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REVIEW

When "Personhood" Begins in the Embryo: Avoiding a Syllabus of Errors

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The following essay was delivered at the conference "Ontogeny and Human Life" at the Ponifical Athenaeum "Regina Apostolorum," November, 2007. Sponsored by the Legion of Christ, the Pontifical Academy for Life, and the John Templeton Foundation, the sessions focused on when the conceptus became a "person." My essay focused on the scientific conclusions that could aid such discussions. Moreover, after listening to the philosophical, legal, and theological discussions that ensued, I responded theologically as well. New concepts in modern embryology have made scientists revise their views concerning the autonomy of embryos and the mechanisms that generate such embryos. There are interactions between the sperm and the female reproductive tract and egg which had never been known until recently. There are also interactions between the developing organism and its environment that had been unsuspected a decade ago. Gut bacteria induce the development of the mammalian digestive system and immune system by changing the gene expression patterns in the mammalian intestine. Conversely, chemicals in our technological society can adversely affect the embryo, rendering it sterile or prone to tumors later in life. While there is no consensus among scientists as to when human life begins, both Church and science can become allies in persuading governments to regulate or ban the production and use of these fetotoxic chemicals. These new views of embryonic development change many of the stories told about human embryos and fetuses, and they have implications concerning the use of science as evidence for theological positions. **Birth Defects Research (Part C) 84:164–173, 2008.** © 2008 Wiley-Liss, Inc.

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INTRODUCTION

I wish to thank the Pontifical Council for Culture and the organizers of the program in "Science, Theology, and the Ontological Quest" for inviting me to speak on November 15, the Feast Day of Saint Albertus Magnus. The *Doctor Universalis* is one of the very few saints to have actually studied embryology, and the historian Joseph Needham (1959) writes that with Albertus Magnus, "a new spirit of investigation leapt into being." So, it is particularly appropriate to speak on this day about embryonic mammalian development, a subject of great interest to him.*

Albertus helped define the natural sciences, and he gave two warnings to those who would study nature. The first is that one cannot expect to find truth solely by logic. One also needs experience, one's own or that of others, to comprehend nature (Synan, 1980). The second warning is not to accept the common stories that one hears. *Scientiae enim naturalis non est simpliciter narrata accipere, sed in rebus naturalibus inquirere causas.* "The aim of natural science is not simply to accept the narratives of others, but to investigate the causes that are at work in nature" (*De Miner.*, lib. II, tr. ii, i).

I wish to use these two *caveats* to structure my discussion of some new scientific discoveries in embryonic development. I will attempt to disprove four stories that are often being told about embryos, stories that are widely accepted, but which science knows to be false. In some instances, they have been supported, until recently, by eminent scientists and are repeated in introductory biology textbooks. So I wish to discuss a veritable "Syllabus of Errors."

ERROR I. THE INSTRUCTIONS FOR DEVELOPMENT AND HEREDITY ARE ALL IN THE FERTILIZED EGG

The molecular analysis of gene regulation has given us new insights into how the context of the embryo helps control its development. Indeed, two of the most exciting and important new concepts in

*Footnotes in the original paper have been placed in brackets in the current essay.

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developmental biology are (1) the appreciation that the environment plays crucial roles in regulating gene expression during development, and (2) the recognition that DNA is normally modified by methyl groups (small organic molecules) that suppress the expression of the genes that are methylated.

Each gene has associated with it a regulatory region that determines where (in what cells), when (at what stage), and how much (a lot or a little) the gene is activated. During the past decade, it has been established that in the regulatory regions of *active* genes the DNA often is largely *unmethylated*, while the DNA constituting the regulatory regions of *inactive* genes are usually *highly methylated*. Indeed, this differential methylation underlies the mechanism whereby different genes become expressed in different types of cells. These methyl groups can prevent transcription factors (gene activation proteins) from binding to the regulatory DNA regions and activating these genes. Thus, in the cells that become our red blood cells, the genes encoding globin proteins are not methylated, while these same genes are methylated in every other cell type. In the pancreas, the genes encoding insulin and glucagon proteins are unmethylated, while these genes are methylated in every other cell type (for reviews, see Gilbert et al., 2005; Gilbert, 2006).

Until about 10 years ago, the environment was seen to play only a permissive role in regulating gene expression (see Gilbert, 2005). All the instructions for development were believed to be contained within the nucleus or derived from interactions between the nucleus and the egg cytoplasm. But recent studies in each of the living kingdoms have shown that the environment is an important source of developmental instructions. However, the idea that all the instructions for normal development are found in the nucleus or in the fertilized egg is still used by philosophers commenting on mammalian embryology (see Gilbert and Howes-Mischel, 2004; Gilbert et al., 2005).

Indeed, sociologists Nelkin and Lindee (2004) have shown that in American popular culture, DNA functions as the secular analogue of the soul. It is seen as the essence of our being, as determining our behaviors, and as that from which one can be resurrected after death (à la *Jurassic Park*). One sees this idea of DNA as soul in the writings of philosopher George (2001, George and Lee, 2004), columnist Colson (2002), and retired cell biologist Kischer (2002a). It is especially prevalent on web sites involving abortion and stem cell research. The "justthefacts" website (Justthefacts, 1999) for instance, claims: "From the moment of conception, 46 chromosomes with 30,000 genes combine to determine all your physical characteristics: sex; facial features; body type; color of hair, eye, and skin. Even more amazingly, intelligence and personality—the way you think and feel—were already in place within your genetic code. At the moment of conception you were essentially and uniquely you!" The American Life League website (2008) similarly proclaims, "It is a scientific fact that human life begins at conception/fertilization. From conception, a human embryo has a complete genetic code and his or her growth and development is totally coordinated from within." While such a view might have been considered within the realm of scientific debate when Paul Ramsey was writing in the 1970s, this view of "genetic determinism" is now known to be erroneous. [Ramsey (1970) quoted genetic evidence that being human is an essential property of the organism, and that it is defined by having a human genome. "Genetics," he wrote, "teaches that we were from the very beginning what we essentially are in every cell and in every human attribute." Although some might argue that the environmentally induced characters are "accidental" and not "essential," early death due to immunodeficiency and malnutrition does not seem to be "essential," even though that would be our nuclear inheritance. More radically, Ward Kischer, writes, "the single celled embryo is the scientific equivalent of a 100-year-old senior." This position leads one to some morally dangerous places. Given that the blastocysts and early embryos stored in infertility clinics do not have brains or even nerves, they cannot suffer. Thus, if such a clinic were on fire, should a morally responsible person carry out the freezer with its hundreds of frozen embryos or carry out the unconscious receptionist? I would contend that the one person who can suffer (the mother, daughter, spouse, friend) is more worthy of protection than the blastocysts. Similarly, the blastocysts' inability to suffer makes comparisons of embryonic stem cell researchers (and their supporters) to Adolph Hitler (e.g., Kischer, 2002a,b; Mierzwa, 2004) morally irresponsible, cheapening both the Holocaust and the argument for zygote protection. In my eyes, the person who equates the death of a microscopic clump of human cells with the agony of a gassed Jew who has seen his family members, community, culture, and body systematically destroyed, has lost all moral authority. The Catholic and medical approaches to stem cell research embody two different concepts of dignity. In medicine, dignity is seen as the alleviation of suffering, restoring the ability of the afflicted to walk, defecate, and see. Thus, Heschel (1985) writes that "To save a life is to do the work of God. To heal is to do the holy....the highest form of *Imitatio Dei*," and Kace (2007), a paraplegic, claims, "It's immoral that hundreds of thousands of embryos are discarded yearly instead of used to research cures for human suffering." In laboratory animals, stem cells have allowed the crippled to walk again. The Catholic Church has adopted a more Platonic view and sees dignity in having the potential to become a human being and having the love of God, even though the form and organs of a person have not yet developed (Pope Benedict, 2006).]

Let me give three examples from mammalian development to show how the environment can determine (more than the genes) some of the characteristics of who we are and what we are. These

Figure 1. Discordant appearance of two genetically identical mice. Their different appearance (phenotype) is because of the diet the mother ate while these embryos gestated in utero. The sleek brown mouse was born from a mother that had ample supplementation of methyl groups in her diet (i.e., Vitamin B12), whereas the obese yellow mouse was born to a mother who did not have that supplementation. The methyl groups bound to DNA and prevented the *Agouti* gene from being expressed. The endocrine disruptor bisphenol-A also acts through DNA methylation and can undo the gene repression by the methyl donors, causing those mice to also be yellow and obese. (Photograph courtesy of Dr. R. L. Jirtle).

three examples are maternal diet, bacteria, and maternal care. The photograph in Figure 1 shows two genetically identical mice. The cause of their differences is the diet fed their mother while pregnant (Waterland and Jirtle, 2003). The sleek brown mouse was born of a mother who received supplementation of folic acid (Vitamin B12) in her diet. The obese yellow mouse was born of a mother that lacked such folic acid supplementation.

The reason for the differences is that with folic acid supplementation, a particular coat color gene (whose product would transform brown fur into yellow fur and increase the number of fat cells) was methylated and thereby inactivated. Each mouse had the ability to become either brown or yellow, and the environment instructed the outcome. Different environments produced different phenotypes from the same set of genes. Anatomical and epidemiological evidence suggests that maternal diet during pregnancy also affects human gene expression and development. Indeed, those humans who experienced near-starvation conditions during gestation have only half the number of kidney tubules as those having a normal diet *in utero*, and they are predisposed to hypertension, insulin-resistance, and obesity later in life (see Moritz et al., 2003; Gluckman and Hanson, 2005).

The second example involves the development of our intestine and our immune system. In those mammals studied, the development of the intestine, the intestinal capillaries, and the immune system depend on the bacteria found in our guts. These bacteria produce factors that activate genes that would otherwise not be expressed. Bacteria-free rabbits and mice have difficulties absorbing food from their intestines and have immune deficiency syndromes caused by the absence of normal immune systems. These defects can be "cured" by inoculating them with normal bacteria early in their lives (Hooper et al., 2001; for review see Gilbert, 2006).

The third example is truly remarkable. Probably few people here would believe me if I told them that (a) maternal care gets encoded into the DNA, and (b) that scientists can tell if an animal received ample maternal care by looking at its genes. But this is the case in rats. If newborn rats are given maternal care (licking and grooming) during the first week of life, these rats have a normal stress response. However, without such maternal care, the rats have high levels of anxiety produced by relatively low levels of stress. The reason for the high stress response comes from the lack of the normal glucocorticoid (stress hormone) receptors on the rats' brain cells. These glucocorticoid receptors normally monitor the cortisol stress hormones and repress the production of these hormones by the adrenal gland. Why aren't the brain cells making the glucocorticoid receptor? Weaver et al. (2004) showed that in the rats that did not receive adequate maternal care, the regulatory region of the gene encoding the glucocorticoid receptor is heavily methylated, precisely in the region that controls expression in brain cells. In the rats that had received maternal care, this same region of DNA was unmethylated, allowing the glucocorticoid receptor gene to be expressed in the brain. So do the genes control whether a rat is anxious or not? No. It is the environment that is instructive here, inducing a particular behavioral phenotype. The genome is permissive, giving the possibilities for both potential behaviors.

Therefore, neither the nucleus nor the fertilized egg contains all the instructions for our development. We have outsourced many of these instructions to the environment.

ERROR II. THE EMBRYO IS SAFE WITHIN THE WOMB

Many commentators assume that once fertilization occurs, a baby will be born from that union of sperm and egg. Kischer (2002a,b) says this explicitly: "From the first moment of fertilization, human development is a *fait accompli*,

under conditions which we have come to understand and embrace as NORMAL."

Scientists know that this is definitely not the case. First, biomedical research indicates that (even without including induced abortions) most conceptions (perhaps less than 30 percent) do not survive to birth (Mange and Mange, 1999). Most of these embryos miscarry before the eighth week of pregnancy, because of abnormal numbers of chromosomes (Simpson, 2007). This natural process of embryo death is one of the reasons that Harvard University government professor Sandel (2003) told the President's Council on Bioethics that our society is not prepared to value a zygote as a person:

> If the embryo loss that accompanies natural procreation were the moral equivalent of infant death, then pregnancy would have to be regarded as a public health crisis of epidemic proportions: Alleviating natural embryo loss would be a more urgent moral cause than abortion, *in vitro* fertilization, and stem cell research combined.

But in addition to the death of embryos *in utero*, every human embryo on the planet appears to be poised in a precarious position due to man-made environmental agents. These industrial chemicals have been shown to damage the embryos in a manner that may be expressed later in life as cancer or reproductive failure. Moreover, these fetotoxic compounds can work by causing inappropriate DNA methylation, thereby interfering with normal gene expression. Indeed, perhaps our most dangerous error is to assume that the embryo is safe within the womb unless the mother takes particular drugs such as diethylstilbesterol (DES) or thalidomide, uses retinoic acid, or drinks alcohol. One of the new advances in developmental biology is the opening of the entire field of endocrine disruptors. Here, we find that many of the artifacts of our technological society to which we are exposed to daily—plastics, flame-resistant fibers, refrigerants, dental fillings, and pesticides—are acting on embryos to make them more likely to have cancers and reproductive failures later in life.

Let me just mention two recent studies. The first involves vinclozolin, a fungus-inhibiting compound used in the wine industry to protect grapes. This chemical can also block the functions of testosterone. If male mouse embryos are exposed to this compound while they are in the uterus, they have severely impaired fertility. The block against testosterone causes their testes to become malformed, and their sperm count is only 20% normal. Moreover, the exposure of the fetus to this fungicide at a particular time in development not only impairs the fertility of males in the generation exposed in utero, but also impairs fertility in males for at least three generations afterward. One possible mechanism by which the effect of these endocrine disruptors can be transmitted from one generation to the next is that vinclozolin alters DNA methylation in the sperm precursor cells. Anway et al. (2005, 2006) found several genes whose methylation patterns were altered after exposure to such endocrine disruptors.

Another compound, bisphenol-A (BPA), is one of the most widely used chemicals in the world. It can act as an environmental estrogen and perturb normal development, promoting prostate cancer and low sperm count in males and breast cancer and infertility in females. Four corporations in the United States make almost 2 billion pounds of BPA each year for use in the resin lining in food cans, the polycarbonate plastic in baby bottles and children's toys, and dental sealant. Bisphenol-A is also used in making the brightly colored Nalgene polycarbonate water bottles. However, as several laboratories have shown (Krishnan et al., 1993; Howdeshell et al., 2003), BPA is not fixed in plastic forever. If one lets water sit in an old polycarbonate rat cage at room temperature for a week, you can measure up to 310 micrograms per liter of BPA in the water. That is a biologically active amount—a concentration that will reverse the sex of a frog. BPA can also cause chromosome anomalies in germ cells. When a laboratory technician mistakenly rinsed some polycarbonate cages in an alkaline detergent, the female mice housed in these cages had chromosome abnormalities in 40% of their egg precursor cells (the normal amount is about 1.5%). When bisphenol-A was administered to the pregnant mice under controlled circumstances, Hunt et al. (2003) showed that a short, low-dose exposure to BPA was sufficient to cause chromosomal defects in maturing mouse eggs. Bisphenol-A at environmentally relevant concentrations can cause disruptions in the anatomy of the fetal sex organs, low sperm counts, and behavioral changes when these fetuses become adults (vom Saal et al., 1998; Palanza et al., 2002; Kubo et al., 2003). Indeed, recent research has implicated bisphenol-A in a suite of trends. In males, BPA exposure is associated with the lowering of human sperm counts and prostate enlargement. In females, BPA is associated with infertility, the decrease in the age of sexual maturation (vom Saal and Hughes, 2005), and with predisposing the adult to breast cancer (Murray et al., 2006; Vandenberg et al., 2006; Durando et al., 2007). It is probable that exposure to BPA in the uterus induces conditions which can lead to tumors when a second exposure of estrogenic hormones or mutation-producing agents is experienced later in life. Like vinclozin, exposure in utero to BPA not only causes changes in the methylation pattern of the fetus exposed to it but also to subsequent generations of fetuses (Ho et al., 2006; Dolinoy et al., 2007; Myers, 2007).

The endocrine disruptors in our environment might be doing a huge amount of damage and causing enormous amounts of suffering and misery. Medical embryology and the Catholic Church have each declared a mission to saving human fetuses. This is an area

where they can productively act as allies. The view that the embryo is safe once it has embedded into the womb is an erroneous misconception that can make bad health policy and prevent an important alliance between scientific and religious groups.

ERROR III. THERE IS A MOMENT OF FERTILIZATION WHERE THE PASSIVE EGG RECEIVES THE ACTIVE SPERM

Another area of new knowledge in embryology is in fertilization physiology. We are used to hearing the story that our sperm race through the Fallopian tube in a dramatic contest to be the first there to unite with the egg (see Belecos et al., 1988). We are told that the egg is the passive recipient of the sperm's animation, and that fertilization is largely the performance of the sperm. We hear this being repeated by important members of the Church, as when Adrianus Cardinal Simonis (1987) informed us that fertilization is evidence for the passive duties of women, since the egg merely "waits" for the male's sperm, which he describes as "the dynamic, active, masculine vector of new life."

But this story is wrong. First, the sperm's propulsion is not even the main force getting it to the egg; rather, the uterine contractions are far more critical. [Sperm can be seen near the egg within 30 min of intercourse, a time "too short to have been attained by even the most Olympian of sperm relying on their own power" (Storey, 1995)]. More importantly, though, the first sperm to reach the egg are incapable of fertilizing it. Newly ejaculated sperm are not capable of fusing with the egg. The sperm have still not finished their differentiation, and this finishing process occurs in the oviduct, where the oviduct cells bind to the sperm and alter the sperm's cell membrane. This process, called capacitation, is the earliest stage of fertilization. Once the sperm find the egg and bind to the outer coat of the egg, the proteins on that outer coat initiate chemical reactions in the sperm cell membrane which cause the sperm to secrete the enzymes needed for the sperm to reach the egg cell membrane. Once the sperm reaches the cell membrane, the egg and sperm membranes fuse, and the sperm nucleus enters the egg cytoplasm. After waiting a few hours for the egg nucleus to complete its meiotic divisions, the two nuclei migrate toward one another.

But the nuclei do not fuse. Rather than create a zygote nucleus, as happens in most non-mammalian embryos, the nuclear membranes dissolve and the chromosomes immediately initiate cell division. The first diploid nucleus in human embryos is not seen in the zygote, but at the two-cell stage. Fertilization is not a "moment" but a process, and this process of fertilization—from capacitation to zygote formation—can take from 2 to 4 days (depending on the stage where the egg is ovulated). Thus, the oviduct is not merely a passive conduit through which sperm travel, and the sperm and the egg are both active partners in fertilization. Moreover, there is no "moment of fertilization," but rather a lengthy process that can take days to complete. So despite the connotations of the word "impregnation," the deposition of sperm does not imply that fertilization occurs immediately or that a pregnancy has happened.

However, the error of immediate fertilization (impregnation) persists and appears to be widespread in the American Catholic community. In the state where I reside (Pennsylvania), only 6% of the Catholic Hospitals will administer emergency contraception to a woman who has recently been raped (Bucar, 1999; Clara Bell Duvall Education Fund, 2000). One of the justifications for withholding such treatment is the belief that once the sperm is in the woman's body, fertilization is almost immediate. While the US Council of Catholic Bishops state that emergency contraception can be utilized to prevent the rapist's sperm from fertilizing the victim's egg, the victim must undergo medical tests to show that this conception did not yet occur. No such medical tests exist. So in the mistaken belief that fertilization occurs quickly upon insemination, rape victims are forced to either bear their assaulter's child or have an abortion.

ERROR IV. THERE IS A CONSENSUS AMONG SCIENTISTS AS TO WHEN LIFE BEGINS

The lay Catholic press is especially keen to report as a fact the idea that scientists have all agreed that individual human life (often defined as "personhood") begins at fertilization. For example, Kischer (2002a,b), the chairman of the "American Bioethics Advisory Commission," writes, "Every human embryologist, worldwide, states that the life of a new individual human being begins at fertilization (conception)." Actually, one of the few statements that can be made without any hesitation is that there is no consensus among scientists about when an individual human life begins.

There are at least four stages of development that different scientists have claimed as the point where personhood begins, including: (1) fertilization (the acquisition of a novel genome), (2) gastrulation (the acquisition of an individual physical identity); (3) electroencephalogram (EEG) activation (the acquisition of the human-specific electroencephalogram, or brain-wave, pattern); and (4) the time of or surrounding birth (the acquisition of independent breathing and viability outside the mother's body).

View 1: Individual Human Life Begins at Fertilization

In this "genetic" view of human life, a new individual is created at fertilization (conception), when the genes from two parents combine to form a new genome with unique properties. Geneticist Jerome LeJeune (justthefacts.com) writes, "human life begins at the time of conception" and embryologist O'Rahilly and Muller (1994) concludes, "Fertilization is an

important landmark because, under ordinary circumstances, a new genetically distinct human organism is thereby formed." The assertion that fertilization is the only stage of development where life can begin is repeated on many websites (see, for instance, www.standupgirl.com and www.justthefacts.com).

View 2: Individual Human Life Begins at Gastrulation

Some scientists assert that the early embryo is not an individual until it undergoes gastrulation. This "embryologic" view proposes that a human receives individual identity around day 14, when the embryo undergoes gastrulation (Warnock, 1984). It is at this stage that the embryo can no longer form identical twins, triplets, or quadruplets; and it is at this stage that the fusion of two embryos will no longer occur to create one single embryo. At gastrulation, the cells begin the process of differentiation into the specific cell types of the new body. Because it is the point at which an embryo can give rise to only one person, many scientists consider gastrulation to be the point at which an embryo becomes an individual person. This embryologic view is expressed by scientists such as Renfree (1982) and Grobstein (1988). Green (2001) writes, "But twinning and fusion events suggest that, even well after the formation of the zygote, biological individuality is not firmly established. Only at gastrulation can we say that the lengthy process of individuation is complete."

Renfree (1982), an embryologist, has pointed out the theological relevance of twinning and fusion events to the discussion of ensoulment. "Assuming that monozygotic twins have separate souls, it follows that ensoulment must occur after cleavage ...." This position has been endorsed theologically by several authorities (see Shannon and Wolter, 1990; Gilbert et al., 2005). [The idea that ensoulment and personhood begin at conception has caused scientific problems for the Church in explaining the separate souls of twins and the single soul of fused embryos. In identical twinning, a single embryo, derived from a single fertilization, splits into two embryos before day 14. If ensouled at conception, what happens to the soul? Is there a second ensoulment of the twins? Does the soul split? Grisez (1970) claims that "we should think of twins as the grandchildren of the putative parents, the individual that divided being the true offspring, and the identical twins of that offspring by atypical reproduction." Ramsey (1973) and Kaveny (2006) have criticized this view (which has been adopted by many in the Church) as totally unscientific. Ramsey, for instance, conjectures that perhaps Grisez is writing about flatworms, not humans. Fusion events are rare, but are certainly not unknown in humans. Here, two embryos fuse together before day 14 to make a single embryo that becomes a single person. These can occur by the fusion of fraternal twins or by the formation of "semi-identical twins, wherein the polar body as well as the egg has enough cytoplasm for development and becomes fertilized as well. In some instances, such a human chimera can naturally have both XY (male) and XX (female) cells in his or her body (Mayr et al., 1979; Dewald et al., 1980; Yu et al., 2002). In writing about such fusions, Grisez suggests that the fusion is like that of a plant graft, to which Ramsey responded, "With considerable astonishment we may ask whether any such 'individuality' is the life we should respect and protect from conception." The statement of the Pontifical Academy for Life (2000) claims that early embryos cannot be destroyed because each one is a "human individual" with a "well defined identity." For many scientists, philosophers, and theologians, the embryological evidence calls that opinion into question.]

The view that a human does not become an individual before gastrulation at around day 14 is particularly crucial in the debate about allowing research on human embryonic stem (hES) cells. The embryologic view is consistent with the use of hES cells in biomedical research and has been supported as such by the conclusions of Britain's Warnock Committee (1984), the Canadian Royal Commission on New Reproductive Technologies (1993), and the NIH Human Embryo Research Panel in the United States (see Parson, 2004).

View 3: Individual Human Life Begins Upon the Acquisition of the Human EEG Pattern

This "neurological" view of human life looks for symmetry between the ways we define human life and human death. Several countries (including the United States) have defined the end of human life as the loss of the cerebral EEG pattern: death is determined by the "flatlining" of the EEG, even though the patient may have a heartbeat and be breathing. The "neurological" argument proposes that if the loss of the human EEG pattern determines the end of life, then its acquisition (which takes place at about 24–28 weeks) should be defined as when a human life begins. Morowitz and Trefil (1992) have written that just as our species acquired humanness when the enlarged cortex developed so the individual fetus acquires humanness when its cortex begins to function.

Cerebral nerve cells accumulate in number and continually differentiate through the end of the second trimester of human pregnancy. However, it is not until the seventh month of gestation that a significant number of connections between the newly amassed neurons begin to take form. It is only after the neurons are linked via these *synaptic connections* that the wave pattern characteristic of active, conscious brain activity emerges. Just as a pile of unconnected microchips cannot function as a computer, the unconnected neurons of the fetal brain lack the capacity for conscious function before week 24. If one considers the quality of conscious awareness to define a human individual, this is

a legitimate view of the starting point of a person's life.

Proponents of this view (see Brody, 1975) have also noted that the symmetries between the fetus before EEG functioning and the corpse after EEG functioning can be extended, in that neither is counted as a person, but both are human. Neither corpses nor fetuses are counted in censuses. They are expected to be treated respectfully (one does not eat a corpse since it once was human), but neither has moral agency or given the rights of personhood. [Newer evidence, using magnetoencephalography (Eswaran et al., 2007) suggests that the human EEG pattern usually doesn't emerge until week 28. Moreover, when it emerges, it appears to be one of sleep rhythms. Mellor et al. (2005) reviewed the studies regarding fetal pain and came to the conclusion that the fetus is not conscious. To be conscious one has to be awake, and the EEGs indicate that the fetus is asleep. Thus, the fetus would not feel pain even if it had the requisite neuroanatomy. Mellor and colleagues find that the placenta, in addition to secreting hormones to continue pregnancy and immune-blocking agents to prevent the mother from rejecting the fetus, also secretes neuroinhibitors and analgesic compounds such as adenosine and pregnenolone, which can act to keep the fetus asleep and unable to sense painful stimuli. (This means that the presumed pain perceptions in prematurely born infants would not reflect the situation inside the uterus.) They also note that turning from noxious stimuli is characteristic of anencephalic fetuses. Thus, even without a cortex (necessary to interpret a stimulus as painful), the fetus will make reflex movements.]

View 4: Individual Human Life Begins At or Near Birth

There is also the view that a fetus should be considered human when it can survive on its own. Traditionally, the natural limit of such viability was imposed by the respiratory system—a fetus could not survive outside the womb until its lungs were sufficiently mature, which occurs at about 28 weeks. Today, however, technological advances can enable an infant born as prematurely as 25 weeks to survive, although such infants are at high risk for having physical and/or mental disabilities.

Finally, there are those who believe human life begins when an individual has become fully independent of the mother. This traditional "birthday" is often recognized by seeing the head of the baby emerge or having the umbilical cord cut. One advantage of such moments is that they are well-defined, public, and obvious (Tooley, 1973). Moreover, despite the feelings of some philosophers that birth is merely a "move from one room to another", birth is a difficult passage through a perilous discontinuity between fetal and neonatal existence. The lungs must be able to function, the first breath changes cardiac anatomy and the routing of the circulatory system, the head must get through the birth canal, and the kidneys and anus must function properly. Whereas other stages of development have continuities between stages, birth is a definite new beginning. (There is more discussion on this view in the Coda to this essay.)

View 5: The Gradual Attainment of Personhood

This perspective claims that there is no point at which one can say an embryo has suddenly become human, and that the whole question of "when does human life begin?" is framed in the religious perspective of "ensoulment" and thus cannot be answered scientifically. The geneticist Theodosius Dobzhansky (1976) remarked:

> The wish felt by many people to pinpoint such a stage probably stems from the belief that a soul, conceived as preternatural entity, descends upon a formerly soulless living stuff, and suddenly transforms the latter into human estate. I hope that modern theologians can accept the idea that the transformation is not sudden, but gradual.

But theologians such as St. Albertus Magnus and St. Thomas Aquinas *had* thought such ideas. Indeed, the Thomistic view of sequential ensoulment could be consistent with modern developmental biology. The pregastrula embryo has the "vegetative" properties of growth and pluripotency, while gastrulation, the act that separates plants from animals, starts the being on an "animal" pathway. The origins of the rational mind come around week 24–28 with the anatomical correlates of cerebral function, when the fetus can learn and interact. In this view, the embryo would be given progressively more rights as it developed through different stages. [Agreeing with this gradual idea, St. Albertus Magnus (quoted in Demaitre and Travill, 1980) was explicit in noting that "*Informe autem puerperium ubi non est anima viva, lex ad homiicidium pertinere noluit.*" ("But the case of the unformed infant, where there is no living soul, is not covered by the law of homicide.") Currently, Gordon Dunston (1984) is probably most associated with the perspective that gradual attainment of personhood falls into the Aristotelian-Thomistic view. This developmental notion has been used by Harris (1986) to criticize the argument that we must give to the fetus all rights of personhood simply because it is a human. Such a view, she writes, would mandate that "we must give the five-year-old the right to vote, the six-year-old the right to drink, the nine-year-old the right to drive." Her claim is that one can grant that the life of a person may begin at conception without granting that a distinct person emerges at conception. The embryo and fetus would be given different rights at different developmental stages. I cannot say when a conceptus becomes a "person". There is certainly no consensus among scientists on this issue.]

CONCLUSION

Although Thomas Huxley (1877) may have been the first to explicitly state that we must "learn what is true in order to do what is right," this important concept can be traced to early Medieval rabbinic commentaries (Zornberg 1995; reviewed in Gilbert et al., 2005). New concepts in modern embryology have made scientists revise their views concerning the autonomy of the embryo. There are hitherto unknown interactions between the gametes and between the developing organism and its environment. These interactions were unknown a decade ago. The anatomy and physiology of an organism may depend on what its mother ate, and differences in maternal care can modify DNA in ways that cause profound influences on that organism's behavior. Gut bacteria help the mammalian digestive system and immune system to develop by changing the gene expression patterns in the mammalian intestine. Conversely, chemicals in our technological society can adversely affect the embryo, rendering it sterile or prone to tumors later in life. Religion and science can become allies in persuading governments to regulate or ban such compounds. Last, while there is no consensus among scientists about when human life begins, probably no one appreciates better the "miracle" of life than developmental biologists. As the French embryologist Rostand (1962) reflected, "What a profession this is—this daily inhalation of wonder." Such wonder is the source of both the scientific and religious attitude, and it only increases as we study the mammalian embryo.

CODA

[Having spent 2 days listening to priests, lawyers, and physicians discuss theology (and having been asked explicitly about my theological views), I wanted to bring up some theological points that could not be raised in the context of my scientific paper.]

As a biologist and also a person who is greatly concerned about human dignity, I believe that the Image of God is in danger of being trivialized and denigrated by the belief that personhood begins at fertilization. Equating the born person with the zygote or blastocyst runs the very great and real risk of cheapening adult human life by trivializing the Image of God. This is because the equation can be read both ways. The blastocyst, the embryonic structure from which embryonic stem cells are derived, has no limbs, head, or heart. It has no individual unity (still being able to make other embryos) and cannot suffer pain or anguish. Rather than raise embryos to the level of the person, such an equation could easily bring humans down to the level of such relatively unstructured tissues (most of which will soon die before being born). Imagine if all priests were told that they were now Cardinals. That act would not elevate the priesthood as much as it would denigrate the office of Cardinal. I fear that such a denigration and defilement of the Image of God would be an unintended and disastrous consequence of making zygotes and blastocysts persons.

I believe that the Bible puts a brake on such actions by stating that one attains the Image of God only on birth. The syllogism is as follows: (A) Those who kill the Image of God must themselves be killed (Genesis 9:6); (B) If a man should cause a woman to miscarry and lose the fetus, he has to make a reparation to the woman. He does not need to be put to death unless the woman dies (Exodus 21:22). [A panelist in the last session claimed that my translation of Exodus 21: 22 is in error. Although there have been attempts to say that the Vulgate translation of Exodus 21: 22 ("et abortium quidem fecerit...") as well as numerous English translations of this Hebrew passage are wrong, I believe that this panelist is in the minority on this issue. Even William H. C. Propp (who holds the idiosyncratic perspective that this passage is generically about all injuries caused to third parties), recently (Propp, 2006) wrote, "The minority view is that the verb 'yasa(') here connotes a successful premature birth... The majority view is that yasa(') indicates a miscarriage." All classical Hebrew-language commentators, including the most ancient sources (Josephus; the Targums of Onkelos, Neophyti I, and Pseudo-Jonathan) and the medieval rabbis (Rashi, Ibn Ezra, Nahmanides, Abarbanel) write that the fetus dies. (Indeed until the end of the last century, a "successful premature birth" brought about in this manner must have been amazingly rare. The expected fate of a prematurely born infant was immediate death.) In any case, the concern over the denigration of the Image of God caused by the equation of born persons and unstructured embryos remains a real one with or without this Biblical passage.] Therefore (C) The fetus does not have the Image of God. We attain the Image of God,—personhood—at birth. If one uses a developmental approach, then the conceptus acquires different rights as it develops, acquiring personhood when it is born.

The Church's teachings concerning the Image of God have always emphasized that it is this image that sets us apart from the other animals and bestows personhood upon the individual. This image is either the physical attributes of the human being or (especially in Thomas) the human intellect. The Catechism (Pt1, Sect2, Ch1, Art. I, Para6: 357) states, "Being in the image of God the human individual possesses the dignity of a person, who is not just something, but someone." It is precisely this distinction between something and someone that is being endangered by declaring an early embryo or zygote to be a person. The born human being is a "who"; the blastocyst is only a "what."

The Biblical peoples did not know about gastrulation, EEG patterns, or the limits of viability. Maybe these are places where per-

sonhood can be attained. But looking at Scripture, the Image of God is a human birthright. And that is the correct word: Birthright. It is not given at conception, but only at the completion of the long and perilous road from fertilization to birth.

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