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Review Article

Parthenogenesis: A Contemporary Review and Synopsis of the Medical Perspective of "Immaculate" Conceptions

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Abstract

Parthenogenesis is the process by which an ovum (also known as an egg) can develop into an individual without the participation of a male agent. Virgin births are possible in invertebrates and vertebrates such as birds, fish, and reptiles. Although mammals can begin the process of parthenogenesis, they do not typically give birth to parthenogenetic offspring. It has been demonstrated that mice and rabbit embryos can be developed parthenogenetically to a stage equivalent to approximately halfway through pregnancy in laboratory conditions. However, these embryos can then be terminated. According to a recent study, using calcium ionophore as a catalyst, it was possible to activate human embryos through parthenogenesis spontaneously. Parthenogenesis can take many forms, each classified according to the cell division method involved. It was long believed that this event is controlled by a single (master) gene or a single locus with closely linked genes and biomechanical signaling. However, recent research has debunked these long-held beliefs. The process of parthenogenesis could prove helpful in creating regenerative therapies and developing clones that contain favorable gene variants. To generate stem cells for genetic research, scientists have been examining ways to stimulate human egg development before fertilization. This process is done to harvest the stem cells from the eggs. If appropriately designed, therapies based on parthenogenesis can even benefit human health.

Keywords: *Parthenogenesis; Medical Perspective; "Immaculate" Conceptions; Clonal Reproduction; Human Health*

Introduction

Clonal reproduction can also occur through the process of parthenogenesis. Eggs are formed even when no sperm is present, and the offspring are genetically indistinguishable from their mother. Eggs are formed even when no sperm is present, and the offspring are genetically indistinguishable from the mother cell. It is found in relatively few squamate reptile species despite being reasonably common in invertebrates. The only members of the population of a parthenogenetic reptile are females, as this type of reptile arose from the hybridization of two different species. Certain animals can naturally produce parthenogenesis, but parthenogenesis can be created artificially through various chemical and physical means. Only a small percentage of insect species are capable of self-reproduction because they lack males and do not go through a sexual phase. Parthenogenesis in insects like these is called complete parthenogenesis [1].

History and background

First used in 1871 by Carl Theodor Ernst von Siebold (CE 1804–1885), the term "parthenogenesis" literally means "virgin reproduction" or "reproduction without males" [1]. Parthenogenesis is when a female uses clonal asexual reproduction on an untested egg to create a new individual without the assistance of a male. Ova develops into new organisms without the aid of sperm. Throughout history, "parthenogenesis" has been applied to various forms of chaste female reproduction. Charles Bonnet was an eighteenth-century naturalist and philosopher. His most significant contribution to embryology was the discovery of parthenogenesis in aphids, demonstrating that offspring can be produced without a father [2]. Parthenogenesis is distinct from animal cloning, in which the new organism must possess the same genes as the donor cell. To create a genetically identical organism, the nucleus of a diploid cell from a donor organism is transferred into a nucleus-less egg cell. Parthenogenesis is distinct because it arises from the genetic material within an egg cell.

Discussion

Types and mechanisms

Parthenogenesis typically involves a process that maintains or restores the number of diploid chromosomes, as haploid offspring generally are less healthy or incapable of surviving independently. Actual clones and partial clones are the two types of clones. Angiosperms undergo either apospory, in which the gametophyte develops directly from the sporophytic cell of the ovule, or diplospory, in which meiosis is skipped, restarted, or replaced by endoreplication [3,4]. Actual clones of the mother plant are formed due to diplospory precedes crossing-over, and endoreplication follows sister-chromosome pairing.

Parthenogenesis has two significant phases: apomixis and automixis. Apomixis is the mitosis-based production of egg cells. Mitotic oogenesis can result in parthenogenesis in the absence of meiosis. This process is known as apomictic parthenogenesis. Mitotic divisions result in the formation of mature egg cells, which then transform into embryos.

Mitosis is when the female sexual cell, or oocyte, replicates itself during apomictic parthenogenesis. This process creates two diploid cells. These diploid cells contain every necessary chromosome for embryonic development. The offspring are identical replicas of the parent cell. Aphids and flowering plants are two organisms that reproduce in this way. In flowering plants, gametophyte cells are capable of undergoing this process. The offspring produced through apomictic parthenogenesis are identical to their mother. As an example, consider aphids [5].

Ova (egg cells) are produced by meiosis in automixis. Meiosis-involved parthenogenesis is more complicated. Occasionally, the offspring are haploid (e.g., male ants). In other instances, collectively called automictic parthenogenesis, the ploidy is changed back to diploidy in various ways. In the majority of species, haploid individuals are not viable.

In automictic parthenogenesis, the offspring are distinct from both their mother and one another. They are called "half clones" of their mother [5]. In developing egg cells, the meiotic daughter cells are typically divided unevenly.

One large egg cell (oocyte) and several smaller cells known as polar bodies are produced through asymmetrical cytokinesis. In the absence of fertilization, polar bodies degrade. When male sperm fertilizes an oocyte, it transforms from haploid (containing two sets of paired chromosomes) to diploid (containing two pairs of finished chromosomes).

Because automictic parthenogenesis does not require male involvement, the oocyte becomes diploid by fusing with one of the polar bodies or duplicating its chromosomes. The genetic recombination that occurs transforms these individuals into false clones of the parent cell (Figure 1).

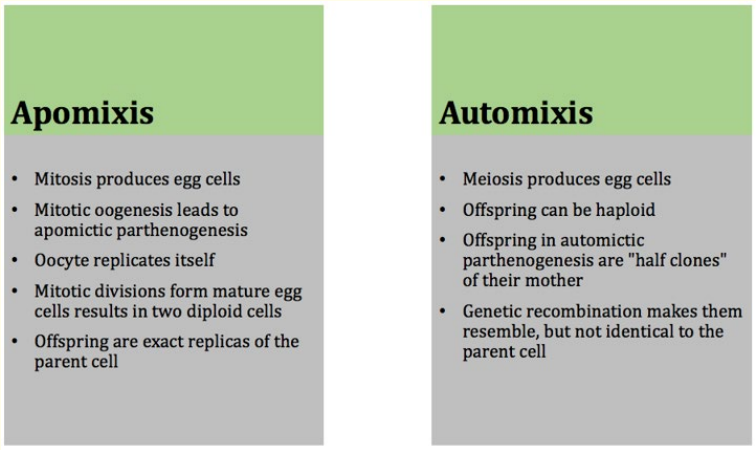

Figure 1: *Two types of parthenogenesis*

Parthenogenesis in vertebrates

During meiosis, the development of parthenogenetic "species" in vertebrates is altered, producing eggs with multiple chromosome sets. Parthenogenesis is exceedingly uncommon in vertebrates. So far, only squamate reptiles (lizards and snakes) have been identified as reproducing parthenogenetically [6]. Although common in invertebrates such as Daphnia and aphids, facultative parthenogenesis––the ability to switch between sexual and clonal reproduction––appears even rarer in vertebrates. Parthenogenetic development has been documented in all vertebrate groups [6].

The term "female-producing parthenogenesis," also known as thelytoky, refers to the process by which animals produce female offspring without the genetic contribution of males [1]. It departs from the original etymology by including the rare cases of sperm-dependent parthenogenesis requiring copulation [1]. Parthenogenesis is not a natural reproduction method in mammals because fetal development is impossible.

Although no natural instances of parthenogenesis in mammals are known, it has been artificially induced in rabbits, mice, pigs, and monkeys, frequently resulting in abnormal development [7].

In vertebrates, parthenogenetic "species" result from altered meiosis, which produces eggs with multiple chromosome sets. Occasionally, a male of a closely related species must court a female for the ovum to develop, but his sperm cannot fertilize the ovum [8].

Incidence and prevalence of parthenogenesis

Despite being notoriously common, spontaneous parthenogenetic activation of the human oocyte inevitably results in ovarian teratoma, a benign tumor documented since at least the 19th century [9].

There may be some differentiation in these parthenogenetic processes, resulting in an anatomically disorganized structure containing fatty tissue, hair, and teeth. Strain and colleagues reported in 1995 [10] the case of an extraordinary and complex parthenogenetic event that produced a viable (male) child named "FD".

After analyzing tissue samples, the team determined that FD is a parthenogenetic chimera or a child with cells from two different lineages. Since then, more than a dozen additional cases of parthenogenetic/androgenetic events in humans have been reported; these are referred to in the scientific community as "genome-wide maternal (or paternal) uniparental isodisomy" [11–14].

The patient frequently presented with clinical abnormalities, and subsequent investigations determined whether they were chimeric, parthenogenetic, or androgenetic.

Biological and genetic markers

Parthenogenesis and apomeiosis are genetic processes [15] that were once believed to be governed by a single (master) gene or a single locus with closely linked genes. The majority of studies indicate that parthenogenesis is dominantly or monogenetically inherited. It can induce embryogenesis in aneuploid eggs and usually functions in di-haploid egg cells; however, premature embryo abortus is a drawback.

Even though it is uncommon to observe parthenogenesis in reduced, haploid plant egg cells, it has been observed in haploid eggs of the di-haploid parthenogenetic Erigeron (see above) and a diploid apomictic Hieracium plant [16]. Several parthenogenesis genes have been identified in plants and animals. The first gene discovered was PsASGR-BABYBOOM-like, which causes somatic embryogenesis in *Arabidopsis* and B. napus when expressed elsewhere [17].

In the *Aspidoscelis cozumela* complex, comprised of the species *A. cozumela, A. maslini*, and *A. rodecki*, the origin of parthenogenesis was investigated by analyzing the partial sequences of two mitochondrial genes, Cytb and ND4. Given the little difference between parthenogenetic species and *A. angusticeps* [18], *A. angusticeps* is the mother species of the parthenoforms.

Biomechanical signaling in parthenogenetic cells and oocytes

Parthenogenesis is typically abortive [19] due to the requirement for functionally specialized maternal and paternal genomes, which act as a developmental barrier, and genomic imprinting. Numerous biochemical channels are required for the activation of parthenogenic processes.

Oocytes and young embryos can actively detect external biomechanical stimuli, convert them to signals within their cells, and alter their behavior. Hippo and Rho GTPase, the two major mechanosensing signaling pathways, are essential for oogenesis and changing the quality of oocytes in female gametes.

In the early stages of mammalian embryo development, the tubal fluid contains Rho and YAP activators. Rho GTPase signaling is essential for coordinating the formation of actin filaments and microtubules and the movement of the polar body and spindle rotation during meiosis [20].

The expression levels of RhoA, RhoB, and RhoC members of the Rho GTPase family were significantly higher in human parthenogenetic cells than in biparental cells. Similarly, introducing Rho and YAP activators from the outside world into the culture medium during *in vitro* embryo culture methods such as parthenogenesis is beneficial to the early stages of embryonic development (Table 1).

Factor	Effect on Parthenogenesis
Maternal and paternal genomes	Required for normal development
Genomic imprinting	Can act as a developmental barrier
Biochemical channels	Required for activation of parthenogenic processes
Mechanosensing signaling pathways	Essential for oogenesis and altering the quality of oocytes
Rho GTPase signaling	Essential for coordinating the formation of actin filaments and microtubules and the movement of the polar body and spindle rotation during meiosis
YAP and TAZ	Essential for oogenesis and activating the zygotic genome
RhoA, RhoB, and RhoC	Expression levels are significantly higher in human parthenogenetic cells than in biparental cells

Table 1: *Factors affecting parthenogenesis*

In the Rho GTPase pathways, YAP and TAZ are essential for oogenesis. They are highly transcribed in both mouse and human oocytes, are accumulated by the mother, and are strong candidates for activating the zygotic genome [21].

Parthenogenesis and assisted reproduction

Parthenogenetic activation of human oocytes derived from infertility treatments has recently gained new interest. It is an alternative to creating embryos that cannot be used to make babies to research assisted reproduction technologies. Using human embryos created for reproduction avoids the ethical and legal complications associated with using parthenogenetic embryos [22].

During infertility treatments, oocytes can be activated parthenogenetically to produce embryos that resemble their biparental counterparts [22]. Using human parthenogenetic embryos as a source of cells for creating pluripotent stem cell lines is possible, and this strategy warrants further consideration.

As a result of the significant number of oocytes lost during infertility treatments [22], human parthenogenetically derived clinical-grade stem cells will produce various cell types that will eventually be used in numerous clinical procedures, such as ART.

Advantages and applications

Concerning the maintenance of sexual reproduction, female-producing parthenogenesis (as well as apomixis in plants) is extensively studied. This reproduction method would spare species without sperm dependence from certain costs associated with sexual reproduction, including the dissolution of co-adapted gene complexes, the production of male offspring, and expenses related to mate selection.

Even though parthenogenesis does not always result in clones, the term "asexuality" is commonly used in this context to refer to female-producing parthenogenesis. The great advantage of producing immunocompatible parthenogenetic embryonic stem cells—a suitable alternative source of pluripotent stem cells—is that they provide parthenogenetic stem cells with their uniparental origin [23]. Based on the discovery that these lineages are homozygous for human leukocyte antigens [24–26], numerous patients may benefit from regenerative therapies using these lineages. The advantages and applications are listed in Table 2.

Advantage	Application
Asexual reproduction	Can be used to produce clones of desired individuals
Immunocompatibility	• Parthenogenetic stem cells are homozygous for human leukocyte antigens, making them ideal for transplantation • Suitable alternative source of pluripotent stem cells • Homozygosity at the major histocompatibility locus allows effective immune matching • Possible broader acceptance of derived tissues in transplantation due to reduced immune rejection
Regenerative medicine	• Parthenogenetic stem cells can be used to repair damaged tissues or organs • Homozygous for human leukocyte antigens
Disease modeling	• Parthenogenetic stem cells can be used to model human diseases
Drug discovery	• Parthenogenetic stem cells can be used to test the safety and efficacy of new drug • Can exhibit normal gene expression or correct genomic imprinting in chimeras • Utilize tissues or cells derived from organoids for therapeutic purposes

Table 2: *Advantages and applications of parthenogenesis*

Conclusion

Scientists who are investigating ways to stimulate human eggs to start developing before they become fertilized can find a boon in parthenogenesis, which can serve as a source of embryonic stem cells that can be used for regenerative therapy. Parthenogenesis can serve as a boon for scientists. Parthenogenesis treatments can benefit human health if developed, tested, and proven successful.

Conflict of Interest Statement

The authors declare that this paper was written without any commercial or financial relationship that could be construed as a potential conflict of interest.

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