

Developmental Biology

Volume 237, Issue 1, 1 September 2001, Pages 29-44

Regular Article

Postmeiotic Unfertilized Starfish Eggs Die by Apoptosis

Özlem Yüce ... Kirsten C Sadler ¹

 [Show more](#)

<https://doi.org/10.1006/dbio.2001.0361>

[Get rights and content](#)

Under an Elsevier [user license](#)

[open archive](#)

Abstract

Fertilization of starfish eggs during meiosis results in rapid progression to embryogenesis as soon as meiosis II is completed. Unfertilized eggs complete meiosis and arrest in postmeiotic interphase for an, until now, indeterminate time. If they remain unfertilized, the mature postmeiotic eggs ultimately die. The aim of this study is to characterize the mechanism of death in postmeiotic unfertilized starfish eggs. We report that, in two species of starfish, in the absence of fertilization, postmeiotic interphase arrest persists for 16–20 h, after which time the cells synchronously and rapidly die. Dying eggs extrude membrane blebs, undergo cytoplasmic contraction and darkening, and fragment into vesicles in a manner reminiscent of apoptotic cells. The DNA of dying eggs is condensed, fragmented, and labeled by the TUNEL assay. Taken together, these data suggest that the default fate of postmeiotic starfish eggs, like their mammalian counterparts, is death by apoptosis. We further report that the onset and execution of apoptosis in this system is dependent on ongoing protein synthesis and is inhibited by a rise in intracellular Ca^{2+} , an essential component of the fertilization signaling pathway. We propose starfish eggs as a useful model to study developmentally regulated apoptosis.

Keywords

programmed cell death; apoptosis; meiotic maturation; oocyte; postmeiotic egg; protein synthesis; starfish

[Recommended articles](#) [Citing articles \(28\)](#)






References

REFERENCES

- 1 A. Abrieu, D. Fisher, M.N. Simon, M. Doree, A. Picard
MAPK inactivation is required for the G2 to M-phase transition of the first mitotic cell cycle
EMBO J., 16 (1997), pp. 6407-6413
- 2 J.A. Anderson, A.L. Lewellyn, J.L. Maller
Ionizing radiation induces apoptosis and elevates cyclin A1-Cdk2 activity before but not after the midblastula transition in *Xenopus*
Mol. Biol. Cell, 8 (1997), pp. 1195-1206
- 3 E. Asselin, C.W. Xiao, Y.F. Wang, B.K. Tsang

Mammalian follicular development and atresia: Role of apoptosis





Biol. Signals Recept., 9 (2000), pp. 87-95




- 4 T. Baker
A quantitative and cytological study of germ cells in human ovaries
Proc. R. Soc. Lond. B Biol. Sci., 158 (1963)
- 5 K. Chiba, M. Hoshi
Three phases of cortical maturation during meiosis reinitiation in starfish oocytes
Dev. Growth Diff., 31 (1989), pp. 447-451
- 6 E.C. Coucouvanis, S.W. Sherwood, C. Carswell-Crumpton, E.G. Spack, P.P. Jones
Evidence that the mechanism of prenatal germ cell death in the mouse is apoptosis
Exp. Cell Res., 209 (1993), pp. 238-247
[Article](#)  [PDF \(803KB\)](#)
- 7 A. De Pol, L. Marzona, F. Vaccina, R. Negro, P. Sena, A. Forabosco
Apoptosis in different stages of human oogenesis
Anticancer Res., 18 (1998), pp. 3457-3461
- 8 U. Eichenlaub-Ritter, A.C. Chandley, R.G. Gosden
Alterations to the microtubular cytoskeleton and increased disorder of chromosome alignment in spontaneously ovulated mouse oocytes aged in vivo: An immunofluorescence study
Chromosoma, 94 (1986), pp. 337-345
- 9 E. Evans, S. Kombluth
Regulation of apoptosis in *Xenopus* egg extracts
Adv. Enzyme Regul., 38 (1998), pp. 265-280
[Article](#)  [PDF \(249KB\)](#)
- 10 D. Fisher, A. Abrieu, M.N. Simon, S. Keyse, V. Verge, M. Doree, A. Picard
MAP kinase inactivation is required only for G2-M phase transition in early embryogenesis cell cycles of the starfishes *Marthasterias glacialis* and *Astropecten aranciacus*
Dev. Biol., 202 (1998), pp. 1-13
[Article](#)  [PDF \(1MB\)](#)
- 11 J.H. Ford, H.Z. Wilkin, P. Thomas, C. McCarthy
A 13-year cytogenetic study of spontaneous abortion: Clinical applications of testing
Aust. N. Z. J. Obstet. Gynecol., 36 (1996), pp. 314-318
- 12 T. Fujimori, S. Hairai
Differences in starfish oocyte susceptibility to polyspermy during the course of maturation
Biol. Bull., 157 (1979), pp. 249-257
- 13 Y. Fujino, K. Ozaki, S. Yamamasu, F. Ito, I. Matsuoka, E. Hayashi, H. Nakamura, S. Ogita, E. Sato, M. Inoue
DNA fragmentation of oocytes in aged mice
Hum. Reprod., 11 (1996), pp. 1480-1483
- 14 T.L. Gumienny, E. Lambie, E. Hartweg, H.R. Horvitz, M.O. Hengartner
Genetic control of programmed cell death in the *Caenorhabditis elegans* hermaphrodite germline
Development, 126 (1999), pp. 1011-1022
- 15 C. Hensey, J. Gautier
A developmental timer that regulates apoptosis at the onset of gastrulation
Mech. Dev., 69 (1997), pp. 183-195
[Article](#)  [PDF \(1MB\)](#)
- 16 M.S. Houk
Respiration of starfish oocytes during meiosis, fertilization, and artificial activation
Exp. Cell Res., 83 (1974), pp. 200-206
[Article](#)  [PDF \(520KB\)](#)
- 17 L.A. Jaffe, A.F. Giusti, D.J. Carroll, K.R. Foltz



Ca²⁺ signaling during fertilization of echinoderm eggs

Semin. Cell Dev. Biol., 12 (2001), pp. 45-51

[Article](#)  [PDF \(180KB\)](#)

- 18 J.F. Kerr, A.H. Wyllie, A.R. Currie
Apoptosis: a basic biological phenomenon with wide-ranging implications in tissue kinetics
Br. J. Cancer, 26 (1972), pp. 239-257
- 19 R. Kluck, E. Bossy-Wetzel, D. Green, D. Newmeyer
The release of cytochrome c from mitochondria: a primary site for Bcl-2 regulation of apoptosis
Science, 275 (1997), pp. 1132-1136
- 20 R. Kluck, S. Martin, B. Hoffman, J. Zhou, D. Green, D. Newmeyer
Cytochrome c activation of CPP32-like proteolysis plays a critical role in a Xenopus cell-free apoptosis system
EMBO J., 16 (1997), pp. 4639-4649
- 21 S. Kornbluth
Apoptosis in Xenopus egg extracts
Methods Enzymol., 283 (1997), pp. 600-614
[Article](#)  [PDF \(2MB\)](#)
- 22 D. Kulms, T. Schwarz
Molecular mechanisms of UV-induced apoptosis
Photodermatol. Photoimmunol. Photomed., 16 (2000), pp. 195-201
- 23 J.B. Mailhes, D. Young, S.N. London
Postovulatory ageing of mouse oocytes in vivo and premature centromere separation and aneuploidy
Biol. Reprod, 58 (1998), pp. 1206-1210
- 24 N. Matova, L. Cooley
Comparative aspects of animal oogenesis
Dev. Biol., 231 (2001), pp. 291-320
[Article](#)  [PDF \(1MB\)](#)
- 25 P. Meier, A. Finch, G. Evan
Apoptosis in development
Nature, 407 (2000), pp. 796-801
- 26 L. Meijer, P. Guerrier
Maturation and fertilization in starfish oocytes
Int. Rev. Cytol., 86 (1984), pp. 129-195
- 27 Y. Morita, G.I. Perez, D.V. Maravei, K.I. Tilly, J.L. Tilly
Targeted expression of Bcl-2 in mouse oocytes inhibits ovarian follicle atresia and prevents spontaneous and chemotherapy-induced oocyte apoptosis in vitro
Mol. Endocrinol., 13 (1999), pp. 841-850
- 28 Y. Morita, G.I. Perez, F. Paris, S.R. Miranda, D. Ehleiter, A. Haimovitz-Friedman, Z. Fuks, Z. Xie, J.C. Reed, E.H. Schuchman, R.N. Kolesnick, J.L. Tilly
Oocyte apoptosis is suppressed by disruption of the acid sphingomyelinase gene or by sphingosine-1-phosphate therapy
Nat. Med., 6 (2000), pp. 1109-1114
- 29 Y. Morita, J.L. Tilly
Oocyte apoptosis: Like sand through an hourglass
Dev. Biol., 213 (1999), pp. 1-17
[Article](#)  [PDF \(514KB\)](#)
- 30 D.D. Newmeyer, D.M. Farschon, J.C. Reed
Cell-free apoptosis in Xenopus egg extracts: Inhibition by Bcl-2 and requirement for an organelle fraction enriched in mitochondria
Cell, 79 (1994), pp. 353-364
[Article](#)  [PDF \(4MB\)](#)
- 31 C.T. O'Neill, M.H. Kaufman

- 31 G. I. O'Neill, M. H. Kaufman
Influence of postovulatory aging on chromosome segregation during the second meiotic division in mouse oocytes: A parthenogenetic analysis
J. Exp. Zool., 248 (1988), pp. 125-131
- 32 G.I. Perez, R. Robles, C.M. Knudson, J.A. Flaws, S.J. Korsmeyer, J.L. Tilly
Prolongation of ovarian lifespan into advanced chronological age by Bax-deficiency
Nat. Genet., 21 (1999), pp. 200-203
- 33 G.I. Perez, X.J. Tao, J.L. Tilly
Fragmentation and death (a.k.a. apoptosis) of ovulated oocytes
Mol. Hum. Reprod., 5 (1999), pp. 414-420
- 34 G.I. Perez, J.L. Tilly
Cumulus cells are required for the increased apoptotic potential in oocytes of aged mice
Hum. Reprod., 12 (1997), pp. 2781-2783
- 35 G.I. Perez, A.M. Trobovich, R.G. Gosden, J.L. Tilly
Mitochondria and the death of oocytes
Nature, 403 (2000), pp. 500-501
- 36 A. Picard, M. Doree
Hormone induced parthenogenic activation of mature starfish oocytes
Exp. Cell Res., 145 (1983), pp. 315-323
[Article](#)  [PDF \(2MB\)](#)
- 37 A. Picard, S. Galas, G. Peaucellier, M. Doree
Newly assembled cyclin B-cdc2 kinase is required to suppress DNA replication between meiosis I and meiosis II in starfish oocytes
EMBO J., 15 (1996), pp. 3590-3598
- 38 V.S. Ratts, J.A. Flaws, R. Kolp, C.M. Sorenson, J.L. Tilly
Ablation of bcl-2 gene expression decreases the numbers of oocytes and primordial follicles established in the post-natal female mouse gonad
Endocrinology, 136 (1995), pp. 3665-3668
- 39 J.D. Robertson, S. Orrenius, B. Zhivotovsky
Review: Nuclear events in apoptosis
J. Struct. Biol., 129 (2000), pp. 346-358
[Article](#)  [PDF \(96KB\)](#)
- 40 K.C. Sadler, J.V. Ruderman
Components of the signaling pathway linking the 1-methyladenine receptor to MPF activation and maturation in starfish oocytes
Dev. Biol., 197 (1998), pp. 25-38
[Article](#)  [PDF \(1MB\)](#)
- 41 J. Simpson
Genetic consequences of aging sperm or aging ova: animal studies and relevance to humans
J. Sciarra, G. Zatuchni, J. Speidel (Eds.), Risks, Benefits, and Controversies in Fertility Control, Harper & Row, Hagerstown (1978), pp. 506-519
- 42 J.J. Smith, E.K. Evans, M. Murakami, M.B. Moyer, M.A. Moseley, G.V. Woude, S. Kombluth
Wee1-regulated apoptosis mediated by the Crk adaptor protein in Xenopus egg extracts
J. Cell Biol., 151 (2000), pp. 1391-1400
- 43 S. Sperandio, I. de Belle, D.E. Bredesen
An alternative, nonapoptotic form of programmed cell death
Proc. Natl. Acad. Sci. USA, 97 (2000), pp. 14376-14381
- 44 J.H. Stack, J.W. Newport
Developmentally regulated activation of apoptosis early in Xenopus gastrulation results in cyclin A degradation during interphase of the cell cycle
Development, 124 (1997), pp. 3185-3195

- 45 S.A. Stricker
Comparative biology of calcium signaling during fertilization and egg activation in animals
Dev. Biol., 211 (1999), pp. 157-176
[Article](#)  [PDF \(427KB\)](#)
- 46 K. Tachibana, M. Takumitsu, Y. Nomura, T. Kishimoto
MAP kinase links the fertilization signal transduction pathway to the G₁/S-phase transition in starfish eggs
EMBO J., 16 (1997), pp. 4333-4339
- 47 T. Takahashi, H. Saito, M. Hiroi, K. Doi, E. Takahashi
Effects of aging on inositol 1,4,5-triphosphate-induced Ca²⁺ release in unfertilized mouse oocytes
Mol. Reprod. Dev., 55 (2000), pp. 299-306
- 48 J.J. Tarin, S. Perez-Albala, A. Aguilar, J. Minarro, C. Hermenegildo, A. Cano
Long-term effects of postovulatory aging of mouse oocytes on offspring: A two-generational study
Biol. Reprod., 61 (1999), pp. 1347-1355
- 49 J.J. Tarin, S. Perez-Albala, A. Cano
Consequences on offspring of abnormal function in ageing gametes
Hum. Reprod. Update, 6 (2000), pp. 532-549
- 50 J.J. Tarin, J. Ten, F.J. Vendrell, A. Cano
Dithiothreitol prevents age-associated decrease in oocyte/conceptus viability in vitro
Hum. Reprod., 13 (1998), pp. 381-386
- 51 K. Thress, E.K. Evans, S. Kombluth
Reaper-induced dissociation of a Scythe-sequestered cytochrome c-releasing activity
EMBO J., 18 (1999), pp. 5486-5493
- 52 K. Thress, W. Henzel, W. Shillinglaw, S. Kombluth
Scythe: A novel reaper-binding apoptotic regulator
EMBO J., 17 (1998), pp. 6135-6143
- 53 J.L. Tilly
Apoptosis and ovarian function
Rev. Reprod., 1 (1996), pp. 162-172
- 54 J.L. Tilly, K.I. Kowalski, A.L. Johnson, A.J. Hsueh
Involvement of apoptosis in ovarian follicular atresia and postovulatory regression
Endocrinology, 129 (1991), pp. 2799-2801
- 55 J. Van Blerkom, P.W. Davis
DNA strand breaks and phosphatidylserine redistribution in newly ovulated and cultured mouse and human oocytes: Occurrence and relationship to apoptosis
Hum. Reprod., 13 (1998), pp. 1317-1324
- 56 O. von Ahsen, D.D. Newmeyer
Cell-free apoptosis in *Xenopus laevis* egg extracts
Methods Enzymol., 322 (2000), pp. 183-198
[Article](#)  [PDF \(1MB\)](#)
- 57 A. Wilcox, C. Weinberg, D. Baird
Timing of sexual intercourse in relation to ovulation—effects on the probability of conception, survival of the pregnancy, and sex of the baby
N. Engl. J. Med., 333 (1995), pp. 1517-1521
- 58 Fertil. Steril., 40 (1983), pp. 773-778

1 To whom correspondence should be addressed. Fax: 9-0212-265-9778. E-mail: kirsten_sadler_phd98@post.harvard.edu.

