



The origin of human life at fertilization:

Quotes from medical textbooks and peer-reviewed scientific literature.¹

Note on the meaning of scientific terminology for human development:

"Organism" is the scientific name for a *living human being*. Only organisms undergo development.

"Zygote" is the one-cell human organism produced by sperm-egg fusion.

"Embryo" is a human organism during the first eight weeks of development.

I. Medical Textbooks

1. Keith L. Moore, *The Developing Human: Clinically Oriented Embryology*, 10th edition. Philadelphia, PA: Saunders, 2016. p. 11

“Human development begins at fertilization, when a sperm fuses with an oocyte to form a single cell, the zygote. This highly specialized, *totipotent cell* (capable of giving rise to any cell type) marks the beginning of each of us as a unique individual.”

2. Schoenwolf, G. C. *Larsen’s Human Embryology*, 5th edition. Philadelphia, PA: Elsevier, Saunders, 2015. p. 2, 14.

“All of us were once human embryos, so the study of human embryology is the study of our own prenatal origins and experiences.” (p. 2)

“Fertilization, the uniting of egg and sperm, takes place in the oviduct. After the oocyte finishes meiosis, the paternal and maternal chromosomes come together, resulting in the formation of a zygote containing a single diploid nucleus. Embryonic development is considered to begin at this point.” (p.14)

3. Jones, R. E. *Human Reproductive Biology*, 4th edition. Waltham, MA. Elsevier, Academic Press, 2014, p. 169.

“the fertilized egg (zygote) is the beginning of a new diploid individual.”

4. Keith L. Moore, *Before We Are Born: Essentials of Embryology*, 7th edition. Philadelphia, PA: Saunders, 2008. p. 2:

¹ Compiled by: Dr. M.L. Condic, Assoc. Professor of Neurobiology and Anatomy, University of Utah, School of Medicine (emphasis added in quotes). Last updated September 2017.

"[The zygote], formed by the union of an oocyte and a sperm, is the beginning of a new human being."

5. Keith L. Moore, *Before We Are Born: Essentials of Embryology*, 9th edition. Philadelphia, PA: Saunders, 2016. p. 1.

"Human development begins at fertilization when an oocyte (ovum) from a female is fertilized by a sperm (spermatozoon) from a male...Embryology is concerned with the origin and development of a human being from a zygote to birth."

6. Sadler, T. W. *Langman's Medical Embryology*, 10th edition. Philadelphia, PA: Lippincott Williams & Wilkins, 2006. p. 11:

"Development begins with fertilization, the process by which the male gamete, the sperm, and the female gamete, the oocyte, unite to give rise to a zygote."

7. Sadler, T. W. *Langman's Medical Embryology*, 13th edition. Philadelphia, PA: Lippincott Williams & Wilkins, 2015. p. 42 (*emphasis added*).

"The main results of fertilization are as follows: Restoration of the diploid number of chromosomes, half from the father half from the mother. Hence, the zygote contains a new combination of chromosomes different from both parents. Determination of the sex of the new individual. An X-carrying sperm produces a female (XX) embryo and a Y-carrying sperm produces a male (XY) embryo. Therefore, the chromosomal sex of the embryo is determined at fertilization."

8. Dudek, R. W. *Embryology*, 4th edition. Philadelphia, PA. Lippincott Williams and Wilkins, 2008, p. 1.

"Sexual reproduction occurs when female and male gametes (oocyte and spermatozoon, respectively) unite at fertilization."

9. Ronan O'Rahilly and Fabiola Miller, *Human Embryology and Teratology*, 3rd edition. New York: Wiley-Liss, 2001. p. 8.

"Although life is a continuous process, fertilization... is a critical landmark because, under ordinary circumstances, a new genetically distinct human organism is formed when the chromosomes of the male and female pronuclei blend in the oocyte."

10. Carlson, B. M. *Human Embryology and Developmental Biology*, 5th edition. Philadelphia, PA. Elsevier, Saunders, 2014, p. 2.

"Human pregnancy begins with the fusion of an egg and a sperm within the female reproductive tract"

II. Peer-reviewed scientific literature; 2001-2016 (chronological order)

1. A profile of fertilization in mammals. Wassarman PM, Jovine L, Litscher ES. Nat Cell Biol. 2001 Feb;3(2):E59-64.

“When mammalian eggs and sperm come into contact in the female oviduct, a series of steps is set in motion that can lead to fertilization and ultimately to development of new individuals.”

2. Penetration, adhesion, and fusion in mammalian sperm-egg interaction. Primakoff P, Myles DG. Science. 2002 Jun 21;296(5576):2183-5.

"Fertilization is the sum of the cellular mechanisms that pass the genome from one generation to the next and initiate development of a new organism."

3. Egg activation at fertilization: where it all begins. Runft LL, Jaffe LA, Mehlmann LM. Dev Biol. 2002 May 15;245(2):237-54.

4. The cell cycle: a new entry in the field of Ca²⁺ signaling. Santella L, Ercolano E, Nusco GA. Cell Mol Life Sci. 2005 Nov;62(21):2405-13.

"Ca²⁺ signaling plays a crucial role in virtually all cellular processes, from the origin of new life at fertilization to the end of life when cells die."

5. The immunoglobulin superfamily protein Izumo is required for sperm to fuse with eggs. Inoue N, Ikawa M, Isotani A, Okabe M. Nature. 2005 Mar 10;434(7030):234-8.

"Representing the 60 trillion cells that build a human body, a sperm and an egg meet, recognize each other, and fuse to form a new generation of life."

6. Signal transduction pathways leading to Ca²⁺ release in a vertebrate model system: lessons from Xenopus eggs. Sato K, Fukami Y, Stith BJ. Semin Cell Dev Biol. 2006 Apr;17(2):285-92.

"At fertilization, eggs unite with sperm to initiate developmental programs that give rise to development of the embryo. Defining the molecular mechanism of this fundamental process at the beginning of life has been a key question in cell and developmental biology"

7. Cell fusion during development. Oren-Suissa M, Podbilewicz B. Trends Cell Biol. 2007 Nov;17(11):537-46.

"Most readers of this review originated from a sperm-egg fusion event."

8. Ca²⁺ signaling differentiation during oocyte maturation. Machaca K. J Cell Physiol. 2007 Nov;213(2):331-40.

"Oocyte maturation is an essential cellular differentiation pathway that prepares the egg for activation at fertilization leading to the *initiation of embryogenesis*."

9. Sperm-egg fusion assay in mammals. Inoue N, Okabe M. *Methods Mol Biol.* 2008;475:335-45.

"As representatives of the 60 trillion cells that make a human body, a sperm and an egg meet, recognize each other, and fuse to *create a new generation*."

10. Sperm chromatin: fertile grounds for proteomic discovery of clinical tools. Wu TF, Chu DS. *Mol Cell Proteomics.* 2008 Oct;7(10):1876-86.

"Sperm are remarkably complex cells with a singularly important mission: to deliver paternal DNA and its associated factors to the oocyte *to start a new life*."

11. Gene expression during the oocyte-to-embryo transition in mammals. Evsikov AV, Marín de Evsikova C. *Mol Reprod Dev.* 2009 Sep;76(9):805-18.

"The seminal question in modern developmental biology is *the origins of new life* arising from the unification of sperm and egg."

12. A role for the elongator complex in zygotic paternal genome demethylation. Okada Y, Yamagata K, Hong K, Wakayama T, Zhang Y. *Nature.* 2010 Jan 28;463(7280):554-8.

"The life cycle of mammals begins when a sperm enters an egg."

13. Fertilization and the oocyte-to-embryo transition in *C. elegans*. Marcello MR, Singson A. *BMB Rep.* 2010 Jun;43(6):389-99.

"Fertilization is a complex process comprised of numerous steps. During fertilization, two highly specialized and differentiated cells (sperm and egg) fuse and subsequently trigger the *development of an embryo* from a quiescent, arrested oocyte."

14. Model systems for membrane fusion. Marsden HR, Tomatsu I, Kros A. *Chem Soc Rev.* 2011 Mar;40(3):1572-85.

"The fusion of sperm and egg membranes *initiates the life* of a sexually reproducing organism."

15. Calcium channels in the development, maturation, and function of spermatozoa. Darszon A, Nishigaki T, Beltran C, Treviño CL. *Physiol Rev.* 2011 Oct;91(4):1305-55.

"A proper dialogue between spermatozoa and the egg is essential for conception of a new individual in sexually reproducing animals. Ca(2+) is crucial in orchestrating this unique event *leading to a new life*."

16. Acrosome reaction in the cumulus oophorus revisited: involvement of a novel sperm-released factor NYD-SP8. Sun TT, Chung CM, Chan HC. *Protein Cell*. 2011 Feb;2(2):92-8.

"Fertilization is a process involving multiple steps that lead to the final fusion of one sperm and oocyte to form the zygote."

17. Starting a new life: sperm PLC-zeta mobilizes the Ca²⁺ signal that induces egg activation and embryo development: an essential phospholipase C with implications for male infertility. Nomikos M, Swann K, Lai FA. *Bioessays*. 2012 Feb;34(2):126-34.

18. Kinases, phosphatases and proteases during sperm capacitation. Signorelli J, Diaz ES, Morales P. *Cell Tissue Res*. 2012 Mar 20.

"Fertilization is the process by which male and female haploid gametes (sperm and egg) unite to produce a genetically distinct individual."

19. Roles of the oviduct in mammalian fertilization. Coy P, Garcia-Vázquez FA, Visconti PE, Avilés M. *Reproduction*. 2012 Oct 1.

"The oviduct or Fallopian tube is the anatomical region where every new life begins in mammalian species. After a long journey, the spermatozoa meet the oocyte in the specific site of the oviduct named ampulla, and fertilization takes place."

20. Oviductal, endometrial and embryonic gene expression patterns as molecular clues for pregnancy establishment. Salilew-Wondim D, Schellander K, Hoelker M, Tesfaye D. *Anim Reprod Sci*. 2012 Sep;134(1-2):9-18.

"In higher animals, the beginning of new life and transfer of genetic material to the next generation occurs in the oviduct when two distinct gametes cells unite resulting in the formation of a zygote."

21. Sperm-egg interaction. Evans JP. *Annu Rev Physiol*. 2012;74:477-502.

"A crucial step of fertilization is the sperm-egg interaction that allows the two gametes to fuse and create the zygote."

22. Regulation of inositol 1,4,5-trisphosphate receptor function during mouse oocyte maturation. Wakai T, Vanderheyden V, Yoon SY, Cheon B, Zhang N, Parys JB, Fissore RA. *J Cell Physiol*. 2012 Feb;227(2):705-17.

"At the time of fertilization, an increase in the intracellular Ca²⁺ concentration ([Ca²⁺])_i underlies egg activation and initiation of development in all species studied to date."

23. Fertilization. Marcello MR, Singaravelu G, Singson A. *Adv Exp Med Biol.* 2013;757:321-50.

"Fertilization-the fusion of gametes to produce a new organism-is the culmination of a multitude of intricately regulated cellular processes."

24. The oocyte-to-embryo transition. Robertson S, Lin R. *Adv Exp Med Biol.* 2013;757:351-72.

"The oocyte-to-embryo transition refers to the process whereby a fully grown, relatively quiescent oocyte undergoes maturation, fertilization, and is converted into a developmentally active, mitotically dividing embryo, arguably one of the most dramatic transitions in biology."

25. How to make a good egg!: The need for remodeling of oocyte Ca(2+) signaling to mediate the egg-to-embryo transition. Nader N, Kulkarni RP, Dib M, Machaca K. *Cell Calcium.* 2013 Jan;53(1):41-54.

"The egg-to-embryo transition marks the initiation of multicellular organismal development and is mediated by a specialized Ca(2+) transient at fertilization."

26. Membrane rafts regulate phospholipase B activation in murine sperm. Asano A, Nelson-Harrington JL, Travis AJ. *Commun Integr Biol.* 2013 Nov 1;6(6):e27362.

"It is intuitive that fertilization-the start of life-involves communication between a sperm cell and an egg."

27. Juno is the egg Izumo receptor and is essential for mammalian fertilization. Bianchi E, Doe B, Goulding D, Wright GJ. *Nature.* 2014 Apr 24;508(7497):483-7.

"Fertilization occurs when sperm and egg recognize each other and fuse to form a new, genetically distinct organism."

28. A transgenic insertion on mouse chromosome 17 inactivates a novel immunoglobulin superfamily gene potentially involved in sperm-egg fusion. Lorenzetti D, Poirier C, Zhao M, Overbeek PA, Harrison W, Bishop CE. *Mamm Genome.* 2014 Apr;25(3-4):141-8.

"Fertilization is the process that leads to the formation of a diploid zygote from two haploid gametes."

29. MicroRNA-34 family expression in bovine gametes and preimplantation embryos. Tscherner A, Gilchrist G, Smith N, Blondin P, Gillis D, LaMarre J. *Reprod Biol Endocrinol.* 2014 Sep 2;12:85.

"In sexually reproducing organisms, embryogenesis begins with the fusion of two haploid gametes"

30. Cross-species fertilization: the hamster egg receptor, Juno, binds the human sperm ligand, Izumo1. Bianchi E, Wright GJ. *Philos Trans R Soc Lond B Biol Sci.* 2015 Feb 5;370(1661):20140101.

“Fertilization is the culminating event in sexual reproduction and requires the recognition and fusion of the haploid sperm and egg to form a new diploid organism.”

31. Maternal non-Mendelian inheritance of a reduced lifespan? A hypothesis. Wilding M, Coppola G, De Icco F, Arenare L, Di Matteo L, Dale B. *J Assist Reprod Genet.* 2014 Jun;31(6):637-43.

“Since a new individual is derived from the fusion of a single sperm and egg, we tested...”

32. An update on post-ejaculatory remodeling of the sperm surface before mammalian fertilization. Gadella BM, Boerke A. *Theriogenology.* 2015 Aug 7. pii: S0093-691X(15)00376-3.

“The fusion of a sperm with an oocyte to form new life is a highly regulated event.”

33. PLC ζ or PAWP: revisiting the putative mammalian sperm factor that triggers egg activation and embryogenesis. Kashir J, Nomikos M, Swann K, Lai FA. *Mol Hum Reprod.* 2015 May;21(5):383-8.

“In mammals, egg activation is initiated by multiple cytosolic Ca(2+) transients (Ca(2+) oscillations) that are triggered following delivery of a putative sperm factor from the fertilizing sperm. The identity of this 'sperm factor' thus holds much significance, not only as a vital component in creating a new life, but also for its potential therapeutic and diagnostic value in human infertility.”

34. The role of syncytins in human reproduction and reproductive organ cancers. Soygur B, Sati L. *Reproduction.* 2016 Nov;152(5):R167-78.

“Human life begins with sperm and oocyte fusion.”

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