Faith & Genetics

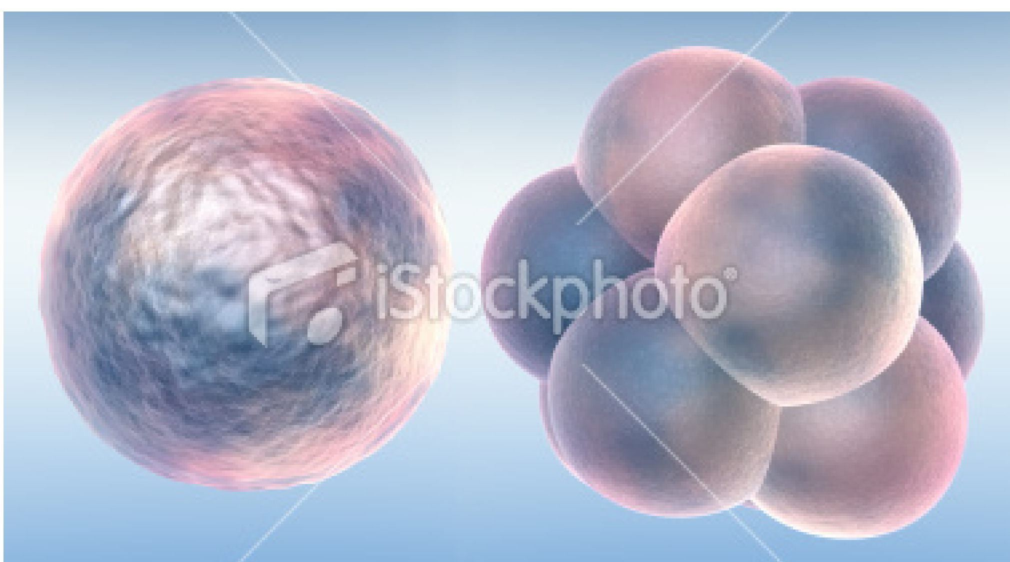
Embryonic Development and Genetic Engineering

Conception and Development of the Embryo

A fertilized egg is called a zygote. This cell is totipotent. That is, this cell has the ability to divide and specialize into all the cell types found in a human being and into all of the cell types that form the extraembryonic tissues, such as the placenta, umbilical cord and amniotic sac. In other words, this zygote has the potential to develop into, and support the development of, an newborn infant. The process by which a zygote develops into an embryo, a fetus and then an infant is, essentially, a process of cell division and increasing specialization of different groups of dividing cells. An infant is composed of trillions of cells, most of which are highly specialized cells in muscles, nerves, the liver, the brain, and so on. The single cell that comprises the initial zygote is completely unspecialized but has the potential to specialize.

The fertilized egg divides into two cells. These two cells are still totipotent. We know this because of identical twins. Sometimes, after a fertilized egg has divided into two cells, the two cells separate and each cell may go on to develop into a separate infant, each with its own supporting tissues (placenta, umbilical cord, and so on).

If the two-celled zygote divides into 4 cells, those 4 cells are still totipotent. We know this because of the rare occurrence of identical quadruplets. In very rare cases, the 4 cells separate and develop into 4 individuals, each with their own placenta, umbilical cord, and amniotic sac.



If the 4-celled zygote divides again into 8 cells, these 8 cells are still totipotent. We know this not because of the birth of identical octuplets, but because of a process that occurs in fertility clinics. Some infertile couples use in vitro fertilization to create a zygote. Eggs from a woman are combined with sperm from a man to create zygotes. These zygotes then begin to divide to become embryos in a Petri dish in a lab. Sometimes, the couple asks to have genetic testing conducted on the embryos. This pre-implantation genetic diagnosis is performed by carefully removing one of the cells at the 8-cell stage. The cell is then examined for genetic abnormalities. The remaining 7-celled zygote is allowed to continue to divide. Although the process is not perfectly efficient, the zygotes that continuing growing can be perfectly normal. That means that the one cell that was removed was not vital for development and the remaining 7 cells had the ability to divide and specialize into all the necessary cell types.

When in early development do cells lose their totipotency? It turns out that there is no defined event or number of cell divisions after which totipotency is lost. The loss of totipotency is a process. Gradually, as the cells divide, they begin to specialize. By the time there are 150 cells or so, the embryo is no longer a cluster of cells. Rather the cells have formed a hollow ball called a blastocyst. At this point, an important degree of specialization has occurred. The cells that form the outside of the blastocyst have specialized to the point that they can only continue on to become the supporting extraembryonic tissues, the placenta, the umbilical cord, the amniotic sac. They have lost the ability to specialize into the cells that will become the fetus. A little cluster of cells that extend into the center of the blastocyst, called the inner cell mass, have specialized to the degree that they can no longer develop into any extraembryonic tissues, but only the cells that will eventually make up the developing fetus and later mature human being. If the inner cell mass is removed from the blastocyst and implanted in the uterus of a woman, it cannot develop into a baby, because it does not have the ability to grow the supporting tissues. However, these inner cell mass cells do have the potential to develop into any cell of the body of the fetus. These cells are said to be pluripotent and constitute embryonic stem cells. Once the inner cell mass is removed from the embryo, the embryo will ultimately die. This is the main reason why these cells are the center of controversy in the stem cell debate. Some feel that embryos are not fully human beings and use that claim to justify killing them for research to potentially develop therapies to help other later. Others feel that the embryo has the status of a human being such that killing the embryo is immoral.

Using Human Embryos or Cell Constructs as Sources of Human Embryonic Stem Cells for Research

There are two ways to create an embryo from which stem cells can be obtained. One is to use embryos created by in vitro fertilization where a human sperm is joined with a human egg in a laboratory and one or more embryos are inserted into the woman's womb. Embryos that do not implant have been used as sources of pluripotent stem cells. This requires destroying the embryo and thus is morally objectionable to many Christians and others. The second method of creating an embryo (some call this an embryoid to distinguish it from an embryo produced from the merger of a sperm and an egg. Some consider the use of embryoids to be less morally objectionable than the destruction of embryos as a source of stem cells for research) is by somatic cell nuclear transfer, the same method by which some mammals have been cloned. Again, this process has not yet succeeded in humans, but if it did succeed, the result would be an embryo from which stem cells could be obtained. In this case, the stem cells would be genetically identical to the person who donated the nucleus for the somatic cell nuclear transfer.

In the past few years, scientists have discovered ways to construct cells in the laboratory that have many characteristics similar to embryos. However, rather than being created by the union of a sperm and an egg or by somatic cell nuclear transfer as described above, these cells are produced from an ordinary body cell like a skin cell. They are then manipulated in the laboratory to lose their normal functions while taking on functions and other characteristics commonly seen in pluripotent stem cells. These induced-pluripotent stem cells are considered by some to be more ethically acceptable for developing new therapies because they are not produced involving the use of natural embryos produced from sperm or eggs that must be destroyed to harvest the stem cells.

Human Engineering and Cloning

It has been proposed that combining stem cells and embryo cloning could allow germline genetic engineering. In this process, pluripotent stem cells would be removed from an embryo or embryoid. These cells would then be infected with a virus that contains whatever genes someone desired to transfer into the cells. The cells could be tested for successful incorporation of the desired gene or genes. Those cells that had successfully been engineered could have their nuclei removed and transferred to denucleated eggs (recall that this is the somatic cell nuclear transfer technique mentioned in 'Animal Cloning'). The resulting cell could be allowed to develop into an embryo then implanted into the uterus of a surrogate mother. If an infant developed and was born, that infant would carry the engineered genes in every one of his or her cells. If that infant grew to adulthood and reproduced, his or her offspring would also possess these introduced genes. It is important to note that this process has not at this point been achieved in primates, including humans, but scientists are currently working to develop this process.