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Editorial

# Do the spermatic axoneme and mitochondria enter the oocyte during the fertilization process?

## ¿Entran el axonema y las mitocondrias espermáticas en el oocito durante el proceso de la fecundación?

Fertilization is the interaction between a spermatozoon and an oocyte; for this process to take place, the spermatozoon must experience a series of physiologic and biochemical enabling changes on its trajectory through the female reproductive tract, and undergo the acrosome reaction upon contacting the zona pellucida. Subsequently, syngamy, early embryonic development, implantation, and late embryonic development occur, which will originate a new individual[1,2].

This interesting interaction between gametes elicits two important questions that were discussed by the Línea de Trabajo Académica – Grupo Reproducción, Semillero de investigación SIMBIOSIS, Escuela de Microbiología, Universidad de Antioquia: a) Does the whole spermatozoon, including axoneme and mitochondria, enter the oocyte?, and b) If it does, what becomes of the spermatic mitochondria after fertilization?

Renown researchers from around the world have tried to understand the role of the spermatozoon in fertilization, in addition to providing genetic material[3-6]. The spermatozoon contributes at least three key factors in human fertilization:

1. Provide haploid genetic material.
2. Generate the signal to initiate oocyte activation.
3. Provide the centriole[7].

The objective of this editorial is to use our current knowledge to answer our two questions.

In mammals, both the axoneme and the mitochondria enter the oocyte at fertilization[5]; in human beings, this interaction is clearly observed in the photograph by Sathananthan et al.[8] (cited and reproduced in Ankel-Simons et al.[3]). The only examples described to date that do not follow this rule are the Chinese hamster (*Cricetulus griseus*) and the worm (*Nereis*), species in which the axoneme does not enter the oocyte[3,9,10].

Sperm mitochondria in the embryos of some mammals such as rats, bovines, and mice[11] are destroyed by a proteolytic machinery in the oocyte cytoplasm before or during the third embryonic cleavage. This has been shown by detecting mitochondria during spermiogenesis using a specific antibody that recognizes ubiquitin; these mitochondria are subsequently destroyed by the 26S proteasome in the cytoplasm of the fertilized oocyte[12]. Furthermore, the inability of the oocyte to eliminate the sperm mitochondria assumes that there is a cause for abnormal embryonic development in animals cloned by nuclear transfer[13]. One interesting rationale for the elimination of sperm mitochondria is that they are damaged by reactive oxygen species during spermatogenesis or during the spermatozoon's travel to the oocyte, and could thus be harmful to the ebryo[14,15]. Another possibility is the dilution of paternal mitochondria, as one spermatozoon carries approximately 100 copies of mitochondrial DNA while the oocyte contains $10^5$ to $10^8$ copies[16]; thus, the paternal contribution of mitochondrial DNA could be diluted to the point where it is impossible to detect by conventional analyses[17].

One procedure commonly used today to overcome fertility problems is the intracytoplasmic sperm injection (ICSI)[18], which consists of the direct introduction of a complete spermatozoon (head, midpiece, and tail) into an oocyte. Torroni et al.[19] analyzed the mitochondrial DNA halogroup in the fathers and their offspring in three families whose children were conceived by ICSI (two families with one child and the other with four children); they all have maternal mitochondria only. In 2004, a study conducted by Johnson et al.[20] showed that ICSI conducted with complete spermatozoa are more successful than those done with sperm heads only; this is probably due to the necessity of the axoneme, or at least the centrosome, which is important in embryonic development[21]. It has been observed that fertilization with complete spermatozoa seems to contribute to the normal development of embryogenesis[22].

Terada et al.[23] showed that when the spermatozoon is incorporated into the oocyte cytoplasm, the sperm centrosome is responsible for the peripheral arrangement

of microtubules—essential for the pronuclear movement, which originates the union of the paternal and the maternal genomes. Furthermore, sperm centrosomes replicate during the first cycle and form the two poles of the mitotic spindle required for embryonic development[23].

In conclusion, mitochondria and the axoneme enter the oocyte but are destroyed soon after the fertilization process begins; although the role of each of these organelles in the reproductive process is currently being debated, based on existing evidence, it is likely that the axoneme and the mitochondria may be implicated in the embryo's development.

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