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Magic from Human Regenerative Technologies -- Stem Cells

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Magic from Human Regenerative Technologies—Stem Cells

By John M. Ritz, DTE

With advancements in stem cell research and development, tissue engineering, or regenerative medicine, many ailments are finding techniques for improvement.

Many people suffer from chronic diseases and problems due to injury from accidents or ailments. Some problems, such as measles and cancer, can be cured or put into remission with time, medicine, or treatments. Other ailments, such as high blood pressure, failing kidneys, and cystic fibrosis, cannot be cured and require continuous use of medications or organ transplants. Many people are in need of organ transplants (113,075 in the U.S., with only about 1,000 donors per month giving organs or tissues to transplant) (UNOS, 2012). In addition, for those who receive transplants, there is a need to continuously receive antirejection medications to keep their bodies from rejecting the new organs. It seems that, for many, there is no cure to failing health conditions. The use of stem cells to aid in mending the human body will be explored with their possible uses, and the ethics associated with this technology will be analyzed. The medical community is using the term regenerative medicine and tissue engineering more and more because of the negativism some attach to stem cell research.

Stem Cells

The human body is an efficient machine, and many times self-corrects when it encounters medical problems. If one breaks a bone, it can heal itself, with the bone and tissue cells growing back together. Cuts and scrapes also heal themselves. When one catches colds or flu, the symptoms usually go away over time as the body's immune system takes over. When a human is created, it progresses from an egg and then grows and develops its organs and body structure. Scientists have explored the basic makeup of the growth and development of animals and humans. They have determined that there are several body cells that can reproduce and regenerate. Medical scientists and researchers are trying to better

understand cell development in hopes of using our own cells to recreate tissues and organs that can be used to grow new organs and tissues if these become damaged. This growth from cells is planned to be used for correcting abnormalities as our bodies wear from use, age, disease, and viruses.

At the root of this research are stem cells. Stem cells are the basic cells that make up our bodies. They constantly reproduce (regenerate) within our body and can differentiate into other cells, hence being known as stem cells (the stem from which cells grow into body tissue and parts). They can grow and develop into skin, nerve cells, organs, and much more. Consequently, stem cells can form into many different types of cells and structures. This development and growth is known as differentiation (cells dividing and multiplying).

All plants and animals have stem cells. For this reason, much of the research into cell differentiation and development is done in animals, particularly mice. As cells develop, they communicate with each other to determine which cells to develop and how. This determines which cells develop into eyes, skin, bone, etc. The cell development has three layers. The endoderm (inner layer) differentiates to become cells that form into linings of the body cavity, including respiratory tract, digestive tract, and other inner organs. The mesoderm is the middle layer, which differentiates to become the circulatory system, bones, muscles, and connecting tissues. The ectoderm is the outer layer, and it differentiates to become skin, hair, nails, sensory organs, brain, and spinal cord (Figure 1).

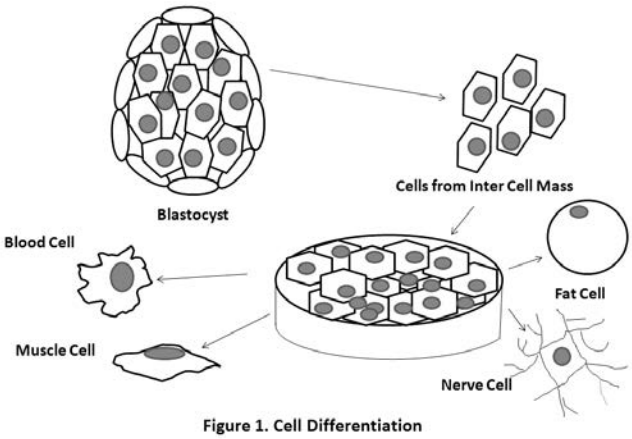

Figure 1. Cell differentiation determines the properties and characteristics of cells as they develop into eyes, skin, bone, etc. This process is an important area of research into cell differentiation and development.

Types of Stem Cells

Stem cells are classified into two main types: embryonic stem cells and adult stem cells. Embryonic stem cells come from embryos that have developed from eggs that have been fertilized by male sperm or in a Petri dish in a lab by artificially inserting sperm into eggs (Kelly, 2007). Fertilized eggs can be used to harvest the embryonic cells that can be programmed genetically by human intervention to become any form of human body mass; e.g., skin, bone, organ. Embryonic stem cells have greater possibilities of repairing damaged human bodies because of their ability to be turned into any cell types, but their use can cause ethical issues in how they are obtained (fertilized eggs or aborted fetuses). There is controversy among groups as to the ethics of using these eggs or a fetus, because some believe it is destroying life (Ostnor, 2008). Additional research is being undertaken to determine if there are other ways of obtaining embryonic stem cells.

One other way to obtain stem cells is to use the adult stem cells that exist throughout our bodies. Adult stem cells are mature and can take on certain human functions such as regenerating muscles or repairing damaged organs. They are harvested from our bodies: the healthy cells are isolated using medical technologies and then are injected into damaged areas. It has been shown that they can be used to advance the healing of broken bones or replace skin damaged by burns, and those taken from bone marrow can be used to treat leukemia. Figure 2 (next page) shows how muscle tissue can be derived from stem cell manipulation.

Medical researchers are now able to take adult stem cells and coax them back into an embryonic state. It is easy to obtain adult stem cells from human skin. These cells are then reprogrammed using chemicals to suggest to the cells what they can become. The process is not yet perfect, since the chemicals can only make suggestions to the cell. However, using a process such as this avoids ethical questions associated with when cells become human life. Using these techniques, it is hoped that a formula will one day be developed to program adult stem cells to become any cells the researchers might need to treat human disorders. This research should happen in the not-too-distant future.

Treatment of Diseases and Disorders

Stem cell research looks promising to help fix many medical disorders in the near future (5 to 20 years away). Areas to be reviewed related to the treatment of diseases and disorders

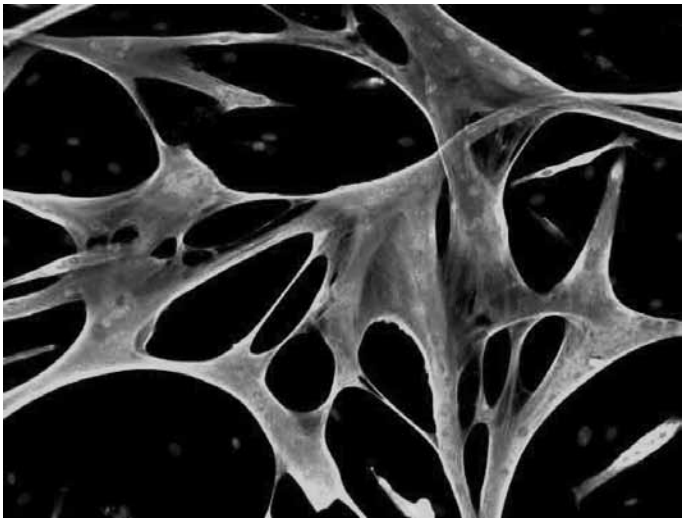

Figure 2. This is a microphotograph of muscle tissue derived from stem cells fusing to form multinucleated myotubes. Researchers at the University of Pittsburgh Children's Hospital Stem Cell Research Center work tirelessly to develop greater possibilities in tissue engineering to unlock the potential of gene therapy and stem cell research. Their goal is to use their research findings to develop useful treatments for damaged or diseased tissues.
Credit: Stem Cell Research Center, University of Pittsburgh.

include the nervous system, blood and heart disorders, bone injuries and diseases, organ repair, and skin replacement.

The human central nervous system controls the operation of organs and other body functions. Diseases that affect the central nervous system include Alzheimer's disease, Parkinson's disease, and Huntington's disease. These are diseases that usually affect people over the age of 50. Alzheimer's disease is accompanied by memory loss and language loss, while Parkinson's disease causes the hands to shake and limbs to become stiff. This makes the person shake and have difficulty walking. Huntington's disease affects the central nervous system and causes involuntary jerky movements and double vision. Researchers are experimenting by injecting embryonic stem cells into the brain. With some procedures, the genes and chromosomes must first be manipulated so they will affect the injured cells. Although the research is in the early stages, some injections are showing regeneration of the brain cells that will halt the progression of these diseases.

Injuries to the spinal cord also affect the central nervous system. Spinal cord injuries occur with high-impact accidents or falls. Many of these injuries come from automobile accidents or sports injuries. Those who have watched football and ice hockey have seen players who, after hard hits, are immobilized to protect the neck and back so they will not be further injured while being taken for x-rays and/or treatment. Spinal cord injuries can severely damage the central nervous system. During the past few years, the injection of adult stem cells has aided some patients to slowly recover from these injuries.

Blood and heart disorders are also projected to be improved by the introduction of stem cells. Researchers have found that adult stem cells can be injected into the heart muscles to improve the damaged heart (infarct). It is easy to separate muscle cells from other parts of the body and grow these in cultures for injection into the heart muscles.

Research with blood stem cells is being used to treat leukemia and other blood diseases such as thalassemia and sickle cell disease. The stem cells are taken from the person's blood marrow or umbilical cord at birth. Using cord blood is noninvasive and less painful for the patient. It can also be taken from a sibling's umbilical cord.

Bone and tendons give structure to the human body. Injuries and excessive wear of these can cause pain and damage. Bone breaks usually mend themselves. Bones and tendons can be transplanted from others, or other materials can be formed into joints that can then be used to replace worn joints. However these operations are painful, and patients have long recovery times. Research has shown that bone marrow injected into broken bones can speed the healing. Tissue engineering using stem cells can also help to mend damaged tendons. Arthritis is a disease that might be treated using regeneration through stem cell injections.

Organ replacement can happen through donor transplants. It is very difficult to obtain organs of others to transplant and also difficult to find those with close enough genetic makeups to transplant. Today much research is being undertaken to grow new organs using the recipients' own stem cells. Manufactured scaffolds (structures) are being computer designed that will match the size of the organ needed. The patient's stem cells are grafted onto the scaffold and grown either in a laboratory environment or on the human's exterior. When they are mature enough, they are transplanted into the human. This is a fascinating regenerative process, and it seems to have many new developmental announcements occurring almost weekly. This may soon be an answer to organ transplant surgery.

Skin is the covering of the human body. Some people have severely damaged skin as a result of burns or ulcers (caused by skin diseases and diabetes). The current practice is to graft skin from other locations on the human body. Doctors cut a section of good skin from the back or thigh and then transplant it to where the skin was damaged. Today, skin is grown in a lab using skin and stem cells taken from the body. When the mass is large enough, then it is transplanted. New, experimental-stage research involves taking skin stem cells and spraying them on burned or ulcerous areas and having them regrow directly on the human. Figure 3 shows a matrix-like material that appears attractive to stem cell regeneration.

Immune System

If one is to have an organ or tissue transplant, e.g., kidney, liver, lung, there must be a match in the blood and genetic make-ups of the donor and recipient. To help the recipient's body to accept this foreign body part, his or her immune system must be desensitized. This is done using antirejection drugs called immunosuppressants. The recipient must take these drugs the remainder of his or her life so his or her body does not reject the transplanted organ. Besides the expense involved, the drugs reduce the effectiveness of the body to fight off other infections or viruses. It is very easy for the person on immunosuppressant drugs to catch colds, the flu, or common viruses that most human bodies can readily defend themselves against.

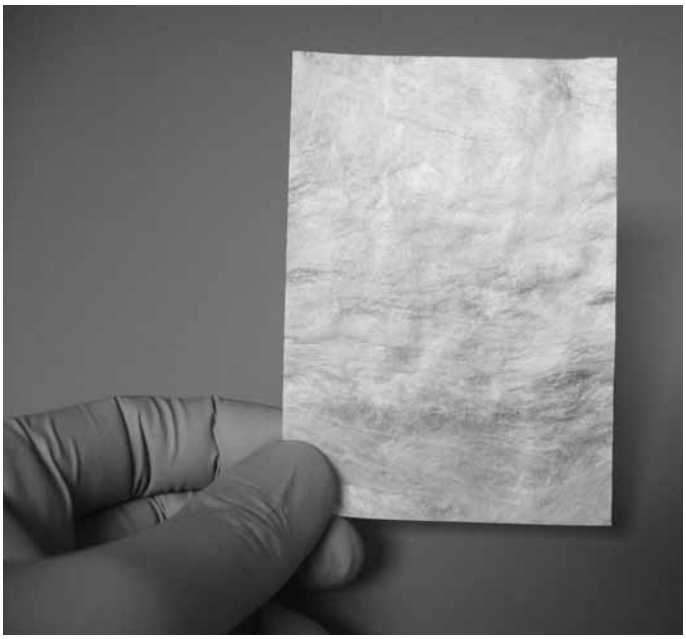

Figure 3. Here a stem cell researcher is holding a sheet of extracellular matrix that is derived from a pig bladder. The cells have been removed, leaving a scaffold-like structure that appears to be rich in factors that are attractive to stem cells at the injured site such as a muscle defect or to repair tissue.

Credit: McGowan Institute for Regenerative Medicine, University of Pittsburgh.

There are about 30 million people in the United States who have been diagnosed with liver disease. Liver disease accounts for approximately 27,000 deaths per year (Heron, 2009). The liver is the human body's largest gland. Its function is to cleanse and detoxify the blood; however, it also aids in digestion. The liver provides bile to break down fats that we consume in food. When a person's liver fails, the only recourse is an organ transplant. However, there is a shortage of transplantable livers because of availability and matching issues. Research is being conducted to reengineer body organs such as the liver to make them functional again. One of the major technical challenges has been the oxygen and nutrient transfer in tissue-engineered liver grafts. The idea is to develop a transplantable liver graft by removing the cellular material while preserving the structural and functional characteristics of the liver's native microvascular network, thus allowing recellularization to take place.

Scientists have removed the cellular material from rat livers as part of research efforts to "engineer" a bridge between a diseased liver and transplant. Decellularized liver grafts could extend the time that a person has to receive a transplant. Each year there are a number of people who die because a liver transplant was not available to them. Figures 4 and 5 (on page 8) show "before and after" images of a decellularized rat liver.

Ethics

It should be distinguished that stem cells are available in two varieties: adult and embryonic. Adult stem cells can be used for some procedures, but others require the embryonic type, since they can take the form of any cells and can take on different developmental processes. Much of the controversy comes from the potential use of embryonic stem cells. Individuals differ in viewpoint as to when human life begins. Some believe that life begins when a human egg is fertilized. Others believe life begins when the child is fully formed and birth occurs. Embryonic stem cells are the cells that form between 5 and 6 days after the egg becomes fertilized (Green, Grabel, & Singer, 2007). So to get them, you need to use fertilized eggs. Some believe that using fertilized human eggs means destroying life and therefore consider the use of

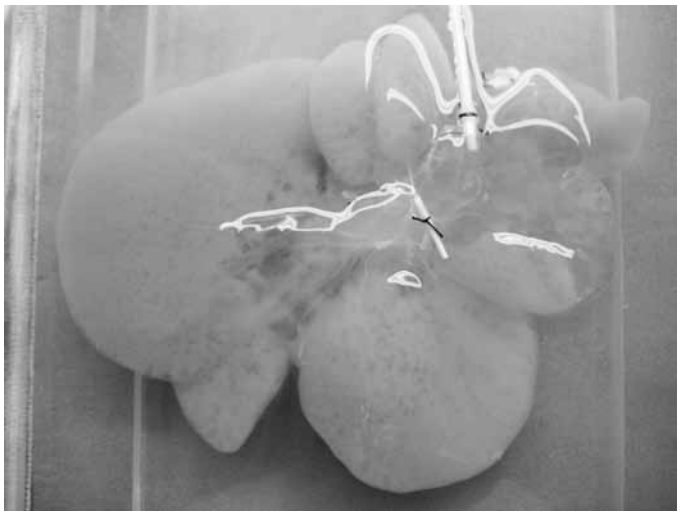

Figure 4. Rat liver before decellularization.
Credit: McGowan Institute for Regenerative Medicine, University of Pittsburgh.

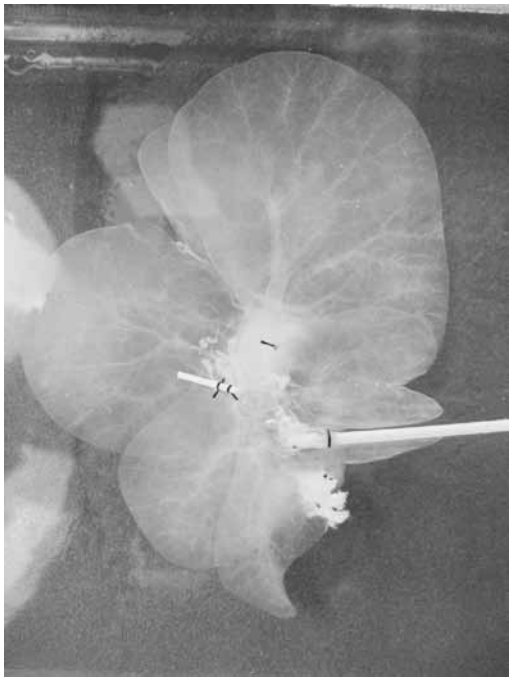

Figure 5. Rat liver after decellularization.
Credit: McGowan Institute for Regenerative Medicine, University of Pittsburgh.

embryonic stem cells unethical. This is why some procedures use adult stem cells. However, researchers are beginning to figure out how to create embryonic cells without using fertilized eggs. Others continue to research ways to do this.

Another ethical issue is determining if people or companies should be able to profit through patents they develop to enable these procedures to become possible. Agriculture companies can patent genetically engineered seed—should companies be able to patent stem cell procedures? In the U.S. it is permitted for companies to patent these techniques so they can make a profit from their research. In October 2011, the European Union top court ruled that its countries could not gain patents by exploiting human embryos. Will the ruling slow this form of medical research in Europe?

Videos to Support Class Instruction

Media materials such as the Internet-accessible videos listed below can augment lesson plans visually and stimulate student interest in stem cell research and medicine. There are many Internet resources available to teachers that are sponsored by universities, research hospitals, PBS, and other organizations.

Organ Replacements

- www.pbs.org/wgbh/nova/body/replacing-body-parts.html

Overview of Tissue Engineering

- www.youtube.com/watch?v=ofiLcTs7_Ys&feature=related

Spinal Cord Injury

- www.youtube.com/watch?v=fd4A7k4qgwg&feature=related

Organ and Tissue Regeneration

- www.youtube.com/watch?v=GwcT1ViM-w&feature=related
- http://protomag.com/assets/video-the-organ-builder

Skin Replacement

- www.youtube.com/watch?v=Bz_FVDvgvSE&feature=related
- http://video.nationalgeographic.com/video/player/national-geographic-channel/shows/explorer-1/ngc-the-skin-gun.html

Printing Human Organs

- www.ted.com/talks/anthony_atala_printing_a_human_kidney.html

Student Activity

Medical technology is one of the most exciting areas for curing damaged or diseased bodies. Although a major area in the study of technology, it is difficult to perform laboratory activities with young people to build their knowledge in this area. However, most families can report that they have benefitted from the results of medical research and technology. In teams of three, have students select one human disease or abnormality where medical technology has improved the life of family members or friends. Allow only one group to research a particular medical technology. Try to select stem cell or regenerative medicine topics, so the newest research can be reported. Topics could include Parkinson's disease, tendon replacement, skin burns, etc. Have each group conduct light research on its selected topic. Have each group prepare a media presentation to inform class members about the diseases/abnormalities and explain how medical technology (including stem cell research) is being advanced to cure the medical condition. In this way, teachers will be developing students' knowledge about medical technologies and addressing ITEEA's Standard 14 (Medical Technologies), Benchmarks G (advances and innovations in medical technologies) and K (medical technologies for prevention and rehabilitation) (*Standards for Technological Literacy: Content for the Study of Technology*, ITEA/ITEEA, 2000/2002/2007).

A technician places recently transfused bone marrow into a sterile bag in preparation for transplant.
Credit: Wikimedia Commons.

Summary

Medical research is providing some of the biggest breakthroughs in technology. Until recent years, when someone was scarred by accident or disease, they were treated but not always cured. With advancements in stem cell research and development, tissue engineering, or regenerative medicine, many ailments are finding techniques for improvement. Seeing a person able to walk again after a spinal cord injury, regrowing a finger that has been severed, or regrowing and transplanting an esophagus that has been damaged appear to be miracles. This article has shown that these types of medical technologies are improving life. Some question whether they are ethical practices. The more we learn of these technologies, the better judgments each can make on an individual basis.

References

Green, L., Grabel, L., & Singer, P. (Eds.). (2007). *Stem cell research: The ethical issues.* Malden, MA: Blackwell Publishing.

Heron M., et al. (2009). Deaths: Final data for 2006. *National Vital Statistics Report. Vol. 57*. Hyattsville, MD: Centers for Disease Control and Prevention.

ITEA/ITEEA. (2000/2002/2007). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Kelly, E. B. (2007). *Stem cells.* Westport, CT: Greenwood Press.

Ostnor, L. (Ed.). (2008). *Stem cells, human embryos and ethics.* New York: Springer.

United Network for Organ Sharing (UNOS). (2012). *Working together, saving lives.* Retrieved from www.unos.org/

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