Biotechnology and Bioethics

Basics of Stem Cell Research

http://www.ama-assn.org/ama/pub/physician-resources/medical-science/genetics-molecular-medicine/related-policy-topics/stem-cell-research/basics-stem-cell-research.page?

What is a stem cell?

A stem cell is an immature cell that has the potential to become specialized into different types of cells throughout the body. There are two basic types of stem cells: adult stems cells and embryonic stem cells. Embryonic stem cells are produced when a newly fertilized egg begins to divide. These stem cells can become any type of cell in the body. Adult stem cells – somewhat of a misnomer because they can also be found in infants and children – are stem cells that reside in already developed tissue. These stem cells can act like a repair system, dividing regularly to provide new specialized cells to take the place of those that die or are lost. Tissues where adult stem cells have been found include the brain, blood, muscle, skin and bone.

Why are stem cells important from a medical perspective?

For decades, researchers have been studying the biology of stem cells to figure out how development works and to find new ways of treating health problems. Because stem cells can give rise to any tissue found in the body, they provide nearly limitless potential for medical applications.

Current studies are researching how stem cells may be used to prevent or cure diseases and injuries such as Parkinson's disease, type 1 diabetes, heart disease, spinal cord injury, Duchene's muscular dystrophy, Alzheimer's disease, strokes, burns, osteoarthritis, rheumatoid arthritis, vision, and hearing loss. Stem cells could also be used someday to replace or repair tissue damaged by disease or injury.

How are stem cells being used today?

Stem cell procedures currently provide life-saving treatments for patients with leukemia, lymphoma, other blood disorders, and some solid tumors. The three main technologies in use today are:

Adult stem cell transplant: bone marrow stem cells

Stem cell technology has been used for more than 20 years in bone marrow transplants, where the patient's bone marrow stem cells are replaced with those from a healthy, matching donor. If the transplant is successful, the stem cells will migrate into the patient's bone marrow and begin producing new, healthy leukocytes to replace the abnormal cells.

Adult stem cell transplant: peripheral blood stem cells (PBSCs)

While most blood stem cells reside in the bone marrow, a small number are present in the bloodstream. PBSCs can be obtained from drawn blood, making them easier to collect than bone marrow stem cells. However, PBSCs are sparse in the bloodstream, so collecting enough to perform a transplant can pose a challenge.

Umbilical cord blood stem cell transplant

Umbilical cords traditionally have been discarded as a by-product of the birth process. In recent years, however, the stem-cell-rich blood found in the umbilical cord has proven useful in treating the same types of health problems as those treated using bone marrow stem cells and PBSCs.

Where do scientists get stem cells?

This is the main area of debate that surrounds this technology. Adult stem cells can be removed from adult tissues with little harmful effect on the individual while embryonic stem cells are derived from multicellular embryos that have been cultured in the laboratory.

Numerous regulatory and ethical constraints exist for the use of embryos in research. There is also a limited number of human embryonic cell lines available for research that meet all criteria for federal funding, but many scientists remain skeptical over the quality of these cells.

Following is a list of current and potential sources of stem cells:

- Early embryos created by in vitro fertilization - either those which are not needed for infertility treatment (sometimes called spare embryos) or created specifically for research;
- Early embryos created by somatic (body) cell nuclear transfer (SCNT), a procedure that bypasses the normal fertilization process by taking the genetic material from a cell in an adult's body and fusing it with an empty egg cell. This is a form of therapeutic cloning, which would allow cells to be customized for each individual and thereby minimize the chances of tissue rejection;
- Germ cells or organs of an aborted fetus;
- Blood cells of the umbilical cord at the time of birth;
- Some adult tissues (such as bone marrow);
- Mature adult tissue cells reprogrammed to behave like stem cells

Genetic Testing:

http://www.accessexcellence.org/RC/AB/IE/Genetic_Testing.php

Interviewer: I've read stories about the Constitutional issues involved -

Dr. Holzman: There are. Let's talk a little bit about genetic tests, what they'll do, and what they won't do. We can divide diseases in which genes play a role into two categories: One is the clear-cut genetic diseases - what we call single gene diseases - where a problem in a single mutation in a single gene will cause disease, and do it invariably if that mutation is present, either inherited from one parent in some types of diseases, or inherited from both parents in other types of diseases. But by virtue of where we stand with the technology now, we have the opportunity to develop tests well in advance of having a therapy treatment for those diseases. So we have a gap, where we are able to predict disease, and that might be a disease that will develop in the unborn children of the people being tested, and we can't do anything about treatment. Now, what do you do in a situation like that? Why should someone want to be tested?

Well, they may want to be tested to know and to prepare to alter their life plans; some of them may know they're at risk and would like to know with certainty whether they are going to develop a disease or not develop a disease. Now there are concerns about pressures compelling people to have tests and to take certain actions.

Interviewer: Could you be more specific about who would be exerting that pressure?

Dr. Holzman: We have tests that can predict the occurrence of disease, and there is nothing specific that can be done to treat, to reduce the disability of disease. Well, people may or may not be interested in those tests, but there are other parties that may be interested. For instance, insurance companies and employers - for the following reason that if a person is going to develop a genetic disease, or a disease to which genes contribute, and where that contribution can be detected by a test, it's likely in the absence of a definitive treatment that when those people get sick, they're going to need a lot of supportive care that may go on for years and years and that's expensive. And an insurance company does not want to pay for those benefits. And if an employer who is paying health benefits for workers has a way of finding out in advance of hiring whether or not a worker is going to develop a disease, that employer is going to be less likely to want to hire that worker since the employer is paying health care benefits. So this is an area where tremendous discrimination based on one's genes is possible, both in employment and directly in getting health care insurance.

Cloning:

http://www.ornl.gov/sci/techresources/Human_Genome/elsi/cloning.shtml

There are three types of cloning technologies: (1) recombinant DNA technology or DNA cloning, (2) reproductive cloning, and (3) therapeutic cloning.

1. The terms "recombinant DNA technology," "DNA cloning," "molecular cloning," and "gene cloning" all refer to the same process: the transfer of a DNA fragment from one organism to another. The DNA of interest can then be produced in a foreign host cell (most frequently right now in bacteria). This technology has been around since the 1970s, and it has become a common practice in molecular biology labs today.
2. Reproductive cloning is a technology used to generate an animal that has the same nuclear DNA as another currently or previously existing animal.
3. Therapeutic cloning, also called "embryo cloning," is the production of human embryos for use in research. The goal of this process is not to create cloned human beings, but rather to harvest stem cells that can be used to study human development and to treat disease. Stem cells are important to biomedical researchers because they can be used to generate virtually any type of specialized cell in the human body. Stem cells are extracted from the egg after it has divided for 5 days.

Recombinant DNA technology is important for learning about other related technologies, such as gene therapy, genetic engineering of organisms, and sequencing genomes. Gene therapy can be used to treat certain genetic conditions by introducing virus vectors that carry corrected copies of faulty genes into the cells of a host organism. Genes from different organisms that improve taste and nutritional value or provide resistance to particular types of disease can be used to genetically engineer food crops. See Genetically Modified Foods and Organisms for more information.

If the low success rates can be improved (Dolly the sheep was only one success out of 276 tries), reproductive cloning can be used to develop efficient ways to reliably reproduce animals with special qualities. For example, drug-producing animals or animals that have been genetically altered to serve as models for studying human disease could be mass produced.

Reproductive cloning also could be used to repopulate endangered animals or animals that are difficult to breed. In 2001, the first clone of an endangered wild animal was born, a wild ox called a gaur. The young gaur died from an infection about 48 hours after its birth. In 2001, scientists in Italy reported the successful cloning of a healthy baby mouflon, an endangered wild sheep. The cloned mouflon is living at a wildlife center in Sardinia. Other endangered species that are potential candidates for cloning include the African bongo antelope, the Sumatran tiger, and the giant panda. Cloning extinct animals presents a much greater challenge to scientists because the egg and the surrogate needed to create the cloned embryo would be of a species different from the clone.

Therapeutic cloning technology may some day be used in humans to produce whole organs from single cells or to produce healthy cells that can replace damaged cells in degenerative diseases such as Alzheimer's or Parkinson's.

Much work still needs to be done before therapeutic cloning can become a realistic option for the treatment of disorders.
Scientists hope that one day therapeutic cloning can be used to generate tissues and organs for transplants. To do this, DNA would be extracted from the person in need of a transplant and inserted into an enucleated egg. After the egg containing the patient's DNA starts to divide, embryonic stem cells that can be transformed into any type of tissue would be harvested. The stem cells would be used to generate an organ or tissue that is a genetic match to the recipient. In theory, the cloned organ could then be transplanted into the patient without the risk of tissue rejection. If organs could be generated from cloned human embryos, the need for organ donation could be significantly reduced.
Reproductive cloning is expensive and highly inefficient. More than 90% of cloning attempts fail to produce viable offspring. More than 100 nuclear transfer procedures could be required to produce one viable clone. In addition to low success rates, cloned animals tend to have more compromised immune function and higher rates of infection, tumor growth, and other disorders. Japanese studies have shown that cloned mice live in poor health and die early. About a third of the cloned calves born alive have died young, and many of them were abnormally large. Many cloned animals have not lived long enough to generate good data about how clones age. Appearing healthy at a young age unfortunately is not a good indicator of long-term survival. Clones have been known to die mysteriously. For example, Australia's first cloned sheep appeared healthy and energetic on the day she died, and the results from her autopsy failed to determine a cause of death.
In 2002, researchers at the Whitehead Institute for Biomedical Research in Cambridge, Massachusetts, reported that the genomes of cloned mice are compromised. In analyzing more than 10,000 liver and placenta cells of cloned mice, they discovered that about 4% of genes function abnormally. The abnormalities do not arise from mutations in the genes but from changes in the normal activation or expression of certain genes.

Genetically Modified Food:

http://www.ornl.gov/sci/techresources/Human_Genome/elsi/gmfood.shtml

Although "biotechnology" and "genetic modification" commonly are used interchangeably, GM is a special set of technologies that alter the genetic makeup of organisms such as animals, plants, or bacteria. Biotechnology, a more general term, refers to using organisms or their components, such as enzymes, to make products that include wine, cheese, beer, and yogurt.
Combining genes from different organisms is known as recombinant DNA technology, and the resulting organism is said to be "genetically modified," "genetically engineered," or "transgenic." GM products (current or those in development) include medicines and vaccines, foods and food ingredients, feeds, and fibers.
Locating genes for important traits—such as those conferring insect resistance or desired nutrients—is one of the most limiting steps in the process. However, genome sequencing and discovery programs for hundreds of organisms are generating detailed maps along with data-analyzing technologies to understand and use them.
In 2006, 252 million acres of transgenic crops were planted in 22 countries by 10.3 million farmers. The majority of these crops were herbicide- and insect-resistant soybeans, corn, cotton, canola, and alfalfa. Other crops grown commercially or field-tested are a sweet potato resistant to a virus that could decimate most of the African harvest, rice with increased iron and vitamins that may alleviate chronic malnutrition in Asian countries, and a variety of plants able to survive weather extremes.
On the horizon are bananas that produce human vaccines against infectious diseases such as hepatitis B; fish that mature more quickly; cows that are resistant to bovine spongiform encephalopathy (mad cow disease); fruit and nut trees that yield years earlier, and plants that produce new plastics with unique properties.
In 2006, countries that grew 97% of the global transgenic crops were the United States (53%), Argentina (17%), Brazil (11%), Canada (6%), India (4%), China (3%), Paraguay (2%) and South Africa (1%). Although growth is expected to plateau in industrialized nations, it is increasing in developing countries. The next decade will see exponential progress in GM product development as researchers gain increasing and unprecedented access to genomic resources that are applicable to organisms beyond the scope of individual projects.
Technologies for genetically modifying foods offer dramatic promise for meeting some of the 21st Century's greatest challenges. Like all new technologies, they also pose some risks, both known and unknown. Controversies surrounding GM foods and crops commonly focus on human and environmental safety, labeling and consumer choice, intellectual property rights, ethics, food security, poverty reduction, and environmental conservation.

Benefits

- **Crops**
  - Enhanced taste and quality
  - Reduced maturation time
  - Increased nutrients, yields, and stress tolerance
  - Improved resistance to disease, pests, and herbicides
  - New products and growing techniques
- **Animals**
  - Increased resistance, productivity, hardiness, and feed efficiency
  - Better yields of meat, eggs, and milk
  - Improved animal health and diagnostic methods

- **Environment**
    - "Friendly" bioherbicides and bioinsecticides
    - Conservation of soil, water, and energy
    - Bioprocessing for forestry products
    - Better natural waste management
    - More efficient processing
- **Society**
    - Increased food security for growing populations

Controversies

- **Safety**
    - Potential human health impacts, including allergens, transfer of antibiotic resistance markers, unknown effects
    - Potential environmental impacts, including: unintended transfer of transgenes through cross-pollination, unknown effects on other organisms (e.g., soil microbes), and loss of flora and fauna biodiversity
- **Access and Intellectual Property**
    - Domination of world food production by a few companies
    - Increasing dependence on industrialized nations by developing countries
    - Biopiracy, or foreign exploitation of natural resources
- **Ethics**
    - Violation of natural organisms' intrinsic values
    - Tampering with nature by mixing genes among species
    - Objections to consuming animal genes in plants and vice versa
    - Stress for animal
- **Labeling**
    - Not mandatory in some countries (e.g., United States)
    - Mixing GM crops with non-GM products confounds labeling attempts
- **Society**
    - New advances may be skewed to interests of rich countries