett, Dr. Patricia Wilson, Dan Deegan, Dr. Anthony Atala and Karen Richardson, of the Wake Forest Institute for Regenerative Medicine, and Dr. Elizabeth Loboa, of the Joint Department of Biomedical Engineering at the University of North Carolina at Chapel Hill and North Carolina State University for their invaluable help in developing this chapter.

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Regenerative Medicine (continued)

Resources

TED Talk: Growing new organs

http://www.ted.com/talks/anthony_atala_growing_organs_engineering_tissue.html

In this TED talk, Dr. Anthony Atala explains the challenges of growing new organs and shows some of the techniques he and the WFIRM team are researching. The 17-minute video is freely available online.

TED Talk: Printing a human kidney

http://www.ted.com/talks/anthony_atala_printing_a_human_kidney.html

In this TED talk, Dr. Anthony Atala explains some of the concepts and research behind the idea of printing new organs and introduces Luke Massella, one of the first recipients of a regenerated bladder. The 17-minute video is freely available online.

National Geographic Video

http://video.nationalgeographic.com/video/national-geographic-channel/full-episodes/explorer/ngc-how-to-build-a-beating-heart

A video that shows experimentation leading to growing new organs.

Bladder Management

http://www.christopherreeve.org/site/c.mtKZKgMWKwG/b.4453411/k.BF84/Bladder_Management.htm

A nice explanation of the function of the urinary system and problems with paralysis by the Christopher & Dana Reeve Foundation.

Regenerative Medicine (continued)

The Extracellular Matrix

http://www.ncbi.nlm.nih.gov/books/NBK26810

An excellent discussion of function of the extracellular matrix in animal tissues, particularly connective tissue.

Epigenetics

http://learn.genetics.utah.edu/content/epigenetics

The University of Utah's Learn Genetics website has an excellent set of readings, videos and interactive activities exploring recent research in epigenetics.

Stem Cells

http://learn.genetics.utah.edu/content/tech/stemcells

The University of Utah's Learn Genetics website has an excellent set of readings, videos and interactive activities exploring recent research in stem cells.

The Promise of Induced Pluripotent Stem Cells (iPSCs)

http://stemcells.nih.gov/info/Regenerative_Medicine/2006Chapter10.htm

An overview of induced pluripotent stem cells from the National Institutes of Health.

Cell Mechanics Laboratory

http://www.bme.unc.edu/labs/cml/index.html

North Carolina State University's Cell Mechanics Laboratory website has pages describing the research Dr. Loboa and her team are doing.

Discover the Scaffolding of Tissue

Procedure adapted with permission from Evaluation of Decellularization Procedures for Porcine Arteries *by Aubrey Smith of California Polytechnic State University.*

Learning Outcomes

- Students will investigate scaffolding and decellularization of animal tissues.
- Students will explain how an extracellular matrix can be used for scaffolding of engineered tissue.

Key Vocabulary

- Scaffold
- Decellularization
- ECM (extracellular matrix)
- Tissue engineering

Time Required

- Approximately 60 minutes of preparation time
- Approximately 3 days of tissue washing
- Approximately 90 minutes of class time for activity and discussion over 2 days

Materials

- Magnetic stirrer
- Animal tissue
- 10% liquid SDS (sodium dodecyl sulfate solution)
- Razor blade/scissors
- Sterile PBS (phosphate buffered saline solution)

Background Information

The body is composed of organs. Organs are composed of tissues. Tissues are composed of living cells and an extracellular matrix. The matrix is made by the cell. It consists of proteins, such as elastins and collagens, and proteoglycans,

Discover the Scaffolding of Tissue (continued)

which are proteins attached to polysaccharides. The living cells can be washed away with detergent, leaving the extracellular matrix. The matrix then can be used as a scaffold for growing new tissues and organs. In this activity, students will remove the living cellular material from animal tissue to reveal the scaffolding of the tissue.

Teaching Notes

Any animal tissue may be decellularized. Solid organs may take weeks to decellularize and require more specialized equipment to perfuse the tissues. For a classroom exercise, a thinner material such as a vein will work better. Ask a butcher to prepare a vein from animal tissue. For this activity, the animal tissue may be frozen or fresh. The teacher may speed up the process by cutting the tissue into the pieces for the student groups. Provide time for each student group to observe the tissue before and after decellularization. These observations may be completed with a microscope.

The tissue must be washed with a detergent solution made from SDS (sodium dodecyl sulfate solution). SDS can be purchased from a chemical supply company. A 0.075% SDS solution, which is appropriate for decellularization, can be made from 10% liquid SDS stock solution. SDS also can be found in several shampoos and toothpastes.

The following equations may be used to calculate the desired volume of 0.075% SDS solution:

Amount of pure SDS solution needed for 75mL of 0.075% SDS solution:
Desired % of SDS in the final solution (decimal form) × 75mL total volume = Volume of pure SDS solution needed

Amount of 10% SDS solution needed for 75mL of 0.075% SDS solution:
Volume of pure SDS (eqn1) ÷ 0.10 (percent dilution of SDS) =
Volume of SDS needed

Example calculation for 0.075% SDS in a 75mL of solution:
Equation 1: 0.00075 × 75mL = 0.05625mL

Equation 2: 0.05625mL ÷ 0.10 = 0.56mL of 10% SDS

For a 75mL solution, 0.56mL of the SDS solution is added to 74.4mL of PBS water

Discover the Scaffolding of Tissue (continued)

The tissue must be stirred for at least 20 hours in the SDS solution before washing. Plan ahead before implementing the activity to ensure the lab can be completed in back-to-back days. After the tissue has been decellularized, the extracellular matrix should be washed with PBS (phosphate buffered saline) solution. PBS solution may be purchased from a chemical supply company.

Safety

Students should use proper laboratory techniques. This process uses animal tissue, so proper care should be taken in handling the materials. Students should wear safety goggles. Please dispose of the tissue properly.

Procedure

Begin the discussion by asking students what the body is composed of. Allow the students to discuss the cells and ask to see if they think there is any structure supporting the cell. Explain that in this activity they will investigate the supportive materials that surround the outside of cells.

Remove tissue from the freezer and defrost the tissue in a warm water bath. (If fresh tissue is used, skip this step.) Cut the tissue into 4 cm to 5 cm sections using scissors or a razor blade. Observe the tissue. Describe the look and feel of the tissue. Use a magnifying glass to make careful observations.

Have students place their tissue pieces in a labeled beaker of 0.75% SDS solution. All tissue pieces may be placed in the same beaker. Place the beaker on the mixer and stir for at least 20 hours. Pour the SDS solution down the drain. Give each group a piece of decellularized tissue and allow the students to rinse the material five times for 10 minutes with sterile PBS. Observe the remaining material. All that should remain is the extracellular matrix. Describe the look and feel of the material. Use a magnifying glass to make careful observations.

Discover the Scaffolding of Tissue (continued)

Assessment

Students should complete the *Discover the Scaffolding of Tissue* Handout. Students should work together to create a poster explaining how scaffolding is the basis for tissue and organ engineering.

Extension

The activity may be extended by allowing students to figure out the most effective protocol. Students may try different types of detergent or compare forms of tissue, such as frozen, defrosted or fresh.

Discover the Scaffolding of Tissue

Engineered tissues and organs need material on which to grow. The base structure for animal tissues and organs is called the extracellular matrix. It functions as a supportive structure, or scaffold, for tissue growth and repair. It normally is created by an organism's own cells. However, doctors have learned to use extracellular matrix from pig intestines to help repair human injuries and scientists are experimenting with creating artificial scaffolds in the laboratory. New cells may be placed on the new scaffold to grow replacement tissues. In this activity, you will investigate the scaffolding of tissue.

Procedure

1. Remove tissue from the freezer and defrost the tissue in a warm water bath. (If fresh tissue is used, begin at step 2.)
2. Cut the tissue into 4 cm to 5 cm sections using scissors or a razor blade.
3. Observe the tissue. Describe the look and feel of the tissue. Use a magnifying glass to make careful observations.
4. Place the tissues in a beaker of 0.75% SDS solution (detergent).
5. Place the beaker on the mixer and stir for at least 20 hours.
6. Pour the SDS solution down the drain.
7. Rinse the decellularized material five times for 10 minutes with sterile PBS.
8. Observe the decellularized material. Describe the look and feel of the material. Use a magnifying glass to make careful observations.

Observations

Original Tissue	Decellularized Material

Discover the Scaffolding of Tissue (continued)

Discussion Questions

1. What is decellularization?

2. What is the extracellular matrix? What is it composed of?

3. What features of the original tissue can be seen in the matrix? How can this matrix be used for regenerative medicine?

4. What other types of materials could be used as scaffolding for tissue engineering? What characteristics of the material would allow it to be used as scaffolding?

Building Better Tissue

Procedure adapted with permission from Alginated Worms *by A. Harper and K. Nickels of Queensland University of Technology.*

Learning Outcomes

- Students will define scaffolding.
- Students will create simple structures, such as sphere or worm, with sodium alginate and a calcium water bath.
- Students will demonstrate the connection between scaffolding and the sodium alginate experiment by creating a poster to explain tissue and organ engineering.

Key Vocabulary

- Regenerative medicine
- Organ engineering
- Scaffold

Time Required

- Approximately 15 minutes of teacher prep time
- Approximately 90 minutes of class time for lab and discussion

Materials

For Demonstration	For 15 Lab Sets
25mL Gaviscon (over-the-counter heartburn medication)	375mL Gaviscon (over-the-counter heartburn medication)
100mL 1% w/v calcium chloride solution	1.5L 1% w/v calcium chloride solution
75mL saturated sodium chloride solution	1.125L saturated sodium chloride solution
2 containers or beakers	30 containers or beakers
1 plastic syringe	30 plastic syringes

Building Better Tissue (continued)

Background Information

Perhaps you have seen scaffolding surrounding a building. This kind of scaffolding is a temporary support for people and supplies to build and remodel the building. Once the building is complete, the scaffolding is removed. In regenerative medicine, tissue and organs can be engineered and built, then placed in the body. But the tissue and organs need support to grow. In animals this support is provided naturally by the extracellular matrix, which is made by the cells themselves. Scientists at the Wake Forest Institute for Regenerative Medicine are experimenting with various ways to provide this supportive structure for replacement tissues and organs. One way is to use decellularized animal tissues. Another way is create a scaffold with synthetic or biocompatible materials that will support new cell growth then gradually break down and be replaced by the extracellular matrix created by the patient's own cells.

These scaffolds are being engineered to create a support structure for the cells. Scientists are experimenting to see which materials and textures work best. They also are working on adding beneficial chemicals such as growth factors and anti-inflammatory agents. In this activity students will create a chemically engineered support to hold another chemical together in a threadlike structure.

This activity is a great way to introduce students to materials engineering. Scientists must investigate which materials have the right characteristics to support and direct the growth of the engineered tissue. The materials must be put through numerous trials. In this activity, the students will be materials engineers and will try to discover the best way to create structures to hold a given liquid.

Teaching Notes

Alginate are used in medicine and as a thickener for foods. In the past 10 years, sodium alginate ($NaC_6H_7O_6$) has been cross-linked with calcium ions to form spheres and threads in which food has been presented in unique ways, such as the fruit caviar you might find as a topping in a frozen yogurt shop. In this experiment students will cross-link alginate with the calcium ions to form threads and spheres.

$$NaC_6H_7O_6 + CaCl_2 \rightarrow CaC_6H_7O_6 + 2NaCl$$

Building Better Tissue (continued)

Gaviscon is an over-the-counter antacid medicine found in many drug stores. One of its components is alginate. Calcium chloride may be purchased from a chemical supply company. It also is the main component of the moisture absorber DampRid, which is available at building supply and drug stores. The calcium chloride solution can be created by making 100mL of 1% w/v (weight of solute/volume of solution) solution by adding 1 gram of calcium chloride (or DampRid) to 100mL of water. Calcium ions will be formed by dissolving the calcium chloride in water.

In medicine, alginate is used in making scaffolds for tissue engineering and cell culture as well as to create bandages. Alginate dressings aid in wound healing because they can slowly release medications and eventually be absorbed by the body.

Safety

Students should use proper laboratory techniques. Even though this process is used in food processing, the materials used in this lab should not be ingested. Students should wear safety goggles. Do not swallow these products.

Building Better Tissue (continued)

Procedure

Begin the discussion by showing the picture of scaffolding below. Ask students to name what is in front of the building and explain how it is used. Encourage the students to see that scaffolding provides support for building and for supplies.

Explain that the activity will show how chemicals can be manipulated to create support like this scaffolding. Pour 100mL of calcium chloride solution into a container. Pour Gaviscon into another container. Squirt Gaviscon into the calcium chloride solution. Do not to allow the calcium chloride solution to be sucked back into the sodium alginate pipette. If the calcium chloride goes into the pipette, it will become clogged with cross-linked ions. Encourage the students to see what shapes they can create. Allow the students to take their creations out of the calcium chloride solution and onto a paper plate for observation.

Building Better Tissue (continued)

Assessment

Students may complete the *Building Better Tissue* student handout. Students should work together to create a poster explaining how scaffolding is the basis for tissue and organ engineering.

Extension

The activity may be extended by researching the types of materials used to create scaffolds and the advantages and disadvantages of each type. Students may use the resources found on selected websites, such as the Regenerative Medicine Foundation (http://www.regenerativemedicinefoundation.org).

Building Better Tissue

Engineered tissues and organs need materials on which to grow. The base structure for tissues and organs is called a scaffold. In this activity chemicals will be used to create a support for other materials.

Procedure

1. Pour 100mL of calcium chloride solution into a labeled container.
2. Pour Gaviscon into a different labeled container.
3. Squirt Gaviscon into the calcium chloride solution. Be careful. Do not allow the calcium chloride to be sucked into the pipette. Observe.
4. Record and draw what happened.

5. Create as many different shapes as you can. What other shapes can you create?

6. Take the shapes out of calcium chloride solution. How do the shapes act outside the solution?

Building Better Tissue (continued)

Discussion Questions

1. What is scaffolding?

2. How could the different shapes created in this activity help in organ engineering?

3. What characteristics should scaffolding used in regenerative medicine have?

Stem Cells Are All the Same … Aren't They?

Learning Outcomes

- Students will define a stem cell.
- Students will research information on different types of stem cells, such as multipotent stem cells and pluripotent stem cells.
- Students will create and present a commercial for the assigned type of stem cell.
- Students will analyze the advantages and disadvantages of the different types of stem cells.

Key Vocabulary

For All Classes:

- Stem cell
- Adult stem cell
- Embryonic stem cell
- Totipotent stem cell
- Pluripotent stem cell
- Multipotent stem cell
- Hematopoietic stem cells

For AP Classes:

- Induced pluripotent cell
- Mesenchymal stem cells
- Neural stem cells (NSCs)

Time Required

- Approximately 90 minutes to research stem cells (may be done outside of class)
- Approximately 60 minutes to create stem cell commercial (may be done outside of class)
- Approximately 90 minutes to present commercials and conduct gallery walk (for class of 30 students)

Stem Cells Are All the Same … Aren't They? (continued)

Materials

- Computers with Internet access and print materials for research
- Rubric

Background Information

Regenerative medicine holds the possibility of using stem cells to engineer and grow tissues and organs. Stem cells have been politically controversial. But the media often neglects to discuss what stem cells really are, how they are being used in research and treatments, the many different kinds of stem cells and recent advances in stem cell research that may reduce or eliminate the need for controversial embryonic stem cells.

Stem cells can be used as unique building blocks in bioengineering and growing tissues and organs. This activity will provide students opportunities to define stem cells and research their characteristics.

Teaching Notes

This activity asks students to use the Internet to research what stem cells are and the different types of stem cells. The vocabulary list has suggestions for all classes to research and additional terms for AP classes. The students will research the characteristics, advantages and disadvantages of different stem cells. To make the most effective use of student research time, suggested resources have been provided. Depending on student access to the Internet, you may choose whether to have students do this research in or out of class. After gathering and synthesizing information, the students will create a commercial to share their findings with other students. The commercials may be presented as a skit for the class or as a video file. The discussion of stem cells will culminate with a gallery walk that synthesizes the stem cell information.

Sharing the rubric at the end of this lesson plan helps students meet expectations.

Stem Cells Are All the Same … Aren't They? (continued)

Safety

Students should follow school/district Internet access guidelines to ensure safe browsing.

Procedure

Begin with warm-up questions: *What is a stem cell? Where have you heard this phrase?* Discuss answers and list them on the board. Explain to students they will have the opportunity to define this term and research how different types of stem cells are used in different therapies.

Explain that stem cells are the worker cells of regenerative medicine. The students will work to answer the question *What is a stem cell?* They will use two to three resources to research this basic question and find out what is different between adult and embryonic stem cells. In order to move to the next section of this activity, each student will write a paragraph explaining what a stem cell is, which may be used as a formative assessment.

After the students have completed their paragraph satisfactorily, students will be placed in a group of two or three students and choose to research pluripotent or multipotent stem cells. (The teacher will need to make sure students are evenly divided between these topics.) Their research will be presented to the rest of the class in a one- to two-minute commercial. The student will be required to explain how the specific stem cell is used and the advantages and disadvantages.

Discussion: Helping Students Build Understanding and Make Connections
After students share the commercials they will synthesize the information by completing a gallery walk. Place four (or more) posters on the wall with the following labels: *Pluripotent Advantages*, *Pluripotent Disadvantages*, *Multipotent Advantages*, *Multipotent Disadvantages*. Divide the class into groups of no more than four students each. Students in each group will write down as many facts on the sheet as they can remember in three minutes. After three minutes, the posters will be passed to the next group and the process repeated until all groups have written on each of the posters. Place the posters on the wall and allow students to walk around the room silently and place two checks on each paper for the strongest point. These posters will provide a visual representation of the research that can be posted in the class and referred to throughout this course. To conclude the discussion, allow students to create a

Stem Cells Are All the Same … Aren't They? (continued)

concept map showing the connections between the types of stem cells, such as the diagram below.

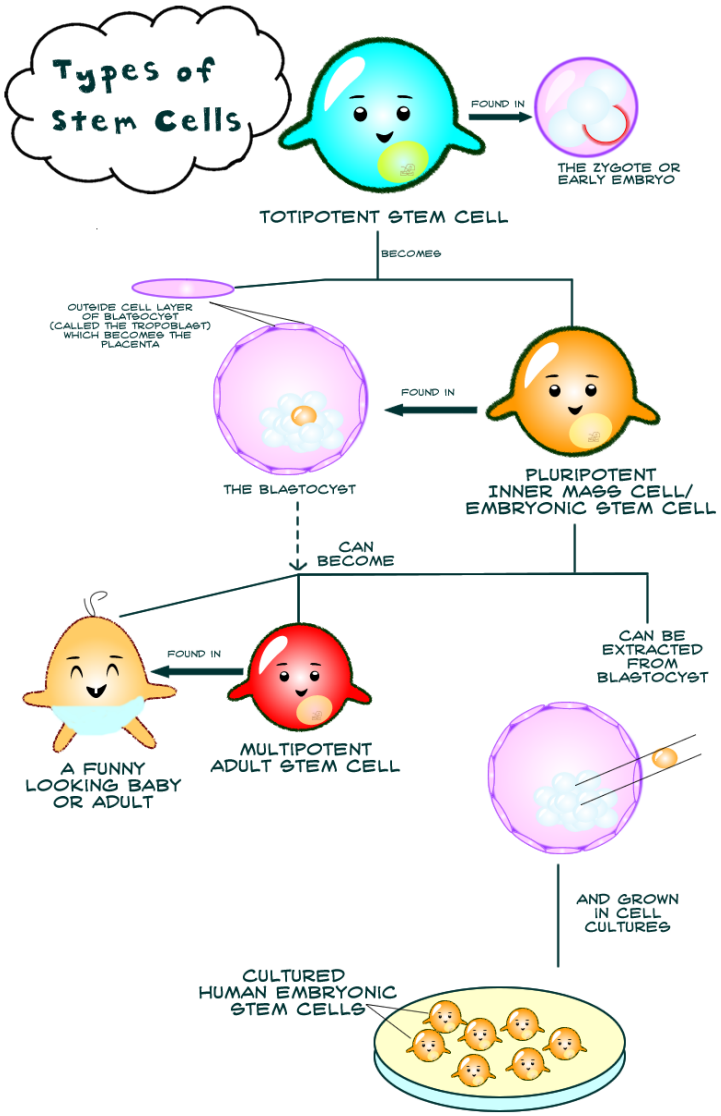

Image Credit: Stem Cells FAQ

Stem Cells Are All the Same … Aren't They? (continued)

Assessment

The student work should be evaluated using a rubric. (A suggested version is provided at the end of this lesson plan.) Rubrics help students understand what is expected of them. They should be shared with students in advance and may be developed with students. Teachers may adjust this rubric to fit their grading system and to emphasize different aspects of the project as appropriate for their curriculum.

Extension

This activity may be extended by asking students to research how stem cells may be used to combat chronic disease, such as cancer.

Resources

There is a plethora of stem cell information online. Because this research area is evolving rapidly, online information is more likely to be up-to-date than information in print. Some options include:

National Institutes of Health

The National Institutes of Health has a number of resources on stem cells, including:

- Current Research
  http://stemcells.nih.gov/research/current.asp
- Frequently Asked Questions
  http://stemcells.nih.gov/info/faqs.asp
- Stem Cell Basics
  http://stemcells.nih.gov/info/basics
- Stem Information Glossary
  http://stemcells.nih.gov/info/glossary.asp

Other

- GlaxoSmithKline Cloning Technologies and Stem Cell Research
  http://www.gsk.com/policies/GSK-on-cloning-technologies-and-stem-cell-research.pdf

Stem Cells Are All the Same … Aren't They? (continued)

- Information for Patients
  http://stemcells.wisc.edu/patients
- StemBook
  http://www.stembook.org
- Stem Cell Facts (PDF)
  http://www.isscr.org/public/ISSCR08_PubEdBroch.pdf
- Stem Cell Research: Science and the Future
  http://www.npr.org/templates/story/story.php?storyId=5204335
- Stem Cells at Genetics Science Learning Center
  http://learn.genetics.utah.edu/content/tech/stemcells
- Stem Cells: What They Are and What They Do
  http://www.mayoclinic.com/health/stem-cells/CA00081
- Tissues of Life
  http://www.smm.org/tissues/stem_cells.php

Stem Cells Are All the Same … Aren't They? (continued)

Rubric

Category/ Points	4	3	2	1
Notes and sources	Student took notes for each section and shows sources of all information.	Student took notes for most sections (4 or more) and shows sources of most.	Student took notes for at least 2 sections and shows sources for some information.	Student found little information or does not show any sources.
Commercial content	Shows a full understanding of the stem cell.	Shows a good understanding of the stem cell.	Shows partial understanding of the stem cell.	Does not seem to understand the stem cell very well.
Accuracy (of both written notes and oral presentation)	Student uses appropriate sources. Material accurate based on available sources.	Presents accurate material 90% to 95% of the time.	Presents accurate material 75% to 89% of the time.	Hard to tell if the student knew the material.
Comprehension	Student is able to accurately articulate the topic.	Student is able to accurately articulate most of the topic.	Student is able to accurately articulate part of the topic.	Student is unable to accurately articulate the topic.
Commercial quality	Provides an exceptional commercial that meets the time requirements.	Provides a complete commercial that falls within 30 seconds of the time requirements.	Provides a simple commercial that does not meet the time requirements.	Performs the commercial in-person for the class and/or does not complete the commercial.

Stem Cells Are All the Same … Aren't They?

What is a Stem Cell?

Stem cells. This phrase is heard on the news. Politicians talk about them. But what are they?

Before delving deeper into the uses of different types of stem cells, define the phrase "stem cell." Write a paragraph definition and provide an explanation of adult and embryonic stem cells. Use the resources below to assist your research.

- GlaxoSmithKline Cloning Technologies and Stem Cell Research
  http://www.gsk.com/policies/GSK-on-cloning-technologies-and-stem-cell-research.pdf
- Information for Patients
  http://stemcells.wisc.edu/patients
- StemBook
  http://www.stembook.org
- Stem Cell Basics
  http://stemcells.nih.gov/info/basics
- Stem Cell Facts (PDF)
  http://www.isscr.org/public/ISSCR08_PubEdBroch.pdf
- Stem Cell Research: Science and the Future
  http://www.npr.org/templates/story/story.php?storyId=5204335

Stem Cells Are All the Same … Aren't They? (continued)

Create a Commercial

Your team has just been asked to produce a commercial explaining what a stem cell is and how a specific type of stem cell (pluripotent or multipotent) is used. Your job is to research the specific type of stem cell assigned. Find the answers to the following questions. On another sheet of paper make a chart similar to this one but with enough space to record all your findings. Be sure to record the sources of your information

Stem cell classification: _____

	Notes	Source of Information
Definition		
Source		
Use		
Advantages		
Disadvantages		

Stem Cells Are All the Same … Aren't They? (continued)

Use the resources below to assist your research.

- Current Research
  http://stemcells.nih.gov/research/current.asp
- Frequently Asked Questions
  http://stemcells.nih.gov/info/faqs.asp
- GlaxoSmithKline Cloning Technologies and Stem Cell Research
  http://www.gsk.com/policies/GSK-on-cloning-technologies-and-stem-cell-research.pdf
- Information for Patients
  http://stemcells.wisc.edu/patients
- StemBook
  http://www.stembook.org
- Stem Cell Basics
  http://stemcells.nih.gov/info/basics
- Stem Cell Facts (PDF)
  http://www.isscr.org/public/ISSCR08_PubEdBroch.pdf
- Stem Cell Research: Science and the Future
  http://www.npr.org/templates/story/story.php?storyId=5204335
- Stem Cells: What They Are and What They Do
  http://www.mayoclinic.com/health/stem-cells/CA00081
- Stem Cells at Genetics Science Learning Center
  http://learn.genetics.utah.edu/content/tech/stemcells
- Stem Information Glossary
  http://stemcells.nih.gov/info/glossary.asp
- Tissues of Life
  http://www.smm.org/tissues/stem_cells.php

Regenerative Medicine: Changing Life

Learning Outcomes
- Students will define regenerative medicine.
- Students will use online resources to research current advancements in regenerative medicine.
- Students will create and present a magazine cover highlighting current advancements in regenerative medicine.

Key Vocabulary
- Regenerative medicine
- Organ engineering
- Scaffold
- Bioprinting

Time Required
- Approximately 90 minutes to research regenerative medicine (may be done outside of class)
- Approximately 60 minutes to create regenerative medicine magazine cover (may be done outside of class)
- Approximately 90 minutes to present regenerative medicine covers (for class of 30 students)

Materials
- Computers with Internet access and print materials for research
- Rubric

Background Information
Regenerative medicine holds the possibility of using stem cells to engineer and grow tissues and organs. In the past, if someone had a diseased bladder he or she most likely would develop kidney disease and possibly would die. But in 2001, a young boy was given a new bladder that had been grown for him in the lab. This field of medicine continues to evolve, thus students must keep up with new advances by reading current research.

Regenerative Medicine: Changing Life (continued)

Teaching Notes

This activity allows students to work in groups to complete a webquest to learn about regenerative medicine and the advances in it. Depending on student access to the Internet, you may choose to have students do this research in or out of class. After gathering and synthesizing information, the students will create a magazine cover highlighting their favorite advances in regenerative medicine. This activity may be adapted into an individual project.

Safety

Students should follow school/district Internet access guidelines to ensure safe browsing.

Procedure

Begin by watching a video on regenerative medicine, such as *Heal, Feed, Sustain: How Biotechnology Can Help Save the World* (http://www.ncabr.org/biotech) or PBS NewsHour's *Spare Part For Humans* (http://www.pbs.org/newshour/bb/science/july-dec11/tissuescience_12-15.html). After watching the video, the students will have many questions. Write these questions on the board. Explain that they will be able to answer many of these questions and others after completing this project.

Explain that regenerative medicine is a constantly changing field, thus they will be using online resources to discover current advances. The student will work in groups of two to complete the following *Regenerative Medicine: Changing Life* handout. The students will use two to three resources to answer the questions. In order to move to the next section, the teacher may use the student sheet as a formative assessment.

After the students have completed the research, the students will create a magazine cover highlighting a key use of regenerative medicine and details of this use.

Regenerative Medicine: Changing Life (continued)

Assessment

The magazine cover may be evaluated using the rubric at the end of this lesson plan. Rubrics help students understand what is expected of them. They should be shared with students in advance and may be developed with students. Teachers may adjust this rubric to fit their grading system and to emphasize different aspects of the project as appropriate for their curriculum.

Extension

This activity may be extended by asking students to research and create a projected timeline for the research and clinical trial process for the new applications of regenerative medicine.

Resources

There is a plethora of stem cell information online. Because this research area is evolving rapidly, online information is more likely to be up-to-date than information in print. Some options include:

A Brief Definition of Regenerative Medicine
http://www.future-science-group.com/_img/pics/A_brief_definition_of_regenerative_medicine.pdf

California Institute for Regenerative Medicine
http://www.cirm.ca.gov

Cell and Gene Therapies
http://www.wakehealth.edu/research/research_default.aspx?id=46066

Inside Regenerative Medicine from the North Carolina Biotechnology Center
http://www.ncbiotech.org/business-commercialization/biotech-sectors/regenerative-medicine/inside-regenerative-medicine

McGowan Institute for Regenerative Medicine
http://www.mirm.pitt.edu

Regenerative Medicine: Changing Life (continued)

Military Applications
http://www.wakehealth.edu/Research/WFIRM/Research/Military-Applications.htm

Regenerative Medicine
http://stemcells.nih.gov/info/scireport/2006report.htm

Replacement Organs and Tissues
http://www.wakehealth.edu/research/research_default.aspx?id=46887

Tengion (video)
http://www.tengion.com/news/video1-small.cfm

Wake Forest Institute for Regenerative Medicine
http://www.wakehealth.edu/WFIRM

WFIRM In The News
http://www.wakehealth.edu/Research/WFIRM/News/WFIRM-in-the-News.htm

Regenerative Medicine: Changing Life (continued)

Rubric

Category/ Points	4	3	2	1
Notes and sources	Student took notes for each section and shows sources of all information.	Student took notes for most sections (6 or more) and shows sources of most.	Student took notes for at least 3 sections and shows sources for some information.	Student found little information or does not show any sources. Cites none of the pictures used.
Content from the webquest	Shows a complete understanding of a regenerative medicine advancement. Cites all pictures used.	Shows a good understanding of regenerative medicine advancement. Cites some pictures used.	Shows partial understanding of regenerative medicine advancement. Cites one of the pictures used.	Does not seem to understand regenerative medicine advancement. Cites none of the pictures used.
Current nature of sources	All material taken from current sources.	Presents current material 90% to 95% of the time.	Presents current material 75% to 89% of the time.	Presents little to no current material.
Magazine quality	Creates a magazine cover about regenerative medicine with an appropriate picture and title that highlights a current advancement with several coverlines.	Creates a magazine cover about regenerative medicine with an appropriate picture and title that highlights a current advancement with a coverline.	Creates a magazine cover about regenerative medicine with an appropriate picture and title.	Creates a basic magazine cover about science with an appropriate picture and title.
Presentation/ magazine pitch	Speaks clearly with correct pronunciation of terms. Maintains eye contact. Presents the information in a logical and interesting process.	Speaks clearly with mostly correct pronunciation of terms. Maintains eye contact most of the time. Presents the information in a logical process.	Occasionally speaks clearly with some correct pronunciation of terms. Maintains eye contact some time but reads most of the presentation. Difficult to follow presentation.	Does not speak clearly or pronounce terms. Lack of eye contact because the presentation is read. Unable to follow presentation.

Regenerative Medicine: Changing Life

Thanks for accepting this assignment. You will be researching regenerative medicine and the current advancements in this field. You have a list of questions to answer. As you research, you also should add a couple questions of your own to the list. Keep track of your notes and sources in the chart below. (A list of suggested sources is provided on the next page.) After you have completed the research, create a magazine cover for the current advances in regenerative medicine. At the end of this process, you will have the opportunity to pitch your magazine cover to the publication board.

Question	Notes	Website/Last Update
What is regenerative medicine?		
What are the building blocks/ tools of regenerative medicine?		
What is a current advancement of regenerative medicine?		
Where is this current advancement being studied?		
What are the uses of this current advancement?		
How will this advancement be used?		

Regenerative Medicine: Changing Life (continued)

Suggested Sources

A Brief Definition of Regenerative Medicine
http://www.future-science-group.com/_img/pics/A_brief_definition_of_regenerative_medicine.pdf

California Institute for Regenerative Medicine
http://www.cirm.ca.gov

Cell and Gene Therapies
http://www.wakehealth.edu/research/research_default.aspx?id=46066

Inside Regenerative Medicine from the North Carolina Biotechnology Center
http://www.ncbiotech.org/business-commercialization/biotech-sectors/regenerative-medicine/inside-regenerative-medicine

McGowan Institute for Regenerative Medicine
http://www.mirm.pitt.edu

Military Applications
http://www.wakehealth.edu/Research/WFIRM/Research/Military-Applications.htm

Regenerative Medicine
http://stemcells.nih.gov/info/scireport/2006report.htm

Replacement Organs and Tissues
http://www.wakehealth.edu/research/research_default.aspx?id=46887

Tengion (video)
http://www.tengion.com/news/video1-small.cfm

Wake Forest Institute for Regenerative Medicine
http://www.wakehealth.edu/WFIRM

WFIRM In The News
http://www.wakehealth.edu/Research/WFIRM/News/WFIRM-in-the-News.htm