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Microtubule Patterning during Meiotic Maturation in Mouse Oocytes Is Determined by Cell Cycle-Specific Sorting and Redistribution of γ -TubulinCatherine M.H. Combelles ... David F. Albertini ¹

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Abstract

The topography of microtubule assembly events during meiotic maturation of animal oocytes demands tight spatial control and temporal precision. To better understand what regulates the timing and location of microtubule assembly, synchronously maturing mouse oocytes were evaluated with respect to γ -tubulin, pericentrin, and total tubulin polymer fractions at specific stages of meiotic progression. γ -Tubulin remained associated with cytoplasmic centrosomes through diakinesis of meiosis-1. Following chromatin condensation and perinuclear centrosome aggregation, γ -tubulin relocated to a nuclear lamina-bounded compartment in which meiosis-1 spindle assembly occurred. γ -Tubulin was stably associated with the meiotic spindle from prometaphase-1 through to anaphase-2, but also exhibited cell cycle-specific relocalization to cytoplasmic centrosomes. Specifically, anaphase onset of both meiosis-1 and -2 was characterized by the concomitant appearance of γ -tubulin and microtubule nucleation in subcortical centrosomes. Brief pulses of taxol applied at specific cell cycle stages enhanced detection of γ -tubulin compartmentalization, consistent with a γ -tubulin localization-dependent spatial restriction of microtubule assembly during meiotic progression. In addition, a taxol pulse during meiotic resumption impaired subsequent γ -tubulin sorting, resulting in monopolar spindle formation and cell cycle arrest in meiosis-1; despite cell cycle arrest, polar body extrusion occurred roughly on schedule. Therefore, sorting of γ -tubulin is involved in both the timing of location of meiotic spindle assembly as well as the coordination of karyokinesis and cytokinesis in mouse oocytes.





Keywords

 γ -tubulin; centrosome; spindle; nuclear lamina; oocyte; meiosis; nuclear; cytoplasmic maturation[Recommended articles](#) [Citing articles \(70\)](#)

References






REFERENCES



- 1 D.F. Albertini
Cytoplasmic reorganization during the resumption of meiosis in cultured preovulatory rat oocytes
Dev. Biol., 120 (1987), pp. 121-131
[Article](#) [PDF \(14MB\)](#)






- 2 D.F. Albertini
Cytoplasmic microtubular dynamics and chromatin organization during mammalian oogenesis and oocyte maturation
Mutat. Res., 296 (1992), pp. 57-68
[Article](#)  [PDF \(1017KB\)](#)
- 3 D.F. Albertini
Regulation of meiotic maturation in the mammalian oocyte: Interplay between exogenous cues and the microtubule cytoskeleton
BioEssays, 14 (1992), pp. 97-103
- 4 Albertini, D. F., Wickramasinghe, D., Messinger, S., Mattson, B. A., and Plancha, C. E. 1993. Nuclear and cytoplasmic changes during oocyte maturation. In "Preimplantation Embryo Development" B. D. Bavister, Ed.), pp. 3-21. Springer-Verlag, New York.
- 5 D.F. Albertini, M.J. Carabatsos
Comparative aspects of meiotic cell cycle control in mammals
J. Mol. Med., 76 (1998), pp. 795-799
- 6 M. Antczak, J. Van Blerkom
Oocyte influences on early development: The regulatory proteins leptin and STAT3 are polarized in mouse and human oocytes and differentially distributed within the cells of the preimplantation stage embryo
Mol. Hum. Reprod., 3 (1997), pp. 1067-1086
- 7 N. Avazeri, A.M. Courtot, A. Pesty, C. Duquenne, B. Lefevre
Cytoplasmic and nuclear phospholipase C- β 1 relocation: Role in resumption of meiosis in the mouse oocyte
Mol. Biol. Cell, 11 (2000), pp. 4369-4380
- 8 P. Binarova, V. Cenklova, B. Hause, E. Kubatova, M. Lysak, J. Dolezel, L. Bogre, P. Draber
Nuclear gamma-tubulin during acentriolar plant mitosis
Plant Cell, 12 (2000), pp. 433-442
- 9 B. Bowerman, C.A. Shelton
Cell polarity in the early *Caenorhabditis elegans* embryo
Curr. Opin. Genet. Dev., 9 (1999), pp. 390-395
[Article](#)  [PDF \(893KB\)](#)
- 10 P.G. Calarco, R.P. Donahue, D. Szöllösi
Germinal vesicle breakdown in the mouse oocyte
J. Cell Sci., 10 (1972), pp. 369-385
- 11 M.J. Carabatsos, C.M. Combelles, S.M. Messinger, D.F. Albertini
Sorting and reorganization of centrosomes during oocyte maturation in the mouse
Microsc. Res. Tech., 49 (2000), pp. 435-444
- 12 A. Cheung, K. Swann, J. Carroll
The ability to generate normal Ca(2+) transients in response to spermatozoa develops during the final stages of oocyte growth and maturation
Hum. Reprod., 15 (2000), pp. 1389-1395
- 13 C.M. Combelles, M.J. Carabatsos, S.N. London, J.B. Mailhes, D.F. Albertini
Centrosome-specific perturbations during in vitro maturation of mouse oocytes exposed to cocaine
Exp. Cell Res., 260 (2000), pp. 116-126
[Article](#)  [PDF \(217KB\)](#)
- 14 S.M. Downs, S.A. Daniel, E.A. Bornslaeger, P.C. Hoppe, J.J. Eppig
Maintenance of meiotic arrest in mouse oocytes by purines: Modulation of cAMP levels and cAMP phosphodiesterase activity
Gamete Res., 23 (1989), pp. 323-334
- 15 S.J. Doxsey, P. Stein, L. Evans, P.D. Calarco, M. Kirschner
Pericentrin, a highly conserved centrosome protein involved in microtubule organization
Cell, 76 (1994), pp. 639-650
[Article](#)  [PDF \(7MB\)](#)
- 16 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

- 17 J.J. Eppig, R.M. Schultz, M. O'Brien, F. Chesnel
Relationship between the developmental programs controlling nuclear and cytoplasmic maturation of mouse oocytes
Dev. Biol., 164 (1994), pp. 1-9
[Article](#)  [PDF \(781KB\)](#)
- 18 D.L. Gard
Gamma-tubulin is asymmetrically distributed in the cortex of Xenopus oocytes
Dev. Biol., 161 (1994), pp. 131-140
[Article](#)  [PDF \(2MB\)](#)
- 19 D.L. Gard, B.J. Cha, E. King
The organization and animal-vegetal asymmetry of cytokeratin filaments in stage VI Xenopus oocytes is dependent upon F-actin and microtubules
Dev. Biol., 184 (1997), pp. 95-114
[Article](#)  [PDF \(6MB\)](#)
- 20 R.L. Gardner
Scrambled or bisected mouse eggs and the basis of patterning in mammals
BioEssays, 21 (1999), pp. 271-274
- 21 S.D. Georgatos, A. Pyrpasopoulou, P.A. Theodoropoulos
Nuclear envelope breakdown in mammalian cells involves stepwise lamina disassembly and microtubule-drive deformation of the nuclear membrane
J. Cell Sci., 110 (1997), pp. 2129-2140
- 22 L. Gerace, A. Blum, G. Blobel
Immunocytochemical localization of the major polypeptides of the nuclear pore complex-lamina fraction. Interphase and mitotic distribution
J. Cell Biol., 79 (1978), pp. 546-566
- 23 C. Gueth-Hallonet, C. Antony, J. Aghion, A. Santa-Maria, I. Lajoie-Mazenc, M. Wright, B. Maro
γ-Tubulin is present in acenriolar MTOCs during early mouse development
J. Cell Sci., 105 (1993), pp. 157-166
- 24 R. Heald, R. Tournebize, T. Blank, R. Sandaltzopoulos, P. Becker, A. Hyman, E. Karsenti
Self-organization of microtubules into bipolar spindles around artificial chromosomes in Xenopus egg extracts
Nature, 382 (1996), pp. 420-425
- 25 B. Hogan, F. Costantini, E. Lacy
"Manipulating the Mouse Embryo: A Laboratory Manual," Cold Spring Harbor Laboratory Press, Cold Spring Harbor (1986)
p. 332
- 26 C.Y. Howell, T.H. Bestor, F. Ding, K.E. Latham, C. Mertineit, J.M. Trasler, J.R. Chaillet
Genomic imprinting disrupted by a maternal effect mutation in the Dnmt1 gene
Cell, 104 (2001), pp. 829-838
[Article](#)  [PDF \(757KB\)](#)
- 27 H.C. Joshi, M.J. Palacios, L. McNamara, D.W. Cleveland
Gamma-tubulin is a centrosomal protein required for cell cycle-dependent microtubule nucleation
Nature, 356 (1992), pp. 80-83
- 28 Karpen, G. H., and Endow, S. A. 1998. Meiosis: Chromosome behavior and spindle dynamics. In "Dynamics of Cell Division" S. A. Endow and D. M. Glover, Eds.), pp. 203-236. Oxford Univ. Press, Oxford, U.K..
- 29 K. Kemphues
PARsing embryonic polarity
Cell, 101 (2000), pp. 345-348
[Article](#)  [PDF \(117KB\)](#)
- 30 J.V. Kilmartin, B. Wright, C. Mistein

- 30 J. V. Nathaniel, B. Wright, C. Milstein
Rat monoclonal antitubulin antibodies derived by using a new nonsecreting rat cell line
J. Cell Biol., 93 (1982), pp. 576-582
- 31 I. Lajoie-Mazenc, Y. Tollen, C. Detraves, M. Julian, A. Moisand, C. Gueth-Hallonet, A. Debec, I. Salles-Passador, A. Puget, H. Mazarguil
Recruitment of antigenic gamma-tubulin during mitosis in animal cells: Presence of gamma-tubulin in the mitotic spindle
J. Cell Sci., 107 (1994), pp. 2825-2837
- 32 J. Lee, T. Miyano, R.M. Moor
Spindle formation and dynamics of gamma-tubulin and nuclear mitotic apparatus protein distribution during meiosis in pig and mouse oocytes
Biol. Reprod., 62 (2000), pp. 1184-1192
- 33 F.J. Longo, D.Y. Chen
Development of cortical polarity in mouse eggs: Involvement of the meiotic apparatus
Dev. Biol., 107 (1985), pp. 382-394
[Article](#)  [PDF \(13MB\)](#)
- 34 B. Maro, S.K. Howlett, M. Webb
Non-spindle microtubule organizing centers in metaphase II-arrested mouse oocytes
J. Cell Biol., 101 (1985), pp. 1665-1672
- 35 B. Maro, M.H. Johnson, M. Webb, G. Flach
Mechanism of polar body formation in the mouse oocyte: An interaction between the chromosomes, the cytoskeleton and the plasma membrane
J. Embryol. Exp. Morphol., 92 (1986), pp. 11-32
- 36 S.M. Messinger, D.F. Albertini
Centrosome and microtubule dynamics during meiotic progression in the mouse oocyte
J. Cell Sci., 100 (1991), pp. 289-298
- 37 J. Mitra, R.M. Schultz
Regulation of the acquisition of meiotic competence in the mouse: Changes in the subcellular localization of cdc2, cyclin B1, cdc25C and wee1, and in the concentration of these proteins and their transcripts
J. Cell Sci., 109 (1996), pp. 2407-2415
- 38 S.M. Murphy, T. Stearns
Cytoskeleton: Microtubule nucleation takes shape
Curr. Biol., 6 (1996), pp. 642-644
[Article](#)  [PDF \(188KB\)](#)
- 39 M. Nakaya, A. Fukui, Y. Izumi, K. Akimoto, M. Asashima, S. Ohno
Meiotic maturation induces animal-vegetal asymmetric distribution of aPKC and ASIP/PAR-3 in Xenopus oocytes
Development, 127 (2000), pp. 5021-5031
- 40 M.R. Paddy, H. Saumweber, D.A. Agard, J.W. Sedat
Time-resolved, in vivo studies of mitotic spindle formation and nuclear lamina breakdown in Drosophila early embryos
J. Cell Sci., 109 (1996), pp. 591-607
- 41 M.J. Palacios, H.C. Joshi, C. Simerly, G. Schatten
Gamma-tubulin reorganization during mouse fertilization and early development
J. Cell Sci., 104 (1993), pp. 383-389
- 42 G. Pereira, E. Schiebel
Centrosome-microtubule nucleation
J. Cell Sci., 110 (1997), pp. 295-300
- 43 J. Pines
Four-dimensional control of the cell cycle
Nat. Cell Biol., 1 (1999), pp. E73-E79
- 44 C.L. Rieder, J.G. Ault, U. Eichenlaub-Ritter, G. Sluder
Morphogenesis of the mitotic and meiotic spindle: Conclusions obtained from one system are not necessarily applicable to the other

- 45 H. Rime, C. Jessus, R. Ozon
Distribution of microtubules during the first meiotic cell division in the mouse oocyte: Effect of taxol
Gamete Res., 17 (1987), pp. 1-13
- 46 V. Rotaru, I. Lajoie-Mazenc, Y. Tollon, B. Raynaud-Messina, C. Jean, C. Detraves, M. Julian, A. Moisand, M. Wright
Condensation-decondensation of the gamma-tubulin containing material in the absence of a structurally visible organelle during the cell cycle of Physarum plasmodia
Biol. Cell, 91 (1999), pp. 393-406
[Article](#)  [PDF \(12MB\)](#)
- 47 G. Schatten
The centrosome and its mode of inheritance: The reduction of the centrosome during gametogenesis and its restoration during fertilization
Dev. Biol., 165 (1994), pp. 299-335
[Article](#)  [PDF \(4MB\)](#)
- 48 H. Schatten, G. Schatten
Centrosomes and microtubule organization during mouse and sea urchin fertilization
Prog. Clin. Biol. Res., 217B (1986), pp. 91-94
- 49 H. Schatten, G. Schatten, D. Mazia, R. Balczon, C. Simerly
Behavior of centrosomes during fertilization and cell division in mouse oocytes and in sea urchin eggs
Proc. Natl. Acad. Sci. USA, 83 (1986), pp. 105-109
- 50 A.C. Schroeder, J.J. Eppig
The developmental capacity of mouse oocytes that matured spontaneously in vitro is normal
Dev. Biol., 102 (1984), pp. 493-497
[Article](#)  [PDF \(1MB\)](#)
- 51 C. Simerly, S.S. Zoran, C. Payne, T. Dominko, P. Sutovsky, C.S. Navara, J.L. Salisbury, G. Schatten
Biparental inheritance of gamma-tubulin during human fertilization: Molecular reconstitution of functional zygotic centrosomes in inseminated human oocytes and in cell-free extracts nucleated by human sperm
Mol. Biol. Cell, 10 (1999), pp. 2955-2969
- 52 D. Szöllösi, P. Calarco, R.P. Donahue
Absence of centrioles in the first and second meiotic spindles of mouse oocytes
J. Cell Sci., 11 (1972), pp. 521-541
- 53 R. Tournebise, R. Heald, A. Hyman
Role of chromosomes in assembly of meiotic and mitotic spindles
Prog. Cell Cycle Res., 3 (1997), pp. 271-284
- 54 J. Van Blerkom, H. Bell
Regulation of development in the fully grown mouse oocyte: Chromosome-mediated temporal and spatial differentiation of the cytoplasm and plasma membrane
J. Embryol. Exp. Morphol., 93 (1986), pp. 213-238
- 55 J. Van Blerkom
Microtubule mediation of cytoplasmic and nuclear maturation during the early stages of resumed meiosis in cultured mouse oocytes
Proc. Natl. Acad. Sci. USA, 88 (1991), pp. 5031-5035
- 56 Y. Wei, L. Yu, J. Bowen, M.A. Gorovsky, C.D. Allis
Phosphorylation of histone H3 is required for proper chromosome condensation and segregation
Cell, 97 (1999), pp. 99-109
[Article](#)  [PDF \(226KB\)](#)
- 57 C. Wiese, Y. Zheng
Gamma-tubulin complexes and their interaction with microtubule-organizing centers
Curr. Opin. Struct. Biol., 9 (1999), pp. 250-259
[Article](#)  [PDF \(1MB\)](#)

- 58 J. Zhang, D.W. Houston, M.L. King, C. Payne, C. Wylie, J. Heasman
The role of maternal VegT in establishing the primary germ layers in *Xenopus* embryos
Cell, 94 (1998), pp. 515-524
[Article](#)  [PDF \(2MB\)](#)
- 59 Y. Zheng, M.L. Wong, B. Alberts, T. Mitchison
Nucleation of microtubule assembly by a gamma-tubulin-containing ring complex
Nature, 378 (1995), pp. 578-583

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