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The following paper is a preliminary analysis of an emerging issue in the ongoing debate over the moral status of the human embryo. As such, it is not an official ethical statement of the Christian Medical Association, nor does it attempt to present the definitive position on the ethics of parthenogenesis. Rather, this paper represents the beginning of a dialogue on an important bioethical issue and hopefully will serve as a valuable resource in facilitating that discussion.

The Ethics of Human Parthenogenesis

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Executive summary

At a time when public opinion is sharply divided over whether government policy should allow the creation and predestined destruction of human embryos in order to obtain embryonic stem cells for medical research, some scientists have suggested that the human parthenogenetic embryo or "parthenote" may represent an ethically acceptable alternative source of embryonic stem cells without the need to harm normal human embryos. Parthenogenesis, which literally means "virgin birth," is defined as the production of an embryo from a female gamete without any contribution from a male gamete, whether or not the resulting organism develops eventually into an adult.[1]

It is possible to stimulate the unfertilized human egg to begin dividing just like an early embryo. This parthenote gives rise to stem cells but is incapable of maturing beyond the early embryo stage because it is genetically programmed to die early in its development. In nature parthenogenesis is occasionally a normal mode of reproduction for some species of insects and reptiles, but when it occurs in humans its result is either a nonviable embryo or a tumor and never the birth of a live baby.

Careful examination of all the medical evidence, however, fails to demonstrate conclusively that the living human parthenote cannot be a human being. Though it is a profoundly defective and abbreviated life, yet it may still be a human life with special dignity science cannot measure.

In addition, the parthenote's gestational incompetence raises important concerns regarding the potential therapeutic efficacy and safety of its progeny stem cells which would similarly be genetically defective. The same defects that render the parthenote nonviable would likely render its stem cells nonfunctional or hazardous if transplanted into a patient. While further research might conceivably overcome these vital flaws through genetic enhancement of the parthenote, augmenting the health of the parthenote could betray a false moral distinction as improved generations of parthenotes came to resemble more and more the traditional human embryo in their capacity for fullness of life.

Biomedical science seeks for stem cell research an entity halfway between a person and a thing. The parthenote might be such a *tertium quid*, pulsing with that intangible essence which directs and orchestrates a new human life, yet which could be treated as a mere physical thing, if only such a category actually existed. It does not. Rather what seems to belong to an intermediate moral category simply appears foggy to the imperfect eyes of human evaluation due to the limitations imposed by scientific knowledge that is either incomplete or inadequate for the task.

How should public policy decisions proceed concerning the treatment of the human parthenote, given that moral uncertainty cannot be avoided and may not soon be definitively resolved? First, classification of human parthenotes as ambiguous humanity is sufficient reason to prohibit a research agenda that would bring into existence countless defective quasi-human lives only to destroy them. Secondly, the biologically flawed stem cells of the parthenote would be unsuitable for use as cellular building blocks for regenerative therapy in human patients. Finally, how society decides to treat the least of human lives is a measure of how it chooses to value vulnerable and impaired human beings in general.

Introduction

On August 9, 2001, President Bush approved the use of federal funds to support research on a limited number of existing stem cell lines derived from already destroyed human embryos. Embryonic stem cells, the primordial building blocks from which arise all bodily tissues, have become the focus of intense interest because of potential medical applications. If further research were to discover the correct sequence and combination of chemical cues controlling the differentiation of stem cells into functional mature cells—for example, nerve cells, heart cells, and pancreas cells—and if this intricate process could be safely controlled, then stem cells might one day be used to produce replacement tissues to treat a number of diseases.

This exciting prospect is not free of moral liability. The procedure of extracting embryonic stem cells necessarily results in the death of a human embryo. Responsible deliberation on human embryonic stem cell research policy, therefore, must consider carefully the moral status of the human embryo.

Two approaches to this question now dominate public discourse. Some judge the serious health needs of society to outweigh any uncertain claim to personhood of nascent human life measuring only a few cells in size. Others hold that it is always wrong to take the life of an innocent human being regardless of the stage of development and that good ends do not justify immoral means. Deeply held moral convictions on both sides have shaped a debate that would seem to be irreconcilably polarized.

Enter parthenogenesis

Biotechnology has proffered a creative solution to the ethical gridlock. Taking advantage of a wrinkle in the sequence of reproductive physiology, researchers have learned to trick the human egg (oocyte) to begin dividing as if it had been fertilized. The resulting cluster of multiplying cells has a mother but no father and is termed a "parthenote." The equivalent term "parthenogenone" is preferred in the British literature.

Although parthenogenesis has been recognized for some time, only recently has it been shown that parthenotes contain stem cells. These stem cells could be harvested guiltlessly, provided the human parthenote has not the moral status of a nascent human being.

Parthenogenesis may be appealing also to those who would approve of human cloning where the intent is medical research but not where the intent is adult human reproduction. Unlike the cloned human embryo created through somatic cell nuclear transfer, which if not used for research could be implanted in a human womb to be born a child, the human parthenote is capable of only a few cell divisions and cannot develop to term. Since the parthenote would fail to survive, a law restricting reproductive cloning by mandating the destruction of embryonic clones would be unnecessary. If, however, the parthenote is a human life, then society would shoulder the moral responsibility of a policy permitting the willful creation of defective human life assigned to destruction in order to serve as cellular raw material.

Questions relevant to public policy

Parthenogenesis has introduced to the discussion a novel entity. The parthenote behaves in some ways like an embryo, yet in other ways it is something quite new. Whether this unfamiliar form of life should be classified as human being or cellular tissue, as person or property, is more ambiguous than in the case of the normal human embryo. Whereas the human embryo lies just within the margin of the human race, it is not yet clear whether the parthenote lies inside, or perhaps just outside, the moral boundary which defines humanity.

Several sets of questions may be predicted to frame the emerging debate over the ethics of creating human parthenotes for medical research. These questions are as profound as they are complex. First are the pragmatic questions concerning whether stem cells derived from parthenotes would be useful and safe.

No less important are the ethical questions. Foremost, there are questions of moral status. Is the parthenogenetic human embryo a human being? Can this be known? If it cannot be decided, and if uncertainty remains, then what policies are appropriate governing creation and deleterious utilization of the parthenote? What bearing does its genetic defectiveness have on its moral status? And does it matter whether defects that would exclude the parthenote from classification as a human life occur naturally or are scientifically engineered?

There are also ethical questions concerning the exploitation of women whose eggs would be needed for research, the equitable distribution of scarce or costly medical therapies arising from parthenogenesis technology, and complicity and right of conscience issues should some physicians and patients morally object to the use of therapies derived from nascent human life.

Furthermore, this technology touches on even deeper questions. What does it mean to be human? What does it mean to be an impaired human? What does it mean to belong to a genetically engineered subhuman class? Should technology be developed that could fundamentally revise the biological basis of the family structure, and what would be its social consequences? Who made us, and for what purpose?

If, in permitting their destruction, we do not seem to be accountable directly to human embryos who will not survive long enough to develop the capacity to sense their own deaths, does this mean that no wrong has been done? Are we accountable for wrongs committed in secret? Are we accountable for what only might have been wrongs? Such questions are not merely academic. Finding good answers to them is of crucial interest to all people.

In order to think clearly about these questions it is necessary first to understand something about what distinguishes human parthenogenesis from normal embryogenesis, the biology of parthenogenesis as it occurs in nature, and the state of the art of experimental parthenogenesis.

Embryogenesis and parthenogenesis

According to a standard textbook of embryology, "The development of a human being begins with fertilization, a process by which the spermatozoon from the male and the oocyte from the female unite to give rise to a new organism, the zygote."[2] The early embryo or zygote is *diploid*, meaning it has a complete set of 46 chromosomes, 23 of which have been contributed from each gamete (sperm and egg). Mature gametes are *haploid*, meaning they have reduced, through the process of meiosis, their number of chromosomes by half during their development from primitive germ cells in the testis or ovary. In this way the embryo receives half its genetic information from the mother and half from the father.

Parthenogenesis, which derives from the Greek words meaning "virgin birth," is defined by the American Society for Reproductive Medicine as "a form of asexual reproduction in which an unfertilized egg divides like an embryo and grows into a new individual."[3] Strictly defined, parthenogenesis is distinct from asexual reproduction because it begins with oocytes, which are germ cells, rather than with somatic cells and thus is more accurately classified as an incomplete form of sexual reproduction.[4]

Unlike normal sexual reproduction, in which genetic material from the mother and father combine to form a unique zygote, the parthenote contains genetic material only from the mother. A parthenogenetic embryo may, in some nonhuman species, develop into an adult.[1]

Parthenogenesis in lower animals

Parthenogenesis occurs naturally in a few species of lower animals such as aphids and wasps, and in some worms, spiders, lizards and snakes. A notable example is the honey bee, whose queen is able to lay two types of eggs. Fertilized eggs develop into worker or queen bees, whereas unfertilized parthenogenetic eggs become drones.[4] Male drone bees thus have a single genetic parent, the queen mother.

There is no known example of parthenogenesis as a normal and stable mode of reproduction in warm-blooded vertebrates. Nevertheless, the eggs of birds and mammals occasionally initiate abortive parthenogenesis resulting in nonviable offspring. The chromosomal arrangements of these parthenogenetic embryos are grossly abnormal. Under conditions of special incubation, a small percentage of chicken and turkey parthenogenetic eggs from virgin hens have hatched chicks. Some of them died within days. Those that survived had chromosome anomalies and were sickly. Rarely parthenogenetic birds have reached adulthood.[4]

Parthenogenetic mammals are even less viable. Parthenotes occasionally arise spontaneously in the ovaries and fallopian tubes of mice, hamsters, and guinea pigs but develop abnormally and stop growing during the embryonic stage. Some will continue to grow into a germ cell tumor.[1,4]

Experimental procedures can induce unfertilized mammalian eggs to undergo parthenogenesis by exposure to certain stimuli such as intense heat or cold, vacuum pressure, noxious chemicals, or electric shocks. The egg thus activated undergoes repeated cell cleavage and may organize into a blastocyst, the earliest phase of an embryo. With the exception of one live born rabbit,[5] no parthenogenetic mammal has survived beyond the embryonic period of development. Depending on which stage of meiosis is suppressed or omitted, the parthenote can inherit various configurations of maternal chromosomes and may itself be haploid, diploid, polyploid, or haplodiploid mosaic.[1,4]

Parthenogenesis in humans

Parthenogenesis occurs sporadically in human ovaries. Moreover, noxious provocation of unfertilized human eggs in a petri dish can initiate parthenogenetic division just as in rodent eggs.[6]

The human parthenote is incapable of developing to term but has three possible fates. First, parthenotes arising spontaneously within the ovary or unintentionally amid in vitro fertilization procedures may become undetected early pregnancy losses.[6,7,8]

Secondly, parthenotes may give rise to ovarian teratomas. A teratoma is a rare tumor consisting of a chaotic, disorganized, nonfunctional mass of tissues derived from all three embryonic germ layers. The teratoma may contain fragments of limbs, primitive neural tissue, loops of alimentary tract, bronchial epithelium, even teeth and hair, but no heart, and is incapable of independent growth. Some of them undergo malignant transformation.[9,10]

Thirdly, it is possible, very rarely, for an individual to be partly parthenogenetic. A single case of a human parthenogenetic chimera has been described in a boy whose blood cells were genetically female (46, XX) and his fibroblasts genetically male (46, XY). From cytogenetic examination of his chromosomes, geneticists concluded that the paternal sperm had fertilized an already parthenogenetically activated embryo, giving rise to developing cells of mixed normal and parthenogenetic lineage.[11]

Not all parthenotes are genetically alike. Depending on when in the course of meiosis parthenogenetic activation occurs, and whether the maternal chromosomes that normally condense to form the second polar body are extruded or retained, human parthenotes may be initially haploid,[9,12] upon mitosis becoming homozygous diploid, or they may be heterozygous diploid.[13] In neither case is the parthenote an exact genetic duplicate or clone of its mother because of the genetic shuffling that occurs early in meiosis when sister chromosomes cross over one another. Nor are its genes expressed in the same way as in the mother because of the absence of paternal factors vital to normal embryonic development.

How parthenotes are defective

There are at least three critical biologic deficiencies that distinguish the human parthenote from the normal human embryo. It is likely that these are among the fatal errors that ensure arrested development of most cultured human parthenogenetic embryos by the third cell division when the embryo is only 8 cells in size.

First is the *lack of paternal imprinting*. In mammals the maternal and paternal genomes are not equivalent but are functionally specialized so that inheritance of both is required for normal embryonic development. Genomic imprinting refers to the expression or repression of certain genes, not on the basis of the structure of the gene, but on the basis of the parent from which they were inherited. Paternally imprinted genes, for example, are expressed when they are inherited from the father, but the same genes when inherited through the mother may be permanently silenced. Failure of paternal imprinting leads to malformation syndromes or arrested development with early miscarriage.[1,14]

The second deficiency is the *absence of the paternal centrosome*. DNA is not the only self-organizing intracellular structure governing embryonic development. There is also the centrosome, a specialized organelle from which mitotic spindle microtubules are generated. Microtubules are the molecular scaffolding that defines cellular architecture and orchestrates the intricacies of cell division. The embryo requires only one centrosome. Inheriting both would confuse mitosis and cause the embryo to have too many chromosomes. Moreover, the maternal and paternal centrosomes are not structurally equivalent.

In the human embryo the centrosome is paternally inherited. The oocyte centrosome, having been inactivated during meiosis, nevertheless has not entirely lost its ability to form a microtubule organizing area and can sustain a few cycles of parthenogenetic division. Its capacity to double and to arrange chromosomes correctly, however, appears to be lost at successive cell divisions.[15,16,17]

The third deficiency is what this writer terms the *naked genetic load*. Geneticists estimate that normal human beings carry, on the average, at least six silent yet potentially lethal recessive genes in their DNA. These are misspellings of essential genes which, if expressed, would give rise to defective proteins incompatible with life. Unlike disorders of dominant inheritance, in which inheriting a single copy of a defective gene causes disease, disorders of recessive single gene inheritance result in disease only if one inherits two defective copies (is homozygous), one from each parent. The person who inherits just one defective gene (is heterozygous) usually shows no sign of disease because the normal gene in the pair compensates for the defective gene. Such a person is a genetic carrier, and the single normal gene functions well enough to secure health. The probability of inheriting silent defective genes varies by species and is known as genetic load. The much greater genetic load of mammals as compared to lower species may explain why parthenogenesis does not naturally occur in mammals.

Inheritance of genes by pairs is accomplished by pairing of chromosomes, so that of the 46 somatic chromosomes, 23 come from each parent. This built-in biological redundancy is one of the design features that maximizes human health. As an illustration, genetic redundancy may be compared to the redundancy of kidneys. Although only one kidney is required for health, nearly all people are born with two. If something goes wrong with one of them, an extra is available. Most genes likewise come in pairs (except for genes in males on X and Y chromosomes). Inheriting even a severe mutation in one copy of a recessive gene usually goes unnoticed because in most cases the extra copy alone is able to fulfill its function.

The usual rules of mammalian inheritance do not so neatly apply to parthenotes. Rather, special problems emerge. Parthenotes arise from oocytes that, in becoming haploid through meiosis, have jettisoned half their chromosomes, hence half their genetic material. These discarded chromosomes condense to form the first and second polar bodies. The parthenogenetically activated oocyte then doubles its chromosomes to become diploid, but instead of being heterozygous as in the normal embryo (possessing two different copies of each gene), it is usually homozygous (possessing two identical copies of each gene from the retained chromosomes).[8,9,11,12]

For the homozygous parthenote, genetic load is an insurmountable problem. Instead of having a complete, balanced genome containing an extra gene to cover each corresponding defective gene, the homozygous parthenote has simply doubled a haploid genome, making not one, but two copies of every lethal recessive gene. All six or more of these genes will not remain silent, but will be fully expressed. The result is that a series of profound genetic deficits renders the continued growth and survival of any homozygous human parthenote extremely improbable. The full genetic load of the human species is exposed in these fragile entities. Their lives can but fail, and very early on.

Notably, some human parthenogenetic embryos will preserve and reincorporate the second polar body, becoming heterozygous diploid.[13,18] It is not known how this phenomenon could be controlled. Provided the reincorporation process is complete, the heterozygous parthenote would not be susceptible to the problem of naked genetic load but would still be deficient in paternal imprinting, centrosome origination, and in many other factors essential to the astonishingly complex process whereby normal embryogenesis unfolds, factors that molecular biology is just beginning to recognize, let alone understand how to control.

Parthenogenesis as a potential source of stem cells

In a November 2001 press release, researchers at Advanced Cell Technology in Worcester, MA claimed to have parthenogenetically activated 22 human eggs surgically collected from three women who were given hormones to hyperstimulate their ovaries. By the fifth day, six of the growing clusters of cells resembled embryonic blastoceles in that they contained a central cavity, although none developed an inner cell mass as would a normal embryo. The parthenotes were then destroyed.[19] The investigators performed no tests on the composition of the cells' genetic material.

This was not a new discovery. Artificial parthenogenetic activation of human eggs in a petri dish has been possible for years.[6] What is new is the idea that such parthenotes could potentially supply stem cells without the need to create and destroy traditional human embryos.

A brief paper in the February 1, 2002 issue of *Science* claimed the first successful isolation of stem cells from a primate embryo derived through the technique of parthenogenesis. A collection of 77 eggs from long-tailed macaques were incubated in culture media supplemented with serum from a pregnant mare and, without any contribution from a male gamete, were subjected to chemical stimulation. Four of the unfertilized eggs, thus activated, began dividing and grew into blastocyst-stage parthenogenetic embryos. From these parthenotes the researchers isolated embryonic stem cells, some of which, through modification of culture conditions, were made to differentiate into primitive neurons (nerve cells) releasing the neurotransmitter dopamine.[20] In a similar experiment not peer-reviewed, other researchers reported having produced neurons from parthenogenetic mouse embryos.[21]

If parthenogenesis can yield mouse or macaque embryos ripe with stem cells, the same technique might in principle be extended to human gametes. Moreover, the manufacture of dopamine-secreting neurons has potential relevance for cell transplantation as a future treatment for Parkinson's disease, which is characterized by loss of dopaminergic neurons in a small region of the midbrain known as the substantia nigra.

The mere presence of dopamine in these stem cells is no guarantee that the cells, if transplanted into the brain, would function properly, release dopamine upon demand, or not release some harmful other neurotransmitter.

Disadvantages of parthenogenetic stem cells

There are several compelling reasons that parthenogenetic stem cells would fail to measure up to the biological potential of embryonic or adult stem cells. The same flaws that render the parthenote's growth and development defective would likely compromise also the function and clinical safety of its stem cell progeny.

First, because the parthenote begins its developmental journey with only half the amount of genetic makeup as a normal embryo, the homozygous diploid parthenote that has merely doubled a haploid set of chromosomes will generate stem cells carrying a naked genetic load. By implication, any and all recessive lethal genes that would have remained silent had they contributed to the genetic makeup of a normal embryo would be fully expressed in the cells of the parthenote, with potentially dire consequences for its stem cells' maturation, function, and stability.

Secondly, altered gene expression due to the absence of paternal imprinting is another reason not all the properties of embryonic stem cells would hold true for parthenogenetic stem cells. Failure of normal imprinting would not only distort stem cell development but could also alter expression levels of tumor-suppressing genes, leading potentially to nonfunctioning cells or cancers.[14]

Thirdly, parthenogenetic therapy might benefit only women of childbearing age. Most of the patients whose diseases and injuries have been targeted for stem cell research are older and not all are women. The problem arises in that parthenogenetically derived cells would be immunologically compatible only with the egg donor. If transplanted into another human being, the immune system would eventually reject the cells as foreign and destroy them. This immune rejection could be postponed by committing the patient indefinitely to take strong drugs that suppress the immune system at the risk of potentially serious long-term side effects.

Fourthly, it is unknown whether a possible side effect of parthenogenetic stem cell therapy might be cancer. Parthenogenetic stem cells have the potential not only to differentiate into specialized cell types but also to grow into tumors. When Cibelli and colleagues injected their parthenogenetically-derived macaque stem cells into mice, some of them grew into teratomas.[20] Through the lens of the microscope the tumors appeared to be benign, although the mice were followed for only a few weeks. In humans most teratomas are likewise benign, but approximately one out of 60 can become malignant.[22] The prospect of making neural replacement tissue from parthenogenic stem cells might further amplify the risk of cancer, since the presence of differentiated neural cell types in human ovarian teratomas correlates with higher rates of malignancy and metastatis.[22]

Fifthly, even if these considerable technical barriers to developing parthenogenetic medical therapies were somehow overcome, there would still be the problem of where to get human eggs to satisfy the clinical demand for parthenotes. Human eggs must be donated by women of childbearing age who are injected with drugs to stimulate their ovaries to hyperovulate and then are then subjected to an invasive surgical procedure to extract the multiple eggs. Except when used to complement in vitro fertilization to achieve pregnancy, the egg retrieval procedure provides no direct benefit to the donor and has many potential risks including pelvic pain, rupture of the ovaries, bleeding, pulmonary embolism, and infertility. It is unlikely that very many women would sign up for this procedure unless compensated. Parthenogenetic technology would end up exploiting women by commodifying their eggs.

In evaluating research destructive to parthenotes, it is also interesting to note that all parthenotes are genetically female.

It is unknown whether stable stem cell lines could be cultured from human parthenotes, whereby a limited number of egg donors might produce an unlimited supply of cells for research. If stable stem cell lines were to prove unachievable, or if immunologic individualization of therapy were to require a fresh parthenote for each patient treated, the numbers of egg donors needed could become staggering. The number of patients in the United States who have illnesses for which embryonic stem cell therapies are being promoted exceeds 100 million.[23] If a parthenote were prepared for each of these patients as a source of transplantable stem cells, assuming a 5% success rate according to the technique of Cibelli et al. in converting macaque eggs to blastocyst stage parthenotes,[20] two billion human eggs would be needed. Assuming a liberal estimate of 10 eggs harvested from each hyperovulation procedure, a clinical demand of that magnitude would require 200 million women of childbearing age to serve as egg donors.

Another conceivable scenario would be to develop the technology to incubate human parthenotes as far as infancy in order to harvest their kidneys, livers, hearts, and other organs for medical transplantation. The inefficiency of parthenogenesis successfully carried to term in vertebrates would strain the human egg market to unimaginable proportions. In chickens, for example, one experiment found that 8532 eggs of Cornish hens were required to produce just 4 surviving parthenogenetic chicks.[4]

Sixthly, if genetic enhancements were to render the human parthenote more viable, so that it could develop further, bringing its stem cells and replacement organs within closer reach, pragmatic solutions to the human egg shortage would likely look to transgenic strategies. These might involve inserting the nucleus of a human parthenote, which society must judge is or is not an early human life, into the egg of a cow or pig, with or without implantation leading to birth. No one knows what one of these hybrid creatures would look like if born, yet.

Government policy and human parthenogenesis research

The NIH Human Embryo Research Panel Report of September 27, 1994 concluded that research attempting the implantation of parthenogenetically produced human eggs would be ethically unacceptable. President Clinton, on December 2, 1994, subsequently directed the NIH not to allocate resources to "support the creation of human embryos for research purposes." His directive did not apply specifically to human parthenotes.[24]

Federally funded research on human parthenogenetic embryos has been illegal since 1996. The "Dickey Amendment," which has been attached annually to the NIH budget, prohibits the allocation of federal funding for "the creation of a human embryo for research purposes or for research in which a human embryo is destroyed, discarded or subjected to more than minimal risk. The term 'human embryo or embryos' includes any organism, not protected as a human subject under 45 CFR 46 as of the date of the Act, that is derived by fertilization, parthenogenesis, cloning, or any other means from one or more human gametes or human diploid cells."[25]

Is the parthenote a human life?

In order to know how it is right to treat the parthenote, it is first necessary to know what the parthenote is. Of immediate relevance is the question of whether the parthenogenetic embryo is a human embryo, hence whether the parthenote is a human being. Arguments on both sides will be summarized.

Position 1: the parthenote is not a human being

- Parthenogenesis, which requires no contribution from a sperm, is distinct from human "conception," which is defined as the union of a sperm and an egg. If human life is defined as beginning at conception or fertilization, then parthenogenesis does not result in a new human life.

- Human parthenogenesis, which occurs occasionally in nature, never results in the birth of a child. If human life is defined as that which has the capacity to grow into a baby or adult human, then the parthenote, which inherently lacks that viability, cannot be a human life. Furthermore, despite efforts to grow them, human parthenogenetic embryos in vitro have never survived beyond the 8-cell stage, and parthenogenetic blastocysts have not developed the inner cell mass characteristic of maturing embryos.[6,15,19]
- The human parthenogenetic embryo is not predetermined to form a human being since it can also form biological entities that are not human beings. The product of human parthenogenesis in nature is either a failed embryo leading to early miscarriage or a teratoma.[9,26] A teratoma is a tumor which is incapable of organizing into a well structured, functionally integrated, purposeful whole organism and thus does not have the capacity of independent growth or to be born a live human.[27]
- The lack of paternal imprinting renders the parthenote incapable of forming extra-embryonic tissues that would become the placenta.[1] Therefore the human parthenote is not truly totipotent but has a moral status equivalent to any pluripotent stem cell found normally in the tissues of an adult human.
- The human parthenote does not look like a human being.
- The human parthenote is an artificially created form of life that has never before existed.

Some difficulties with position 1

- Biotechnology has rendered obsolete the traditional biologic definitions of human life. Dolly the sheep, who was cloned through somatic cell nuclear transfer technology, grew from a single cell without contribution from a sperm. The same would hypothetically hold true for a human clone.
- There are reasons to be concerned about the setting of criteria for human life based on capacity to survive beyond a stipulated age. Personhood is not dependent on survival rate. For example, while children with some types of muscular dystrophy are in most cases genetically incapable of surviving to adulthood, they are nevertheless human beings. Some infants lacking a gene encoding an enzyme needed for normal metabolism will survive only weeks or days following birth, but they should not be considered to be nonhuman just because science lacks the technology to replace the missing enzyme. The parthenote's incapacity to survive to term is irrelevant to its moral status while it still lives, however shortened its life expectancy may be.
- Furthermore, it is conceivable that future technology could enable human parthenotes to grow to term and to adulthood, as has been done with several species of lower vertebrates despite their parthenotes in nature being gestationally incompetent.[4,5]
- The fact that the parthenote has become a teratoma does not necessarily mean it has always been just a tumor.
- If intact paternal imprinting is a necessary criterion for totipotency, and if imprinting simply involves turning certain genes on or off, then it is conceivable that future technology could find a way to control imprinting artificially. This is provided that the phenomenon of parental genetic imprinting is fully reducible to biology.
- A single cell organism is nonetheless an organism. The human parthenogenetic embryo at the first, second, and third cell division looks exactly like a normal human embryo at the same stage of development.
- If the first adult human clone were created through somatic cell nuclear transfer, he or she would also be an artificially engineered type of life new to history. Supposing the hypothetical is not even needed. If being artificially created meant one is not human, then babies created now through in vitro fertilization would be disqualified. If uniqueness separated the life in question from humanity, then all men and women would be disqualified, for every person is biologically unique.

Position 2: the parthenote is a human being

- The human parthenote is a human being, albeit one who has genetic defects so severe as to arrest development very early on. Until the point where embryonic development ceases, the parthenote develops in essentially the same way as does the normal embryo.
- Although parthenogenesis is not a normal mode of reproduction in humans, the fact that it has a natural reproductive outcome in some lower animals opens the door to thinking of it as a biologically incomplete form of reproduction in humans. This conclusion is strengthened by experiments that have brought to term some parthenogenetic vertebrates that do not reproduce this way in nature. Conceivably, with assistance from technology (e.g. if artificial centrosomes were invented), parthenogenesis might eventually prove to have full reproductive potential in humans.
- The human teratoma may, at least in some cases, be the remains of a severely blighted human embryo. There is an emerging view among embryologists that conjoined twins, the fetus in fetu, and the teratoma are simply biologic variations on the same developmental theme, existing along a morphological spectrum without any obvious structural discontinuity.[27,28] Continued growth and disorganized development of the teratoma might

continue long after the embryonic person has ceased to exist, just as hair and nails will continue to grow for a time after the death of an adult human. Some teratomas appear to be the remains of a retained parthenogenetic twin enfolded within the surviving sibling fetus.
- The human parthenote, although having originated from a haploid egg, contains a complete human genome. Science defines a haploid genome to be genetically complete; otherwise the Human Genome Project would be only halfway done.
- The human parthenote also possesses a unique human genome due to the shuffling of genetic material during meiosis.
- Advanced Cell Technology claimed that the parthenotes grown in their laboratories were human embryos.[19]
- An analogy might be the anencephalic infant, who is born with a profound neurological defect and, despite a very limited lifespan, yet is a human being.
- The early human parthenote is a growing cluster of cells having a complete and unique genome and is therefore a distinct life of human origin. The mystery of human life ultimately is not reducible to molecules.

Some difficulties with position 2

- Public consensus has not yet been reached regarding the moral status of the normal human embryo, where the biologic threshold that marks the beginning of human life is clear. Consensus would be even more difficult in the case of the parthenogenetic embryo, where the question of biologic human life is more ambiguous. One will never have the opportunity to look into the face of the parthenote. The parthenote not only fails to survive to birth, but within the means of current technology could not have been brought to term even if implanted in a mother's womb.
- Admitting the possibility that the parthenote is nascent human life would seem to confer similar uncertainty on the status of the adult human pluripotent stem cell. Doubt might then exist as to whether all people, even boys and girls, are in some sense pregnant. This absurdity is resolved by recalling that, in nature, parthenogenesis is a reproductive process involving germ cells, whereas adult stem cells, being somatic cells, do not possess the capacity to direct and orchestrate the development of a new organism. Nor do stem cells spontaneously divide and grow and arrange themselves into organized embryos as the parthenote does begin to do.
- If one can know what the parthenote is by its fruit, then the teratoma would seem to be the test of the biologic outcome of a parthenogenetic embryo. Although the parthenogenetic embryo is able to generate stem cells having certain properties common to normal adult cells, and the parthenogenetic fetus or fetiform teratoma contains certain well differentiated adult tissues, the parthenote develops in a hopelessly undirected manner leading to a chaotic mass of tissues utterly incapable of functioning as an integrated whole.
- Many people who respect the moral status of the human embryo maintain that the embryo, an early human life, is a being who has the potential to develop sentience. In contrast, the human parthenote in nature never develops sentient capacities such as the ability to feel pain, to know that it exists, to reason, to communicate, to experience joy or sadness, or to act with intention or purpose.

The moral status of the human parthenote

Parthenogenesis challenges the scientific understanding of what minimum set of biologic conditions are needed to define the beginning of human life. To consider the parthenote is, in a single cell, to begin to dissect questions of genetics, potential, and being.

The normal human embryo is worthy of respect because he or she has the potential to develop the physical form and functional capacities that everyone acknowledges represent a human being. From the earliest moment the embryo is also a living entity that has a unique and complete human genome and has the active capacity to orchestrate and choreograph its growth and development in extraordinary detail.

Parthenogenetic embryos, on the other hand, lack such potential. Yet their genetic composition is human, and they show evidence of life and growth. Because moral status is independent of age, it is more important to consider whether parthenotes are developing along a human trajectory than to note how far along that trajectory they are able to proceed. The more truncated the parthenote's early life journey, the greater will be the observer's uncertainty as to the true moral status.

Some philosophers, for instance Peter Singer, who dismiss the value of the human embryo would similarly dismiss the parthenote as not possessing such "morally relevant" capacities as sentience, self-awareness, language, and reason. By the same logic Singer dismisses infants, the mentally handicapped, and elderly people with dementia as being less worthy of life than, for example, a monkey.

For those who would assign moral status on the basis of genetics, the parthenote presents a complete and unique copy of the human genome in a cellular package incapable of accessing and implementing that genome fully.

For those who would accord limited moral status to human embryos on the basis of their incomplete potential, the parthenote will fail to measure up to that standard. Further scientific advances may only blur the distinction of whether the parthenote's limited lifespan is a consequence of defects that are intrinsic or that simply lack correction extrinsically through technological intervention.

Sentience and potential, however, may not be the only morally relevant criteria, because human life surely is something much more than a set of physical properties and biological functions.

Some insights from the Christian tradition

For the Christian, all human beings have special dignity because they have been made in God's image (Genesis 1:26-27, 9:6). The image of God is not based on any functional capacity but is simply identified with life that is human. The Scriptures also indicate a continuity of human personhood beginning prior to birth (Job 31:15; Psalm 139: 14-16; Isaiah 49:1; Jeremiah 1:5; Hosea 12:3; Luke 1:30-31, 41). Every human being, regardless of age, health, or potential is a unique person of inestimable worth who is valued by God.

According to the New Testament, God supremely affirmed the dignity of humanity by becoming himself in Jesus Christ a man. Jesus did not simply materialize from heaven, but he lived as we do. Jesus began his human life as an embryo.

This discussion will not attempt to answer the question of whether Jesus, who Scripture records was born of a virgin (Isaiah 7:14; Luke 1:26-38), might have had a parthenogenetic human genome. If he did, that conclusion would in no way minimize his miraculous conception, his teachings, his fulfillment of Jewish prophecy, his sacrificial love for humanity, his redemptive death, his being both fully human and fully divine, or his miraculous resurrection. His virgin birth should, however, give the Christian pause because, in identifying with humanity in all its weakness, Jesus is also qualified to identify with what might possibly be recognized as parthenogenetic humanity.

The Christian will hesitate to exclude from humanity the human parthenote purely on the basis of its genetic defects, because essential to the Christian understanding of humanity is that all people are fundamentally flawed (Genesis 3; Psalm 14:3, 51:5; Isaiah 1:18, 53:6; Romans 3:23; 1 John 1:8). Moreover, the parthenote inherits its flaws from its mother. Its lethal recessive mutations are the same flaws common to humanity, only uncovered.

The life of the parthenote may be futile, but apart from God all human life is in the end futile.

Conclusion

In judging the worth of the life of a defective human parthenote, uncertainty cannot be avoided, not only because the entity under discussion is microscopic and limited in its developmental lifespan, but also because moral status is a property science cannot discern, no matter how exact its measurements. In deciding in the face of uncertainty whether it is morally right to destroy a life, even a life as small, as defective, and as limited as the parthenote, one should always err on the side of not harming vulnerable life of human origin.

How society treats the human embryo and the human parthenote has broad implications for how society will value vulnerable and handicapped human life in general. Philosopher Robert Spitzer maintains that, "Every being of human origin should be considered a person. Doubt about personhood should never be considered a warrant for denying personhood. An error in this regard could lead to every form of genocide, slavery, and political disenfranchisement based not on certain evidence but on doubt. If we as a culture do not together make this critical assumption, we risk the possibility of compromising unconditional dignity, causing irreparable individual harm, and seriously undermining our culture."[29]

Destroying the human parthenote to collect its stem cells might be seen as no different from the outcome nature would have held for it just a day or two later, except for this. Parthenogenesis research goes further by proposing to bring countless numbers of parthenogenetic lives into the world only to annihilate them. Many people find the prospect of creating new human life expressly for research entailing its destruction to be profoundly disturbing, regardless of the degree of potential that life has, and regardless of the promised gains. Given the moral uncertainties discussed herein, unless it can be proven that parthenotes are not nascent human lives, then such a prospect remains deeply unsettling, repugnant, and dehumanizing.

There is the further possibility that future research could correct the defects in human parthenotes so that they could, as has been done in some lower vertebrates, be brought to birth. This would add a whole new dimension to discussing the "birds and the bees" with our children. Into the conversation would fly fatherless chicks and parthenote drones and a beehive of perplexing questions.

A scientific quest to culture healthy human parthenotes would not translate into parthenogenesis becoming a desirable means of human reproduction. There is much wisdom in the traditional family of biblical design. Even if human sexuality were viewed from a naturalistic perspective, parthenogenesis as a good option for humans would seem to have been selected out by evolution.

Genetic enhancement of human parthenotes could conceivably lead also to more robust parthenogenetic stem cells for research and clinical applications. Such a project, if undertaken, would have the unintentional result of breeding parthenogenetic embryos that resembled more and more the traditional human embryo. The alluring claim of circumventing through parthenogenesis the cannibalization of human embryos will then have proven to be an illusion as new generations of human parthenotes display more and more the face of undeniable humanity.

After weighing the current biologic and medical evidence, the moral ambiguities, and what is at stake for humanity, the most prudent public policy decision will exclude as ethically unacceptable the option of harvesting embryonic stem cells from human parthenogenetic embryos.

Valuable resources should not be wasted on the problematic search for stem cells from morally ambiguous sources, whether these be parthenogenetic or other modified forms of human embryos. Rather, resources should be allocated to more research involving ethically noncontroversial sources of human stem cells—from adults, placenta, or umbilical cord blood—for potential medical applications.

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Nota Bene: Nothing written here is to be construed as necessarily reflecting the views of Mayo Clinic or Mayo Foundation.

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