Embryonic Stem-Cell Research: The Promise And The Reality (Part One)

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> ***"Know that the Lord, He is God; It is He who has made us, and not we ourselves." Psalm 100:3***

Embryonic stem-cell research is both scientifically feasible and morally permissible—at least according to the majority of the electorate in the State of California. In the November 2004 elections, an overwhelming majority of those voters approved an initiative that funds embryonic stem-cell research through $3 billion worth of bonds. Emotion rather than reason probably generated most of the "aye" votes, many voters responding to the biotech industry's marketing ploy of airing testimonials from desperately sick or injured celebrities. "Don't deny us the only hope we have," they pled. "A vote against embryonic stem-cell research is a vote against life."

California's electorate aside—and apparently many in both Houses of Congress, where stem-cell research bills are now being debated, as well—is the harvesting of embryonic stems cells in fact moral? Is there any substantive scientific evidence that embryonic stem-cell research can make good on its promises to cure? Who loses from this research? Who gains?

In this two-part article, we will review embryonic stem-cell research: its nature and goals, its scientific challenges, its moral issues, and its alternatives. What is it all about?

Let us start by getting the terms straight.

Embryology 101

(Underlined words are defined in the glossary at the end.)

There are two types of human reproduction: sexual and asexual. In sexual reproduction, the male gamete (or sperm cell) unites with the female gamete (or egg cell) to produce a zygote. This union is called fertilization. Half the chromosomes of the zygote come from the sperm cell, half from the egg cell.

Sexual reproduction comes in two varieties. The first, and more common, is fertilization through coition. This is *in utero* fertilization, where the zygote comes into being in the uterus. The second kind is *in vitro* fertilization (IVF), where the sperm unites with an egg in a laboratory Petri dish. From that point, the zygote (and later, the embryo) can develop in culture.

Asexual reproduction is commonly called cloning. Procedurally, the nucleus of an egg cell is removed in the laboratory. Then, the nucleus from another type of cell, any body cell, is "inserted" into that egg cell. Stimulating this egg cell with an electrical charge creates a viable zygote.

While not usually part of the syllabus of Embryology 101, it is important to understand two things about embryos.

1. First, every human zygote, no matter how it is produced, is a human being who is in his first stage of development. *Every* zygote is an individual. Unless death intervenes, the zygote will become an embryo, then a fetus, then an infant, then an adolescent, and eventually an adult.

2. Second, the absence of a sperm does not render an embryo created through cloning anything less than a full-fledged embryo. *A cloned embryo is an embryo in every sense of the term.* One writer mentions that even a stem-cell researcher as prominent as John Gearhard of Johns Hopkins University insists that the cloned organism starts out its existence as a zygote/embryo.[1]

Upon its creation, the zygote has two tasks immediately ahead of it. In the case of natural conception, it must *implant* itself into the wall of the womb. If it does not accomplish this implantation soon, it will perish for lack of nourishment. All human life, at whatever stage, must have sustenance and a proper environment to continue living.[2]

Embryology Development

The zygote's other task is to grow—to split into more cells. It starts this process almost immediately, and in the case of *in utero* fertilization, long before womb-attachment. Growing, the zygote becomes an embryo and later a fetus. Importantly, initial growth does not simply mean adding more cells; it does not merely imply "getting bigger." At this point, adding size, as a boy does when he "bulks up" by exercising his muscles, is not the aim in a person's development. Instead, *from the single-cell zygote must spring each of the 210 basic cell types in the human body.* Examples of such cell types include brain cells, bone cells, red blood cells. These are called adult cells.

Adult cells by definition perform highly specialized tasks. Red blood cells provide a good example of this specialization. Their task is to supply oxygen to other cells. They are able to carry out that task because they have iron in them. The iron oxidizes; it rusts. (That is why "red" blood cells appear red.) The oxidization process means that oxygen becomes attached to the iron. It is in fact the rusted iron, carried by these red blood cells, which provides oxygen to other cells.

The zygote's task, then, is not just to add numbers of cells, but to produce 210 different types of adult cells. The process by which a zygote does this is called cellular differentiation. Here is where embryonic stem cells enter the picture. When a zygote begins to split into other cells, it does not form specialized, adult cells. Rather, it forms stem cells. These stem cells facilitate cellular differentiation. *Stem* in this usage means "source" or "origin," as in the sentence, "Adultery stems from lustful thoughts." Thus, specialized (adult) cells *stem* from stem cells.

Cellular differentiation works this way: When a stem cell divides, it forms two cells.

» One is a look-alike; it replaces the original stem cell.

» The other cell is truly remarkable; it has the ability to split into something new. That *something new* is a differentiated stem cell, and it is quite different from the stem cell that produced it. This new stem cell is a more specialized cell, but it is not yet an adult cell.

A Stepping-Stone Process

Think of this new, different stem cell as one "stepping stone" toward the final product, an adult cell. Between original zygote and final adult cell, several stepping-stones will be needed. Each stone brings you closer to that adult cell. With each successive splitting of a stem cell, a more specialized cell comes into being, until, after a number of "generations," the adult cell appears. That cell may be, say, a red blood cell—highly specialized in its function. It could be a white blood cell, a brain cell, a bone cell—any of 210 distinct types of adult cells.

What might be the basic difference between stem cells and adult cells? It is probably the *type* of cells they are capable of producing.

> » Adult cells can produce only after their kind. A white blood cell cannot breed a brain cell, but only another white blood cell.
>
> » However, the zygote and stem cells are able to produce cells quite *different* from themselves. The zygote is called totipotent—able to generate all other cells. The earliest stem cells, those descending directly from the zygote, are also characterized by totipotency; they, too, can ultimately (that is, through several "generations" of splits) produce all other types of cells—brain cells, bone cells, etc.

Importantly, this differentiation is not random but is tightly *organized*. Something signals a particular stem cell to act as the ultimate progenitor of a brain cell. That something also signals another stem cell to produce, after several generations, a liver cell. One expert summarizes the challenge this way:

> Embryonic development is one of the most fascinating of all biological processes. A newly fertilized egg faces the daunting challenge of not only generating all of the tissues of the mature animal but organizing them into a functionally integrated whole. . . . If a developing embryo is not to end up a mass of disorganized tissues, it must do more than generate adult cell types. Embryos must orchestrate and choreograph an elaborate stage production that gives rise to a functional organism. They must direct intricate cell movements that bring together populations of cells only to separate them again, mold and shape organs through the birth of some cells and the death of others, and build ever more elaborate interacting systems while destroying others that serve only transient, embryonic functions. Throughout the ceaseless building, moving, and remodeling of embryonic development, new cells with unique characteristics are constantly being generated and integrated into the overall structure of the developing embryo. Science has only the most rudimentary understanding of the nature of the blueprint that orders embryonic development.[3]

Although not understood by man, this "blueprint that orders" is vitally important in the development of the individual. Stem cells that take orders—follow the blueprint—build healthy bodies. Stem cells that do not take orders result in a monster. *Monster* is the English translation of the Greek word teratoma, a type of tumor (benign or malignant) whose initial cells appear totipotent (or at least multipotent). They are like stem cells, keen to produce a wide variety of adult cell types (skin, bone, muscle, hair, teeth). However, the tissue they generate is "all massed together in a chaotic lump. . . . Unlike embryos, tumors generate adult cell types in a hopelessly undirected manner."[4] The teratoma's initial stem-like cells lack a blueprint, or at least refuse to follow one. The result can be an often lethal, malignant monster.

Dissociated Embryonic Stem Cells

What is the nature of this ordering blueprint? Put differently: What generates the signals that tell a particular stem cell to differentiate into a red blood cell as distinct from a bone cell? How does a given stem cell know to generate a line of stem cells that will finally culminate in, say, an adult brain cell?

In this area, there are more questions than answers. Scientists know that there are three types of signals:

> **1. Molecular**: Chemical substances are known to provide signals to embryonic stem cells.
>
> **2. Electrical**: It is widely recognized that embryonic development takes place in an electrical field.
>
> **3. Mechanical**: Embryonic stem cells seem to respond to structural tensions provided by cells in their proximity.

In the early 1990s, scientists learned that they could physically "extract" some stem cells from an embryo they had created through *in vitro* fertilization or through cloning. These separated (or "harvested") cells are called dissociated embryonic stem cells. In culture, these cells reproduce indefinitely—and fast! "One small flask of cells . . . will generate a quantity of stem cells roughly equivalent in weight to the entire human population of the earth in less than sixty days."[5] However, these harvested stem cells simply reproduce; they do not differentiate into more and more specialized adult cell types. This is because they lack signals. Separated from the embryo, these dissociated cells find no blueprint to follow. They become a mass of unorganized (indeed, disorganized) cells, not unlike a teratoma.

This finding disheartened scientists until they discovered they could simulate (or replicate) those signals, or at least the chemical ones. Wow! What a blockbuster! *Just provide the right signals, and there, in culture, is produced adult, disease-free cells of whatever type is needed to bring about a cure.*

Let us say a scientist "signaled" these disassociated stem cells to differentiate, ultimately, into pancreatic cells, which are adult cells. Once produced in sufficient number, these adult pancreas cells could be implanted into a person with a bad pancreas, a diabetic. The effect, scientists promise, would be curative. The pancreas would eventually start producing insulin normally.

Such is the promise of embryonic stem-cell research. That is why the celebrities in California praised it so much. That is why a majority of voters added $3 billion to California's already burdensome indebtedness. The biotech firms love every minute (uh, dollar) of it!

In Search of a Better Blueprint

Bottom line, what is embryonic stem-cell research all about? Certainly, it is about determining which signal produces a pancreas cell, which produces a white blood cell, which one a bone cell, and so on. It is a search for effective signals to embryonic stem cells.

Far more fundamentally, however, it is a search for a blueprint. It is a search to find the organizing plan the zygote/embryo follows as it differentiates cells, configures them into systems, and integrates them into the single organism scientists call *homo sapiens*. In short, stem-cell research is the search for the pattern God uses to "fashion" us in the womb.[6] Psalm 139:13-16 makes it clear that God saw David's blueprint before his first stem cell split; the person David was the result of God's working "skillfully" according to that plan. David writes,

> For You have formed my inward parts;
> You have covered me in my mother's womb.
> I will praise You, for I am fearfully and wonderfully made. . . .
> My frame was not hidden from You,
> When I was made in secret,
> And skillfully wrought in the lowest parts of the earth.
> Your eyes saw my substance, being yet unformed.

We can be sure that scientists, if they could figure out that blueprint, would want to make it "better." They would want to create *their* kind of person, a superman. Paying no attention at all to Psalm 100: 3, they forget that man does not create man. God does.

Next month, we will look at the scientific challenges and moral issues that surround embryonic stem-cell research.

Glossary of Terms

Adult Cell
A specialized cell, like a brain or heart cell. Unlike stem cells, an adult cell can produce cells only of its own type. Many biologists identify about 210 discreet types of adult cells.

Adult Stem Cells
Stem cells present in the extra-uterine individual, retrievable by biopsy. Not to be confused with *adult cells*.

Cellular Differentiation
The process by which stem cells generate cells quite different from themselves. The generated cells are different in that they are more specialized.

Cloning
A fertilization process marked by the absence of a male gamete (sperm). The nucleus of an egg cell is removed in the laboratory. Then, the nucleus from any other body cell is "inserted" into that egg cell. Stimulating the egg cell with an electrical charge creates a zygote, which can develop in culture. The individual produced is said to be a clone of the donor who supplied the substituted nucleus.

Disassociated Embryonic Stem Cells
Embryonic stem cells that are extracted from an embryo created through *in vitro* fertilization or through cloning. The cells so "harvested" from the embryo can be nurtured in culture, where they split indefinitely and quickly. The embryo that donates the stem cells dies.

Embryo
An individual (human or animal) from the time the zygote first begins cellular differentiation. In the case of human, the organism is termed an embryo through the eighth week after fertilization.

Embryonic Stem Cells
Stem cells that are the immediate descendants of the zygote. Responding to molecular, electrical, and mechanical stimuli (or signals), these cells produce more specialized stem cells, which in turn produce even more specialized stem cells. The ultimate product is an adult cell, such as a white or red blood cell.

Female Gamete
Egg (ovum).

Fertilization
The process by which the male gamete (sperm) unites with the female gamete (egg). The immediate result is a new individual in the zygote stage of development. Fertilization can be sexual, effected through coition or IVF, or asexual, effected through cloning.

Fetus
In humans, an individual from the ninth week after fertilization until parturition (birth).

Implantation
The process by which the zygote/embryo attaches itself to the womb for sustenance.

***In utero* Fertilization**
Sexual fertilization wherein the male gamete (sperm) unites with the female gamete (egg) in the uterus. This is coition, the traditional method of fertilization.

***In vitro* Fertilization**
Sexual fertilization wherein the male gamete (sperm) unites with the female gamete (egg) in a laboratory Petri dish. The embryo can then develop in culture. Acronym: IVF.

Male Gamete
Sperm cell.

Multipotent
Capable of differentiating into (that is, ultimately producing) a number of other types of cells, but *not* all types of cells, Multipotency is a characteristic of stem cells that are more than one generation away from original stem cells. Such cells are more specialized, and are less able to generate any type of cell. The more specialized a cell (that is, the more generations it is away from the original stem cells) the less multipotent it is. Also termed *pluripotent*.

Pre-Embryo
An embryo before implantation in the womb. This term has no meaningful biological referent. "Pre-embryo" implies that the fertilized organism, before attachment to the womb, is not an embryo at all. By definition, however, the zygote became an embryo immediately after it began to split. In other words, an embryo is an embryo, regardless of its state of womb-attachment. Before attachment, an embryo is still an embryo—just an un-implanted one. The term *pre-embryo* implies that a zygote

/embryo is not a human organism until attachment and can therefore be destroyed. It is a term coined by politically-minded bio-technicians to give them "time" to kill, a window of time between fertilization and attachment. The term seeks to skirt the moral issue of murder.

Stem Cell
A cell that becomes the source (hence, "stem") of other cells. Stem cells can produce more specialized cells, such as brain or bone cells. See *totipotent* and *multipotent*.

Teratoma
A type of tumor resulting from multipotent (pluripotent) cells. Because the initial cells carry the characteristic of multipotency, they are similar to stem cells. However, the teratoma's cells follow no blueprint. They do not produce an organism with integrated systems, but a confused mass of tissue. In these tumors appear cell types quite different from that of the surrounding tissue (for instance, an ovarian teratoma may contain hair, teeth, and even sweat glands). Also referred to as *teratomata*.

Totipotent
Able to differentiate into (that is, ultimately produce) all other types of cells. Totipotency is a characteristic of the zygote and of the stem cells that are its immediate progeny.

Zygote
The highly specialized single cell resulting from fertilization.

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Saunders, Jr., William L., "Embryology: Inconvenient Facts," *First Things*, December 2004, p. 15. Saunders, Senior Fellow and Director of the Center for Human Life and Bioethics, presents

authoritative arguments for the nature of zygote and embryo, and shows how modern bio-technicians hide meaning behind verbal sophistries. This article is available at http://www.firstthings.com/ftissues/ft0412/opinion/saunders.htm

National Catholic Bioethics Quarterly. This big journal (each issue is over 200 pages) is published by the National Catholic Bioethics Center in Boston. Because of the obvious Catholic focus, members of God's church will find many articles off base, yet this journal remains one of the best single sources of reasoned information on the subjects of bioethics and biotechnology. Some articles are quite technical. For more information, write the *National Catholic Bioethics Quarterly*, PO Box 3000, Denville, NJ 07834-9772 ($48/year).

Endnotes

1 Saunders, Jr., William L, "Embryology: Inconvenient Facts," *First Things*, December 2004, p. 15.
2 After the mid-1980s, bio-technicians spoke of a pre-embryo as an organism before womb-attachment.
The implication is that the pre-embryo is non-human; the implanted embryo human. This false concept will be discussed more fully in Part Two. Suffice it to say that there is really no such thing as a pre-embryo. An embryo is an embryo. An unattached one is an embryo in every sense of the definition. It is just unattached.
3 Condic, Maureen, "The Basics about Stem Cells," *First Things*, January 2002, p 30.
4 Ibid.
5 Ibid.
6 See Psalm 119:73.