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Stem Cells and Its Medical Potential

Stem cells are pluripotent, which means that they can develop into every cell, every tissue and every organ in the human body.

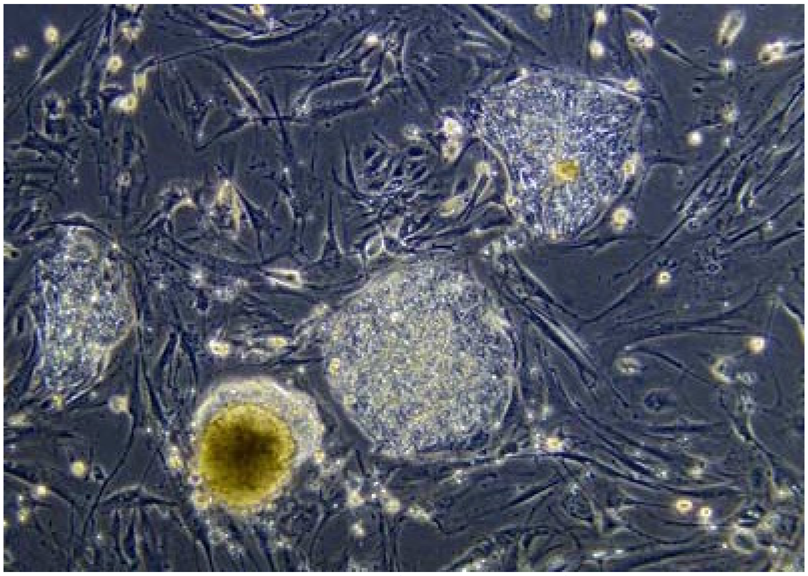


Photo courtesy University of Wisconsin Board of Regents

Microscopic 10x view of a colony of embryonic stems cells
(The stem cell colonies are the rounded, dense masses of cells.)

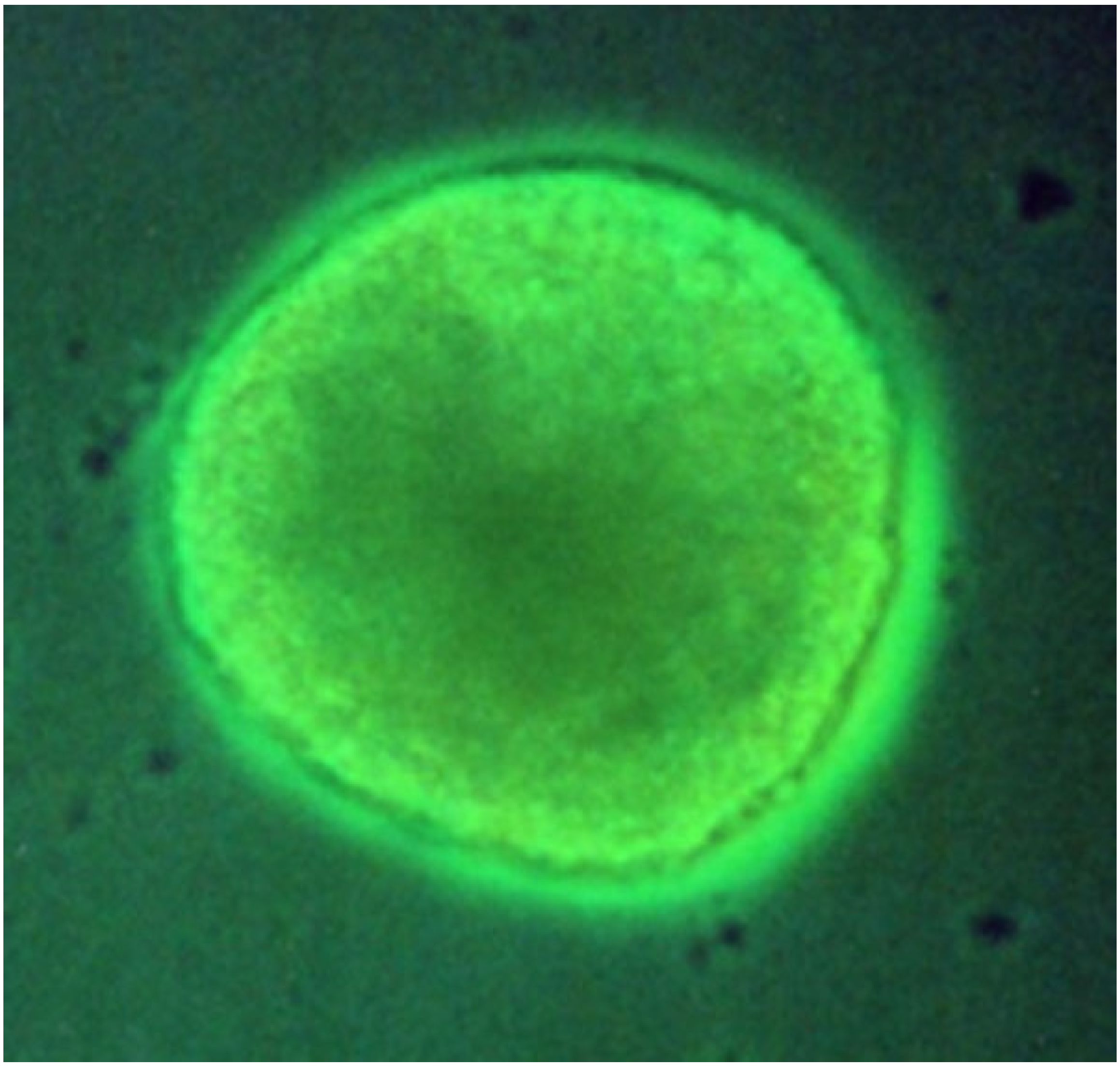
Their limitless potential has made stem cells a significant focus of medical research. Imagine having the ability to return memory to an Alzheimer's patient, replace skin that was lost during a terrible accident or enable a wheelchair-bound person to walk again. However, stem cells can't treat disease until scientist learn how to manipulate stem cells to get them to develop into specific tissues or organs.

A stem cell is essentially the building block of the human body. The stem cells inside an embryo will eventually give rise to every cell, organ and tissue in the fetus's body. Unlike a regular cell, which can only replicate to create more of its own kind of cell, a stem cell is pluripotent. When it divides, it can make any one of the 220 different cells in the human body. Stem cells also have the capability to self-renew -- they can reproduce themselves many times over.

There are two types of stem cells: embryonic stem cells and adult stem cells. Embryonic stem cells come from an embryo -- the mass of cells in the earliest stage of human development that, if implanted in a woman's womb, will eventually grow into a fetus. When the embryo is between three and five days old, it contains stem cells, which are busily working to create the various organs and tissues that will make up the fetus.

Adults also have stem cells in the heart, brain, bone marrow, lungs and other organs. They are our built-in repair kits, regenerating cells damaged by disease, injury and everyday wear and tear. Adult stem cells were once believed to be more limited than stem cells, only giving rise to the same type of tissue from which they originated. But new research suggests that adult stem cells may have the potential to generate other types of cells, as well. For example, liver cells may be coaxed to produce insulin, which is normally made by the pancreas. This capability is known as transdifferentiation.

Adult stem cells are much harder for scientists to work with because they are more difficult to extract and culture than their embryonic counterparts. Stem cells not only are hard to find in adult tissue, but scientists also have difficulty getting them to replicate in the laboratory.



But even embryonic stem cells, which can be grown effectively in the lab, are not easy to control. Scientists are still struggling to get them to grow into specific tissue types.

Ideally, scientists would like to be able to grow a particular type of cell in the laboratory and then inject it into a patient, where it would replace diseased tissue. But stem cells are not yet being used to treat disease because scientists still haven't learned how to direct a stem cell to differentiate into a specific tissue or cell type (brain vs. liver, for example) and to control that differentiation once the cells are injected into a person.

Take the example of diabetes. To treat diabetics, scientists must not only create insulin-producing cells, but they must be able to regulate how those cells produce insulin once they are in the body.

In nature, stem cells are triggered to differentiate by internal and external cues. The internal cues are genes inside each cell, which are like a series of instructions that dictate how it should function. The external cues are chemicals released by other cells or contact with other cells, either of which may change the way the stem cell functions.

Scientists do know that turning genes on and off is crucial to the process of differentiation, so they have been experimenting by inserting certain genes into the culture dish and then using those genes to try to coax stem cells to differentiate into specific types of cells. But some sort of signal is needed to actually trigger the stem cells to differentiate. Scientists are still searching for that signal.

Also, there are other obstacles standing in the way of stem cell use. One is the problem of rejection. If a patient is injected with stem cells taken from a donated embryo, his or her immune system may see the cells as foreign invaders and launch an attack against them. Using adult stem cells could overcome this problem somewhat, since stem cells taken from the patient would not be rejected by his or her immune system. But adult stem cells are less flexible than embryonic stem cells and are harder to manipulate in the lab.

If scientists can ultimately learn how to direct stem cells to differentiate into one type of tissue or another, they can use them for two very important medical purposes.

First, pluripotent stem cells can be used to test new medications for safety and effectiveness. A medication could be tried out on a specific type of cell to gauge its response far more quickly than it could be tested in clinical trials. For example, scientists could use a cancer stem cell line to investigate whether a new anti-tumor drug stopped the cancer from growing.

Stem cells could also be used to repair cells or tissues that have been damaged by disease or injury. This type of treatment is known as cell-based therapy. One potential application is to inject embryonic stem cells into the heart to repair cells that have been damaged by a heart attack. In one study, researchers induced a heart attack in rats, then injected rodent embryonic stem cells into the damaged hearts. Eventually, the stem cells regenerated the damaged muscle tissue, improving the rats' heart function.

Stem cells may also one day be used to repair brain cells in patients with Parkinson's disease. Parkinson's patients are lacking the cells that produce a chemical messenger called dopamine. Without dopamine, their movements become jerky and uncoordinated, and they suffer from uncontrollable tremors. In studies, researchers have injected rodent embryonic stem cells into the brain of rats with Parkinson's disease. The stem cells generated dopamine-producing nerve cells, improving the rats' condition. Scientists hope they can one day replicate their success in human patients.

Eventually, scientists might even be able to grow entire organs in a laboratory to replace ones that have been damaged by disease. The idea is this: They would create a sort of scaffold out of a biodegradable polymer to shape the organ, and then seed it with either embryonic or adult stem cells. Growth factors specific to the organ would be added to guide the organ's development. The tissue-covered scaffold would then be implanted into the patient. As the tissue grew from the stem cells, the scaffold would degrade, leaving a complete ear, liver or other organ.