

ISSUE ★ BRIEF

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CLONING

★ AT A GLANCE ★

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★ OVERVIEW OF CLONING ★

To Clone or Not to Clone? That is the Question

Before you arrive at an answer, you must first answer the following question: “What exactly is cloning?”

Cloning is a scientific term used to describe the process of genetic duplication. It involves the creation of an organism that is an exact copy of another.

Cloning made headlines in 1997, when the first mammal, a sheep named Dolly, was cloned from an adult cell rather than from an embryo. However, human clones have walked among us for centuries. They’re called identical twins and are the result of an embryo dividing at a very early stage to form two individuals with the same genetic makeup. Cloning in nature is not new, either; nature has been cloning plants for billions of years. When a strawberry plant sends out a runner — a modified stem — a new plant grows where the runner takes root. That new plant is a clone.

Today, scientists are pursuing research that could have a profound effect on all of our lives. Using cloning techniques, scientists are seeking to develop new and imaginative ways to address the 21st-century challenges of medicine, research and industry.

Cloning Applications

The first farmers began cloning plants thousands of years ago when they took a cutting and let it root — thereby creating a clone of the original plant. Early farmers also developed techniques for creating larger seeds and sweeter fruit. And much more recently — in the 20th century — scientists produced thousands of “customized” plants by combining genetic engineering with cloning.

Scientists have applied cloning techniques to reproduce genetically modified animals. These animals are better able to resist disease. In the foreseeable future, scientists also hope to revitalize endangered species by cloning existing animals.

Cloning technology also is used in industry. For example, cloning bacteria that eat pollutants holds great promise for dealing with environmental contamination.

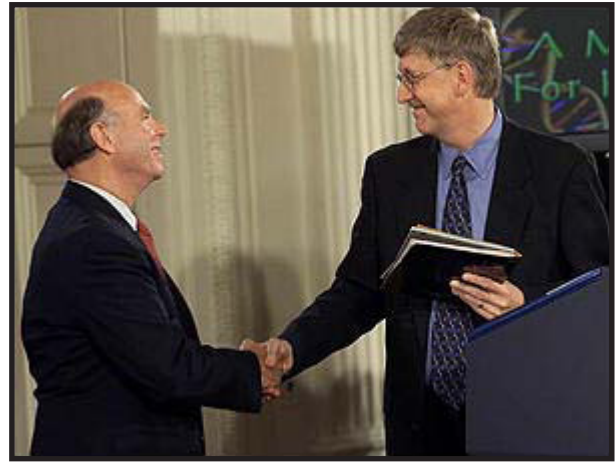
Cloning promises great advances in human medicine as well. Biomedical researchers hope to take cells from a patient, genetically modify them and clone the modified cells to grow the exact cells the patient needs to regain health. Some scientists imagine a day when cloning could be part of a process that grows entire organs for transplants.

Although cloning has many potential benefits, it also is a subject of great controversy. Opponents are concerned about errors, immoral practices and interfering with nature, while supporters are concerned about denying one of biomedical research's most promising discoveries to millions who suffer from debilitating and fatal diseases.

Memorable Moments in Cloning

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| 1880 | August Weissmann concludes that a cell's genetic information diminishes with each cell division. |
| 1902 | Walter Sutton proves chromosomes hold genetic information. |
| 1902 | Hans Spemann divides a salamander embryo in two and shows embryo cells retain all the genetic information necessary to create a new organism. |
| 1938 | Spemann proposes what he called a “fantastical experiment” to transfer one cell's nucleus into an egg without a <u>nucleus</u> — the basic method that eventually would be used in cloning. |
| 1944 | Oswald Avery discovers genetic information is carried by the nucleic acids of cells. |
| 1952 | Robert Briggs and Thomas King clone tadpoles. |
| 1953 | Watson and Crick find the structure of DNA. |
| 1962 | John Gurdon clones frogs from <u>differentiated cells</u> . |
| 1963 | J.B.S. Haldane coins the term <i>clone</i> . |
| 1966 | The complete genetic code is established. |
| 1969 | James Shapiro and Johnathan Beckwith isolate the first <u>gene</u> . |
| 1972 | Paul Berg creates the first recombinant DNA molecules. |
| 1973 | Stanley Cohen and Herbert Boyer create the first recombinant DNA organisms. |
| 1984 | Steen Willadsen reports he has made a genetic copy of a lamb from sheep embryo cells, a process now known as twinning. Other scientists eventually would use his method to twin cattle, pigs, goats, rabbits and rhesus monkeys. |
| 1990 | The Human Genome Project begins. |
| 1997 | Dolly the sheep is born after Ian Wilmut and Keith Campbell use a new technique to produce a Finn Dorset lamb, the first clone created from adult cells. Until then, almost all biologists had believed cells are fixed in their roles, but the creation of Dolly from a mammary gland cell of a 6-year-old sheep shows this is not the case.
Only a week after the Dolly announcement, scientists bring cloning technology closer to humans by twinning rhesus monkeys from embryos. |

- 1998 Japanese scientists successfully clone eight copies of a single cow. Scientists at the University of Hawaii clone more than 50 mice.
- 2000 Great Britain becomes the first country to grant a patent for cloned early-stage human embryos. Geron Corporation, which had received the patent, announces it does not intend to create cloned humans. The group that created Dolly announces the first cloned pigs. Scientists hope that pigs can be genetically engineered for use in human organ transplants.
- 2003 The Human Genome Project is completed. For the first time, we have the ability to read nature's complete genetic blueprint for building a human being.



COURTESY AP
J. Craig Venter, left, CEO of Celera Genomics, and Francis Collins, head of the Human Genome Project, led rival groups that each completed a rough map of the human genome in 2000.

★ THE SCIENCE OF CLONING



Why Clone?

Scientists initially made cloned cells in the laboratory by allowing a single cell to divide into a population of genetically identical cells. Scientists put the original cell in a laboratory dish containing the nutrients needed to keep the cell alive, and the cell's natural process of mitosis (cell division) then produced genetically identical offspring. This process mimics how cells multiply, for instance, in plants and in the human body.

Scientists later developed more complex cloning techniques using animal embryos. Every cell in an animal comes from a fertilized egg. The fertilized egg divides to form an embryo, and each cell in the embryo has the same genetic makeup. At some point in the embryo's growth and development, cells differentiate and become specialized. For instance, a heart cell functions only in the heart and not in the liver, even though the genes of a heart cell and liver cell are the same.

In the 1950s scientists began to experiment with frog embryo cells that were undifferentiated — that is, they had not yet specialized into a particular type of cell. Scientists found that such embryo cells are totipotent (able to give rise to all the different cell types in the body). By exploiting this characteristic, scientists developed three techniques to clone embryo cells: blastomere separation, blastocyst division and somatic cell nuclear transfer.

The two types of cloning that make the news regularly are therapeutic, or biomedical, cloning and human/animal reproductive cloning. The goal of therapeutic cloning is to create embryonic stem cells that genetically match a patient, whereas the goal of reproductive cloning is to create a new animal identical to the animal that donated its genetic material. Both types of cloning begin with the process known as somatic cell nuclear transfer, or SCNT, which is the scientific term for cloning. In SCNT, scientists remove the nucleus from an egg cell (oocyte) and replace it with a nucleus from a donor adult somatic cell, which is any cell in the body except for an oocyte or sperm. To obtain embryonic stem cells, scientists allow the egg to divide for several days until it becomes a blastocyst containing about 150 cells. The inner cells of the blastocyst are harvested and used to develop new embryonic stem cell lines. For reproductive cloning, the embryo is implanted into a uterus of a

surrogate female, where it can develop into a live being, as has been done in some nonhuman animals.

In reproductive cloning (the type used to create Dolly), the embryo is implanted into a surrogate, and, if carried to term, results in an exact genetic replica of the donor of the somatic cell nucleus. In therapeutic cloning, stem cells — blank cells that have the ability to become any of the 200 different types of cells in the body — are taken from the embryo at a very early stage of development and potentially can be used to grow organs or to replace damaged cells in people with degenerative diseases such as diabetes, Alzheimer's and Parkinson's.

Both types of cloning offer promising potential medical applications. For example, through the use of cloned stem cells, therapeutic cloning might hold the key to repairing diseased organs and damaged cells. Reproductive animal cloning has the potential to revive endangered species and to create a population of genetically identical animals for research into human disease. Reproductive human cloning might help infertile couples have children.

However, these practices are controversial. Opponents argue the procedures destroy human embryos. Others feel they make human life merely an instrument. Further problems exist when deciding to allow therapeutic cloning and still prevent reproductive cloning from occurring, these opponents say.

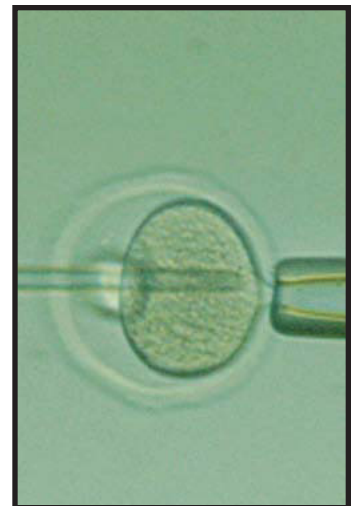
★ ETHICAL AND SOCIAL CONSIDERATIONS ★

A Highly Controversial Issue

Like any new science, cloning offers many ethical and social issues for consideration. To some people, it is ethically unacceptable to destroy a human embryo for any reason. To others, it is acceptable to do so if there exists the prospect of understanding and treating human diseases. The production of embryos using the cloning method offers specific advantages. Embryonic stem cells could be matched to a patient so tissues or organs developed from the embryo would be recognized by the patient's immune system; otherwise, the patient's immune system would reject any foreign tissue or organs, or the patient would have to take drugs to suppress the immune system, which could lead to infections.

Religion plays a large role in the ethical considerations surrounding cloning. Many religions believe human cloning should be banned entirely and forever. Theologians view all forms of cloning as a thorny issue, an example of the ongoing tension between faith and science. Some people believe the scientific advances that enable cloning are a God-given blessing. Others argue that scientists should not presume to “play God” by manipulating genetic makeup. Some opponents claim cloning must be forbidden because it involves destroying human embryos such as the ones used to harvest stem cells. These opponents argue any embryo is a viable human being and never should be destroyed intentionally.

Outside of religious arguments, some people believe embryos should not be created for research but can be used if they are left over from in vitro fertilization procedures. Others believe embryos are clusters of cells no different from other cells and can be created specifically for use in research. Those who believe that an embryo has the moral status of a fully formed person from the moment of conception consider research that destroys the embryo to be immoral. Those who believe an embryo is not equal to a fully formed person consider it immoral not to use existing embryos created through in vitro fertilization to save lives and develop cures for millions of people.



COURTESY NATIONAL SCIENCE FOUNDATION
An up-close look at the process of in vitro fertilization.

Safety issues have plagued cloning since its first use, and early experiments in animal cloning attracted attention to those potential dangers. In some early 1990s experiments, for example, cloned cows developed faulty immune systems. Other projects created cloned mice that grew obese. And in some studies, cloned animals seemed to grow old faster and die younger than normal members of the species. Cloning itself is expensive and highly inefficient; more than 90 percent of cloning attempts fail to produce viable offspring, and more than 100 nuclear transfer procedures could be required to produce one viable clone.

Cloning Humans

To date, no successful attempts to clone humans have been made. In 1998 a South Korean research team announced it had cloned a human embryo through somatic cell nuclear transfer, but the embryo only survived to four cells. And in 2001 researchers at the biotechnology firm Advanced Cell Technology claimed to clone human embryos that divided to six cells before dying. Many scientists argue that because the embryos from these two experiments did not double their cell size every 24 hours, they could not be considered true human embryos.

While these attempts were unsuccessful, the possibility of cloning humans raises a variety of social questions. What psychological issues would result for a cloned child who is the identical twin of his or her parent? Another possible issue is the role financial status could play, because cloning probably would be expensive and available only to the wealthy. Scientists could use genetic engineering to put together genes for such characteristics as beauty or intelligence and then clone the cell to make a kind of superchild. For these reasons and more, the vast majority of people find human cloning unacceptable. To many people, it is important to draw a distinction between cloning to derive cells for therapeutic treatment and cloning to produce a child.

★ EDUCATIONAL ACTIVITY ★

Thinking Critically

The following questions are intended to encourage thought, discussion and debate about the science of cloning. For each application of cloning technologies, it is important to consider:

1. What are the benefits?
2. What are the risks?
3. Who may be helped, and who may be hurt?
4. Should cloning research be subject to rules and regulations?
5. If yes, who should make them?

The opinions below reflect several of the arguments for and against cloning. As you read each one, ask yourself:

- Whose interest does this argument serve?
 - What implication would this argument have for someone with cancer, a spinal cord injury or heart disease?
 - What is going on in my life that might help me relate to these statements?
1. Cloning denies the sanctity of human life.
 2. Cloning embryonic human life under any circumstance crosses an ethical line and takes an irrevocable step, one from which science never can turn back.
 3. Cloning is the greatest scientific discovery in our lifetime. It promises cures for terrible diseases and brings hope to millions.
 4. Even if the dangers of cloning prove overwhelming, open-eyed caution is a better defense than determined ignorance.

★ ADDITIONAL RESOURCES

*A Glossary of Terms*

Alzheimer's disease: A progressive, degenerative disease that attacks the brain and results in impaired memory, thinking and behavior.

Blastocyst division: When a fertilized egg divides until it forms a mass of about 32 to 150 cells.

Blastomere separation: The separation of embryonic cells, known as blastomeres, for use in producing multiple organisms that are genetically identical.

Diabetes: Any of several metabolic diseases affecting the body's use of blood sugars for the intake and excretion of fluids.

Differentiated cells: Cells that are specialized for a particular function (heart muscle or a blood cell, for example) and do not maintain the ability to generate other kinds of cells or to revert back to a less specialized type of cell (such as stem cells).

Embryo: An organism in its earliest stages of development and in a rudimentary form.

Gene: The basic unit of inheritance, consisting of a sequence of DNA that occupies a specific position on a chromosome.

In vitro fertilization: The union of an egg and sperm in a laboratory followed by implantation of the fertilized egg into the uterus.

Nucleus: In biology, the part of a cell that controls growth and reproduction.

Organism: Any living structure, such as a plant, an animal, a fungus or a bacterium, that is capable of growth and reproduction.

Parkinson's disease: A chronic, progressive disease that occurs when nerve cells in a part of the midbrain, the substantia nigra, die or are impaired.

Somatic cell: A cell that contains two complete sets of chromosomes.

Surrogate: One that acts in another's place. In Dolly the sheep's case (the first mammal cloned from an adult cell), the surrogate was another Scottish Blackface ewe.

Relevant Links

<http://www.aaas.org>

The American Association for the Advancement of Science is an international nonprofit organization dedicated to advancing science around the world. The site contains an excellent policy brief describing cloning and the arguments for and against the controversial subject.

<http://www.criticalthinking.org>

The Foundation and Center for Critical Thinking offers primary and secondary schools, colleges and universities professional development programs emphasizing assessment, research, instructional strategies, Socratic questioning, critical reading, critical writing, higher-order thinking, quality enhancement and competency standards. The site contains a detailed description of the philosophy and components of critical thinking.

<http://www.dnapolicy.org>

The Genetics and Public Policy Center was established to create the environment and tools needed by key decision-makers in both the private and public sectors to consider carefully and respond to the challenges and opportunities that arise from scientific advances in genetics. This site contains an insightful summary of the cloning debate and an in-depth report titled *Cloning: A Policy Analysis*.

<http://encarta.msn.com>

Encarta is a digital multimedia encyclopedia published by Microsoft. The site contains a comprehensive discussion of cloning.

<http://www.genome.gov>

The National Human Genome Research Institute (NHGRI) led the National Institutes of Health's contribution to the International Human Genome Project, whose primary goal was the sequencing of the human genome. The project was successfully completed in April 2003. Now, the NHGRI's mission has expanded to encompass a broad range of studies aimed at understanding the structure and function of the human genome and its role in health and disease. The site contains detailed and in-depth information about the research behind cloning. Policy and ethics information also is found on the site.

<http://gslc.genetics.utah.edu>

The University of Utah's Genetic Science Learning Center aims to help people understand genetic science and how it relates to their lives and to society. Its site provides basic information about cloning and its process in addition to interactive learning tools.

<http://www.nasonline.org>

The National Academy of Sciences is an honorific society of distinguished scholars engaged in scientific and engineering research dedicated to the furtherance of science and technology and to their use for the general welfare. The site features in-depth reports on and analysis of many issues surrounding cloning. Members support a worldwide ban on human reproductive cloning but do not support a ban on therapeutic cloning.

<http://www.ornl.gov>

Oak Ridge National Laboratory is a multiprogram science and technology laboratory of the Department of Energy. The site provides an excellent cloning fact sheet discussing general cloning information as well as more detailed topics related to cloning.

<http://www.reproductivecloning.net>

The Reproductive Cloning Network publishes procloning, neutral and anti-cloning articles, though most either are procloning or neutral.