What is an Induced Pluripotent Stem Cell?

By Vanessa Aguilar

How is it that we can see a beautiful morning sunrise, taste a delightful morning cup of coffee, or feel our heart pumping blood through our body during a light jog? The biological answer is: *because of our cells!* Cells are the smallest building blocks of life and we are made up of trillions of them (Bianconi et al., 2013). Every thought, smell, taste – in fact, our complete existence – is a result of their intricate network of communication and multifaceted functions.

There are many different types of cells in our body. Most cells are “specialized,” meaning they perform a very specific function. For example, the retina is made up of cells called rods and cones that allow us to see light and color, respectively.

Although most cells have specific roles, they all start out with the same set of instructions. Cellular instructions come in the form of genes, which are encoded within DNA and housed within the nucleus of our cells. During embryonic development cells become more and more specialized due to gene regulation: a different pattern of genes are turned on in different cell types. It is the specific set of genes that are up-regulated (turned on) or down-regulated (turned off) that ultimately determine the type of cell it will become.

For example, genes that are important for seeing light are up-regulated in a rod cell, while genes important for seeing color are up-regulated in a cone cell.

Once a cell becomes specialized, it usually loses the ability to divide. That means if your cone cells are damaged, the remaining cone cells cannot divide to replace the cells that are damaged in your retina. Your vision would be irreparably damaged.

For many tissues, this is where stem cells come into play.

Stem cells have the capacity to divide and make new cells for a long period of time. Our stem cells help replenish lost, aging, or damaged cells throughout our body. Importantly, stem cells create both more stem cells and cells that will eventually become specialized.

Stem cells in adults [and, actually, stem cells after just a few weeks of embryonic development] are referred to as “adult stem cells.” Adult stem cells are limited in the type of cell they can become. For example, one type of adult stem cell that resides in our bone marrow can replenish our bone, cartilage, and blood cells, but cannot develop into any other cell type (for example, this particular stem cell could not develop into a rod or a cone cell). Therefore, adult stem cells are called *multipotent* due to their ability to turn into multiple cell types. This is in contrast to embryonic stem cells, which only exist in the 7 – 10 day old human embryo; embryonic stem cells are called *pluripotent* because of their ability to turn into ALL cell types.

Recently, scientists have figured out a way to turn a specialized adult cell (like a skin cell), into a cell with pluripotent capabilities (Takahashi and Yamanaka, 2006). This is remarkable because specialized cells usually do not divide at all, and they certainly are not pluripotent; it is a sort of molecular magic trick. These incredible cells are called induced pluripotent stem cells (iPSCs). Since these cells are pluripotent, they have the ability to become any type of cell in the body. These extraordinary cells could be a source of cells used for regenerative medicine, a branch of medicine that aims to repair damaged tissues in humans.

What I didn’t mention before is that some adult tissues do not have an adult stem cell population dedicated to replenishing cells. The retina and kidney are two examples of so-called “non-regenerative tissues.” Imagine the benefits of being able to use iPSCs to grow non-regenerative tissues like the retina…or maybe even a whole kidney! This would greatly reduce our dependence on organ donations and transplantation, a process with incredible limitations and complications.

A profound aspect of using iPSCs in medicine is that the source of adult cells used to create iPSCs can be directly from the individual receiving the stem cell treatment. This would greatly decrease the chance of immune system rejection post-treatment, which is a common complication in organ transplantation ("What is an Induced Pluripotent Stem Cell?" 2015). Also, the most common source of adult cells used to create iPSCs are skin cells, which are easily obtained and not controversial in comparison to human embryonic stem cells.

Many diseases such as cancer, diabetes, and heart disease cause tissue damage that the body is not able to repair. For example, when a heart attack occurs, there is often damage to the heart muscle that becomes scarred. This scarring causes the heart to work less efficiently and could lead to other types of heart conditions. Using iPSCs to regenerate the damaged area could alleviate the consequences of scarring and improve the quality of life for an affected individual. Regenerating the damaged area could also minimize the amount of medication (and, therefore, side effects) a person might otherwise be required to take for life.

Scientists are incredibly excited about the seemingly limitless potential of iPSCs in regenerative medicine. There is now tremendous effort in the field to figure out how to safely and effectively use these amazing cells for all different types of disease. It is a fantastic time to be a scientist working in the field of regenerative medicine.

References

Bianconi, E., Piovesan, A., Facchin, F., Beraudi, A., Casadei, R., Frabetti, F., & ... Canaider, S. (2013). An estimation of the number of cells in the human body. *Annals Of Human Biology*, *40*(6), 463-471. doi:10.3109/03014460.2013.807878

Takahashi, K., & Yamanaka, S. (2006). Induction of pluripotent stem cells from mouse embryonic and adult fibroblast cultures by defined factors. *Cell*, *126*(4), 663-676.

What are induced pluripotent stem cells?. In *Stem Cell Information* [World Wide Web site]. Bethesda, MD: National Institutes of Health, U.S. Department of Health and Human Services, 2015 Retrieved from <http://stemcells.nih.gov/info/basics/pages/basics10.aspx>