



BIOTECH Basics

Stem Cells

What you need to know:

- Stem cells can differentiate into many kinds of cells.
- Alternatively, they may continue to divide and produce more stem cells.
- Stem cells that occur naturally are embryonic or adult in type.
- Induced pluripotent stem cells are differentiated cells that have been genetically reprogrammed to behave like embryonic stem cells.
- Stem cells have the potential to shed light on human disease, screen potential drugs and replace damaged/missing cells in the body.
- A number of technical and ethical hurdles must be overcome before stem cells routinely enter clinical practice.

Introduction

Stem cells: perhaps no other subject in medical research has stirred as much passion and controversy. Ethical issues surrounding certain aspects of stem cell research give rise to very personal views. However, an understanding of scientific details and medical implications can be an important part of forming and expressing opinions. This edition of *Biotech Basics* attempts to provide that understanding, laying the groundwork for discussions concerning stem cells.

What are stem cells?

Stem cells serve to help the body replace cells lost through aging, damage or other daily activities. There are two key characteristics that distinguish stem cells from other cell types.

- **Potency** – Stem cells do not have any of the tissue-specific structures that allow them to carry out specialized functions. Stem cells cannot carry oxygen through the bloodstream, transmit electrical signals in the nervous system or produce enzymes to break down food. However, a stem cell has the ability to develop into blood, nerve and stomach cells. This process of forming mature cells is called differentiation and is guided by a number of key chemical signals and developmental stages.
- **Self-renewal** - Stem cells can renew themselves through repeated cycles of cell division while remaining in an undifferentiated state. This provides a continual pool of stem cells that can differentiate as required.

What types of stem cells have been identified?

Embryonic stem cells develop in an early embryo from specialized cells called the inner cell mass. These ICM cells are pluripotent, meaning they can form all of the cells in the organism's body. Embryonic stem cells originate from ICM cells. The cells are transferred into a petri dish containing a nutrient-rich broth and allowed to grow and spread across the dish. Once these cells are established, subsets can be frozen and shipped to other laboratories for further study. Nearly all human embryonic stem cells currently in use are derived from embryos fertilized at an in vitro fertilization clinic and donated for research purposes. Based on research to date, embryonic stem cells offer the widest range of developmental potential and are the easiest to culture in the lab.

Adult stem cells are found inside a tissue or organ and are capable of forming the cells needed by that tissue. They are maintained throughout the life of the organism and have been identified, among other tissues, in brain, bone marrow, skeletal muscle, skin, heart and intestines. Present in very small numbers, adult stem cells are multipotent, meaning they can develop into only a few cell types. For example, hematopoietic stem cells, can form red and white blood cells, as well as the platelets. These stem cells can be found in bone marrow, as well as in the blood obtained from the umbilical cord after birth. Notably, banking this umbilical cord blood provides a population of stem cells that can be used to treat certain blood-based diseases that may form later in life. Other adult stem cell examples include mesenchymal stem cells that form bone, cartilage and connective tissue, and neural stem cells that can develop into neurons and other cells found in the

If you want to know more:

http://www.cdb.riken.jp/en/05_development/0505_stemcells04.html
Stem Cells: Building and Maintaining the Body – Riken Center for Developmental Biology – a thorough overview of the basics on stem cells, including the differences between embryonic and adult stem cells, as well as research on how to differentiate embryonic stem cells for clinical uses.

<http://www.nature.com/scitable/spotlight/stem-cells-6969855>

Spotlight on Stem Cells – Scitable, by Nature Education – a host of articles and web links addressing stem cell biology, manufacturing, application and regulation

<http://stemcells.nih.gov/info/basics/defaultpage.asp>

Stem Cell Basics – The National Institutes of Health – a thorough introduction to stem cells, including information regarding U.S. policy as it relates to public funding of stem cell research

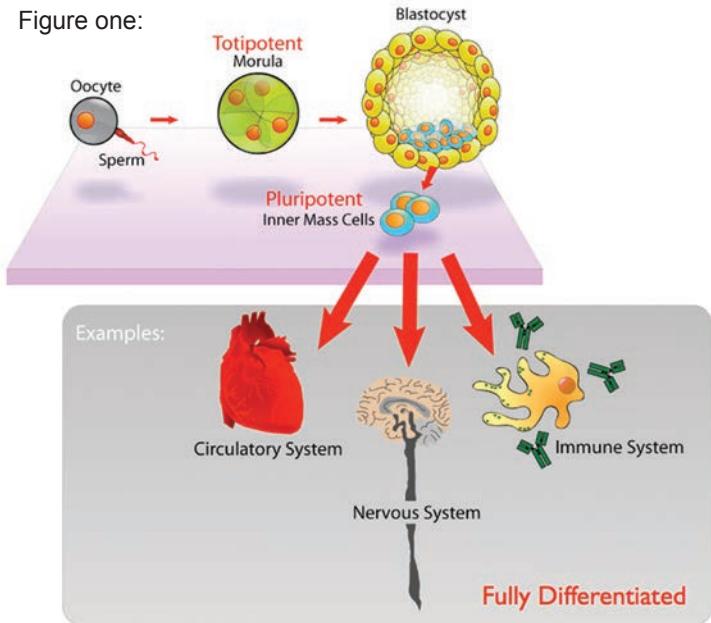
nervous system. In addition to a reduced set of differentiated outcomes, adult stem cells are harder to culture and maintain in a laboratory setting when compared to embryonic stem cells.

In 2006, scientists discovered techniques to genetically reprogram differentiated cells into an embryonic stem cell-like state, giving rise to a third category, induced pluripotent stem cells. These cells may ultimately offer a widely available and non-controversial source of pluripotent cells; however, recent studies indicate that iPSCs and embryonic stem cells are similar but not identical. It is likely that embryonic, adult and induced pluripotent stem cells will each be suited for specific research and clinical needs, but will not be interchangeable across every application.

How might stem cells be used in the lab and clinic?

Researchers are beginning to understand the process of cellular differentiation and the stages that guide a cell into a specific developmental fate. This knowledge has been used in the laboratory to coax pluripotent stem cells into mature cell types

Figure one:



Stem cells vary in their differentiation ability (figure 1). Some are totipotent, meaning they can differentiate into any of the cells in the organism's body, as well as the placenta, umbilical cord and amniotic sac. Pluripotent stem cells can only develop into body cells while multipotent stem cells form only subsets of body cells, such as those found in the blood and lymph system. Once cells have fully differentiated, they can only divide into the same type of differentiated cell: for example, skin cells only divide and form similar skin cells. Image credit: Wikimedia commons – modified from an image created by Mike Jones - http://commons.wikimedia.org/wiki/File:Stem_cells_diagram.png.

– a strategy called directed differentiation. In many cases, this involves activating or silencing specific genes. In other instances it requires the addition of specific growth factors or small molecules. Serious challenges still remain: Even in best-case scenarios, less than 30 percent of the stem cells achieve the desired cell fate. Even so, the potential for directed differentiation opens a number of clinical and research-based stem cell opportunities (figure 2).

Modeling human disease

Understanding how genetic variation impacts disease is a long-standing goal for human genetics. Stem cell analyses, particularly those involving iPSCs created from patients, can be used to model human diseases and compare how changes at the DNA level impact cell function. This will prove especially useful as directed differentiation creates those cell types implicated in the disease. For example, a recent study generated iPSCs from patients with long QT syndrome (an inherited heart condition) who had mutations in a specific gene. The iPSCs were differentiated into cardiac muscle cells for failing hearts, dopamine-producing neurons for patients with Parkinson disease or insulin-producing pancreatic cells for those with Type 1 diabetes.

Figure two:

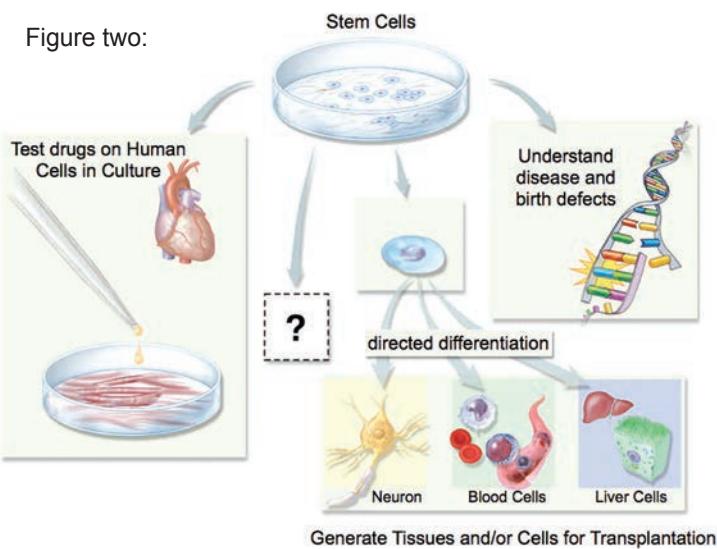


Image credit: The Promise of Stem Cell Research – National Institute of Health - <http://stemcells.nih.gov/info/media/promise.htm>

of the heart. Similarly, directed differentiation produced liver cells from iPSCs of patients with liver diseases. The cells mimicked clinical features of the disorder.

Pharmacological testing

In addition to studies modeling human disease, differentiated stem cells may be used to screen large numbers of candidate molecules to speed drug discovery. In both the long QT and liver disease studies reported above, the differentiated cells tested the effects of both existing and potential drugs – an important first step in identifying new therapies.

Replacement cells

An exciting potential application for human stem cells is creating replacement cells. While organ transplantation can replace damaged or diseased tissues, the need far outstrips the availability of donor organs. Stem cells, placed under directed differentiation, could provide a renewable source of cardiac muscle cells for failing hearts, dopamine-producing neurons for patients with Parkinson disease or insulin-producing pancreatic cells for those with Type 1 diabetes. Potentially, any disorder caused by the destruction and loss of certain cell types could be a candidate for replacement therapy.

There are important safety caveats for human stem cell therapy. Scientists do not yet have full control over how the cells grow and develop. Because of their pluripotent ability, it is possible that implanted stem cells will

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form tumors instead of the desired organ or tissue. Cautious and rigorous clinical testing, while potentially frustrating patients and their families, will be the norm for the next several years.

What are the challenges and concerns involving stem cells?

Historically, stem cell technologies have often been accompanied with unrealistic hype and promises of imminent clinical utility. While impressive progress has been made in stem cell research and application during the past decade, significant hurdles still remain before stem cell therapies become a routine part of the clinical landscape. These include:

- obtaining a full understanding of the reprogramming process for creating pluripotent stem cells;
- determining whether iPSCs are a safe and useful stem cell alternative;
- identifying the methodology required for predictable directed differentiation;
- converting research-based protocols into more efficient, reproducible procedures;
- developing techniques to improve the growth and culturing of adult stem cells;

- addressing ethical concerns surrounding the creation and utilization of embryonic stem cells.

With respect to the last challenge, it is worth noting that Advanced Cell Technology, Inc. has developed a technique that obtains a single embryonic cell without destroying the embryo. This method is similar to that used in preimplantation genetic diagnosis, where a single cell is obtained for genetic testing from a four to eight cell embryo. ACT says the procedure produces embryonic stem cells identical to those derived from the inner cell mass of a later-stage embryo.

Links to HudsonAlpha

Southern Cord, a private cord blood banking service, is one of the newest associate companies to locate at HudsonAlpha. As mentioned above, following the birth of a child, the blood found in the umbilical cord and placenta contains a number of adult stem cells capable of forming the differentiated blood and immune cells. Close to 80 diseases and disorders including cancers, blood disorders, hemoglobinopathies and immunodeficiencies are currently treatable with stem cells obtained from cord blood.

– Dr. Neil Lamb

director of educational outreach

HudsonAlpha Institute for Biotechnology

Spring Benefit reception a success

Hundreds attend make up event after tornadoes

Thanks to everyone who attended the HudsonAlpha reception highlighting research on psychiatric disorders on May 19. More than 250 guests were on hand for the event, which was held in lieu of the Spring Benefit for Research on Psychiatric Disorders. The original benefit was scheduled for April 28, but the event was canceled after tornadoes ripped through Alabama, impacting so many in our area.

The reception maintained the original focus of the benefit - psychiatric research underway at HudsonAlpha. Proceeds from the event support current and future research into major depressive disorder, schizophrenia and bipolar disorder.

Jim Hudson presented special gifts to Linda Smith of Smith Asset Management and Mike Follano of ADTRAN as the event's Genome Sponsors. Corporate and individual sponsors of all levels also received tokens of appreciation. Event sponsors are listed at right.

Thanks again to all who attended the reception, as well as those who provided support to psychiatric

disease research through this event but were unable to attend. View dozens of reception photos on the HudsonAlpha Facebook page.

Lower left: HudsonAlpha co-founder Lonnie McMillian with major institute supporter Linda Smith of Smith Asset Management.

Right: Carter Wells, director of external affairs, addressed the more than 250 guests who attended the benefit reception.



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