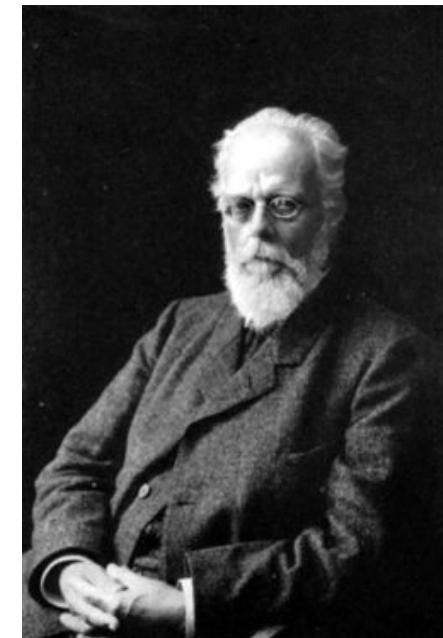
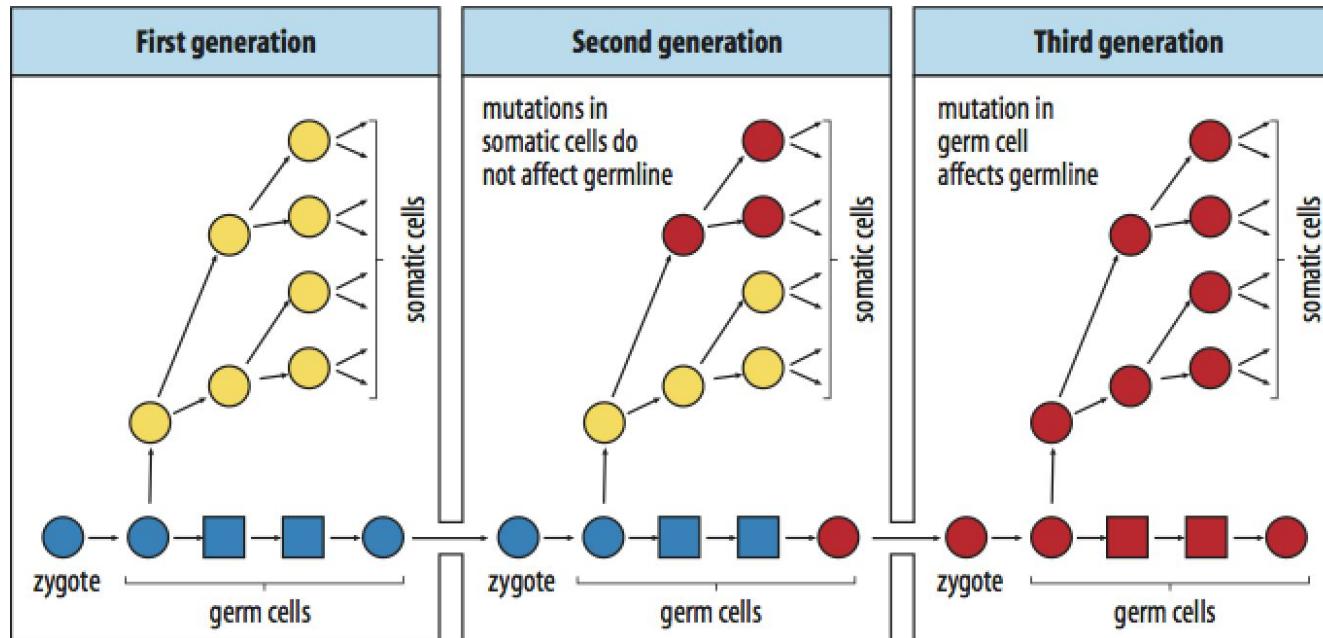


Model organisms and developmental biology

仲寒冰

zhong.hb@sustc.edu.cn

The Germ Plasm Theory (1893)



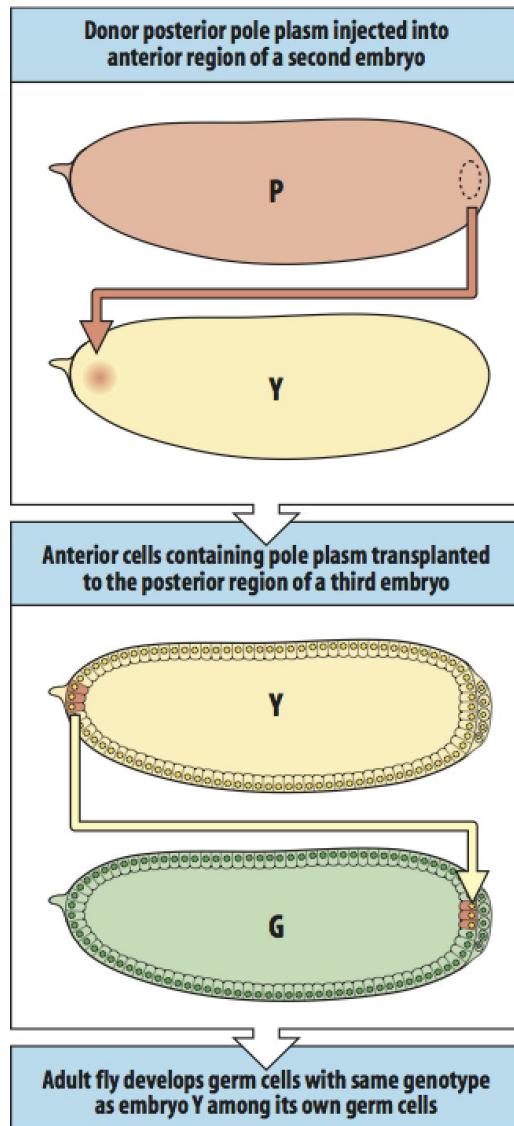
August Weismann

“A hen is only an egg's way of making another egg.”
— Samuel Butler, *Life and Habit*

Germ cells (Germline cells)

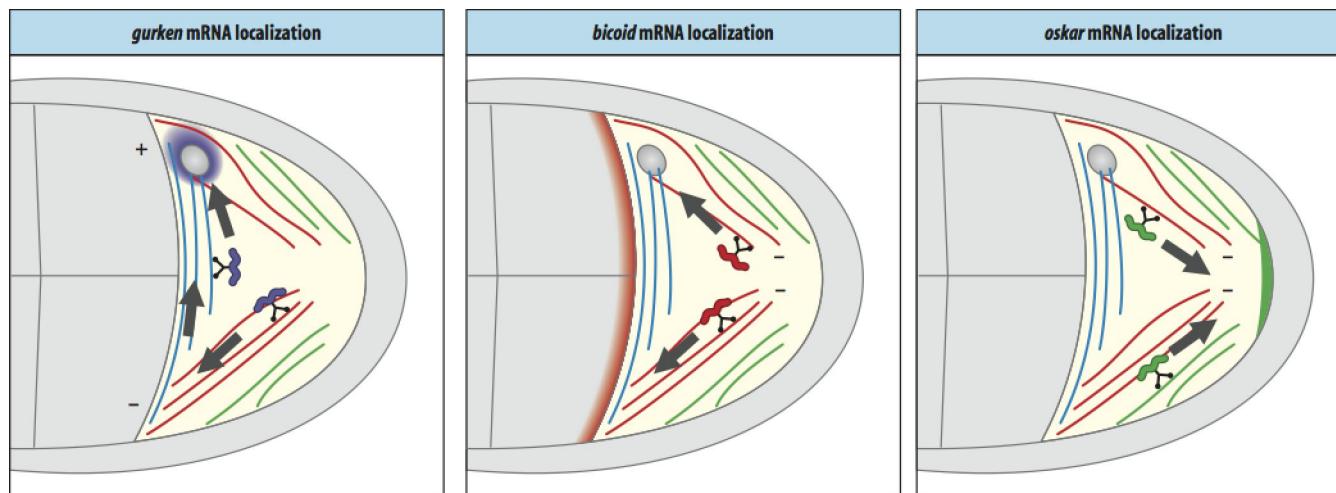
- Give rise to the gametes.
- Transmission of genetic information to next generation.
- Preservation of the genetic integrity of the germline.
- Generally, somatic cells make no genetic contribution to the next generation.

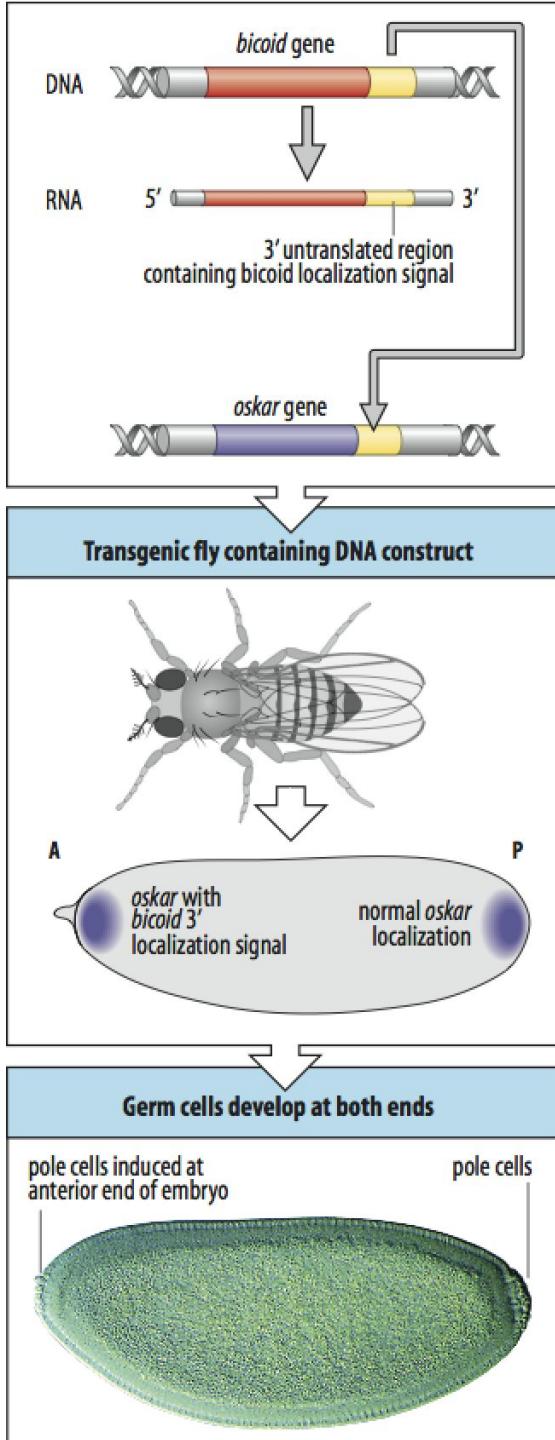
Germ cell fate is specified in *Drosophila* by a distinct germ plasm in the egg



- Pole cells are primordial germ cells.
- The cytoplasm at the posterior pole is called the pole plasm, containing the polar granules.
- Two key experiments. UV and transplantation.

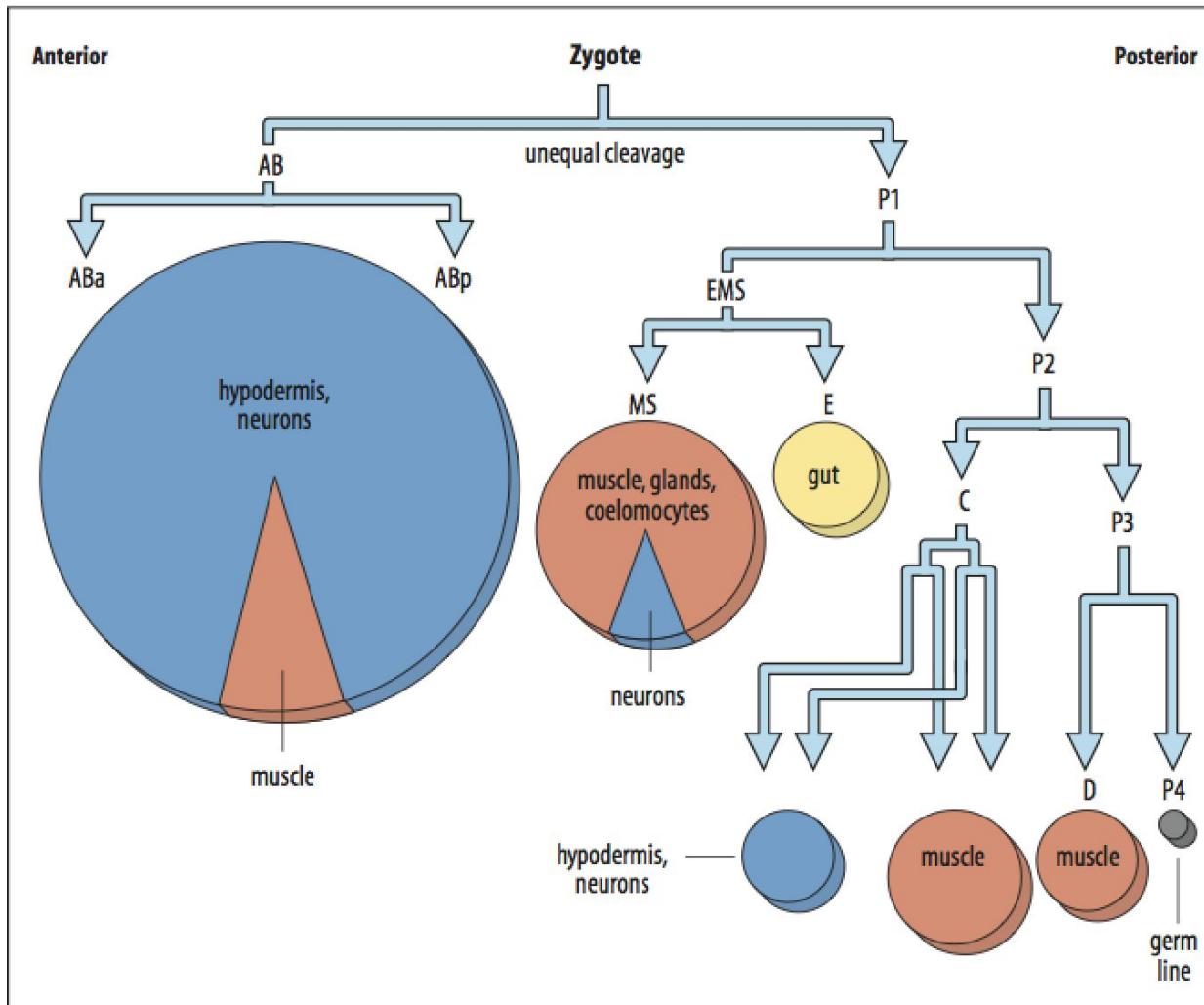
bicoid, *oskar* and *gurken* mRNAs are localized by transportation along microtubules





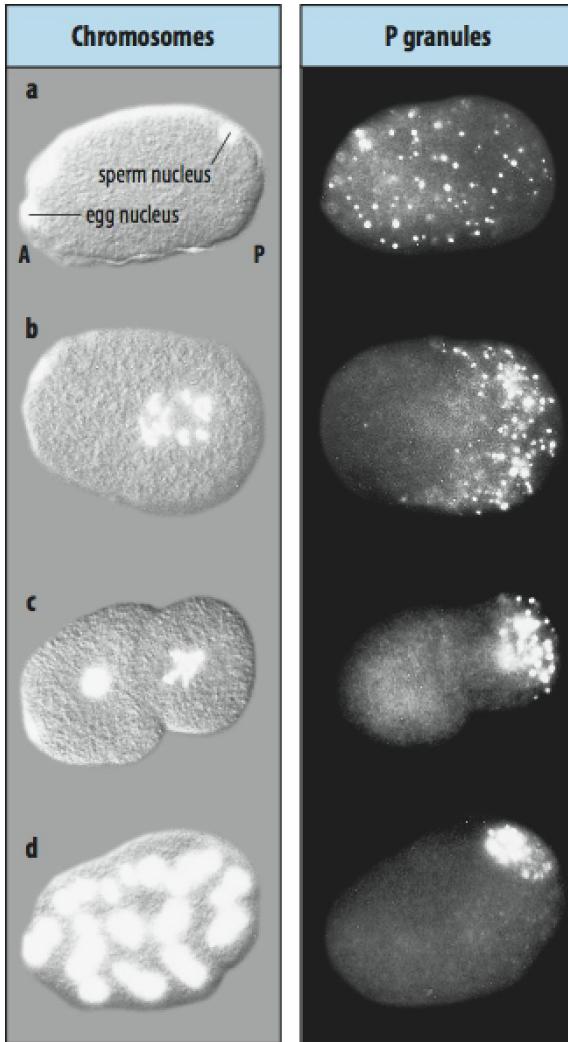
Oskar alone is sufficient to initiate the specification of germ cells in *Drosophila*

Cell lineage and cell fate in the early *C. elegans* embryo



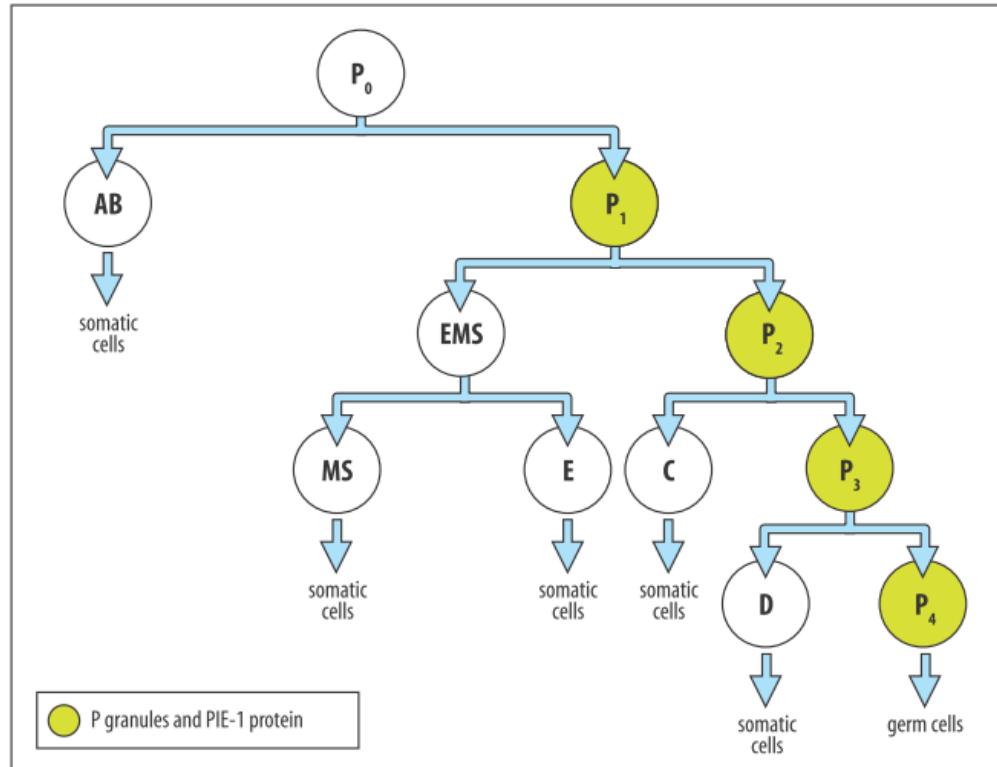
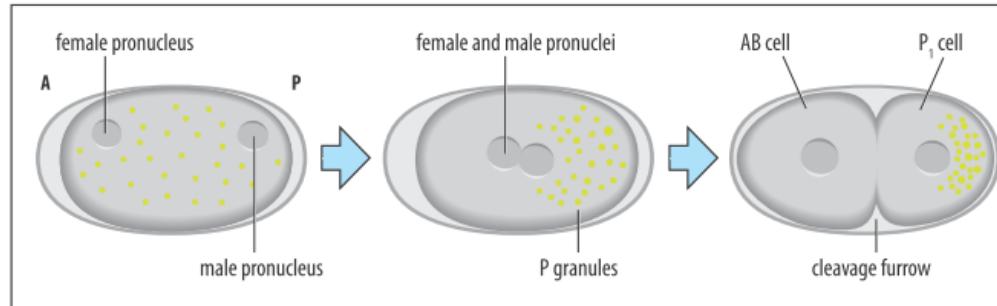
Localization of P granules

颗粒



- Before fertilization, there is no evidence of any asymmetry.
- P granules, which contain maternal mRNAs and proteins, move to posterior end after fertilization.

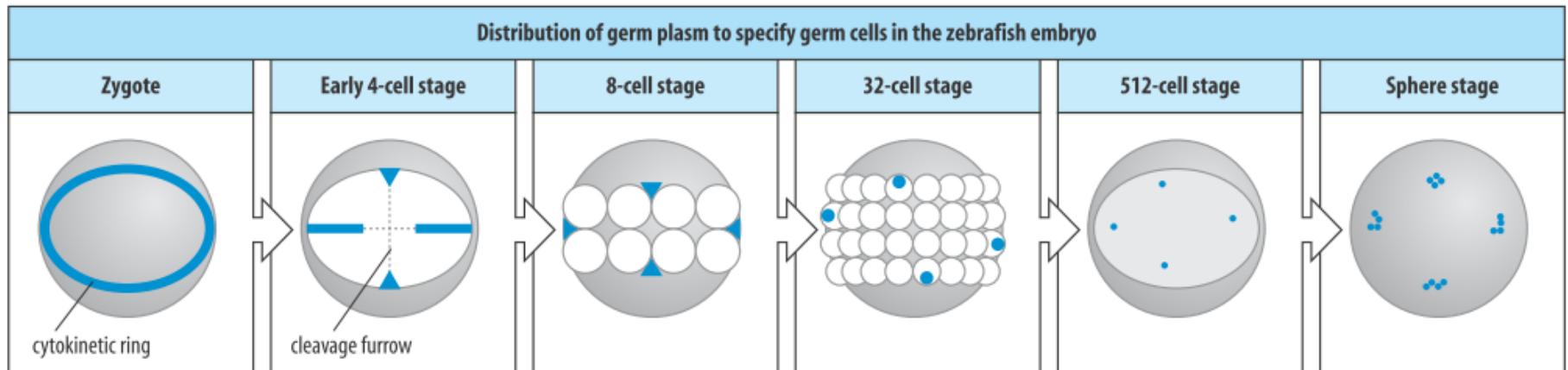
P granules and PIE-1 protein become symmetrically distributed to germline cells during cleavage of the nematode egg



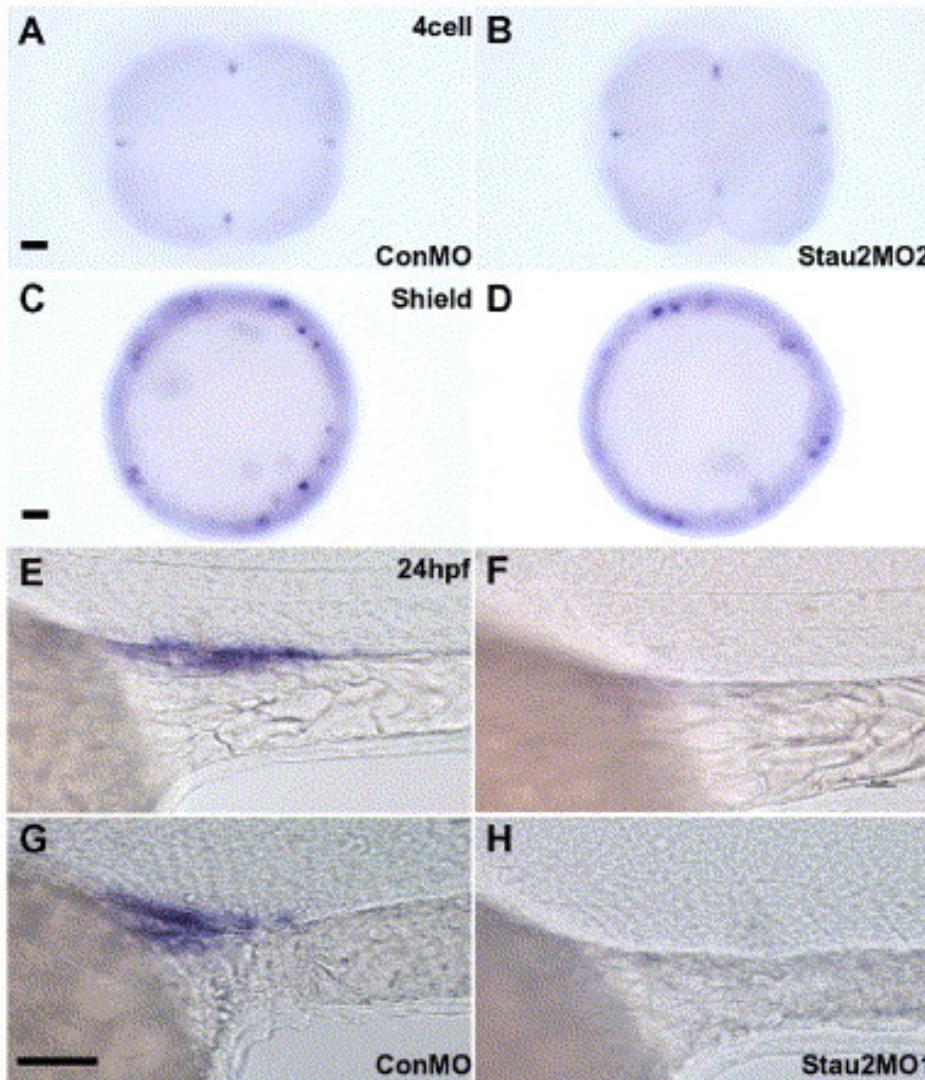
Xenopus

- Distinct yolk-free patches of cytoplasm aggregate at the yolk vegetal pole after fertilization.
- This cytoplasm is retained only in the most vegetal daughter cells. After gastrulation, the germ plasm is located in cells of the floor of the blastocoel cavity. Then migrate to genital ridge.
- UV assay.
- In the Urodeles - the tailed amphibians, there is no evidence for this kind of cytoplasm and the germ cells arise from lateral plate mesoderm.

Distribution of germ plasm in zebrafish embryo during cleavage



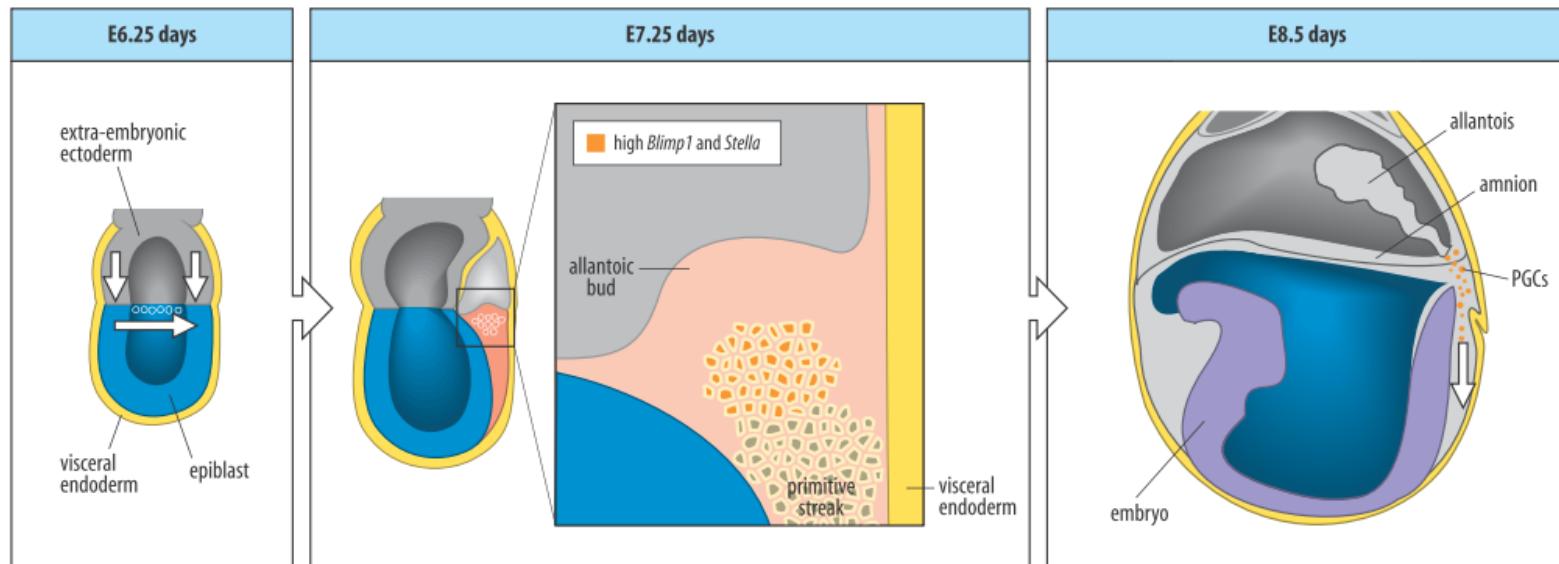
Zebrafish germ plasm contains a number of maternal mRNAs



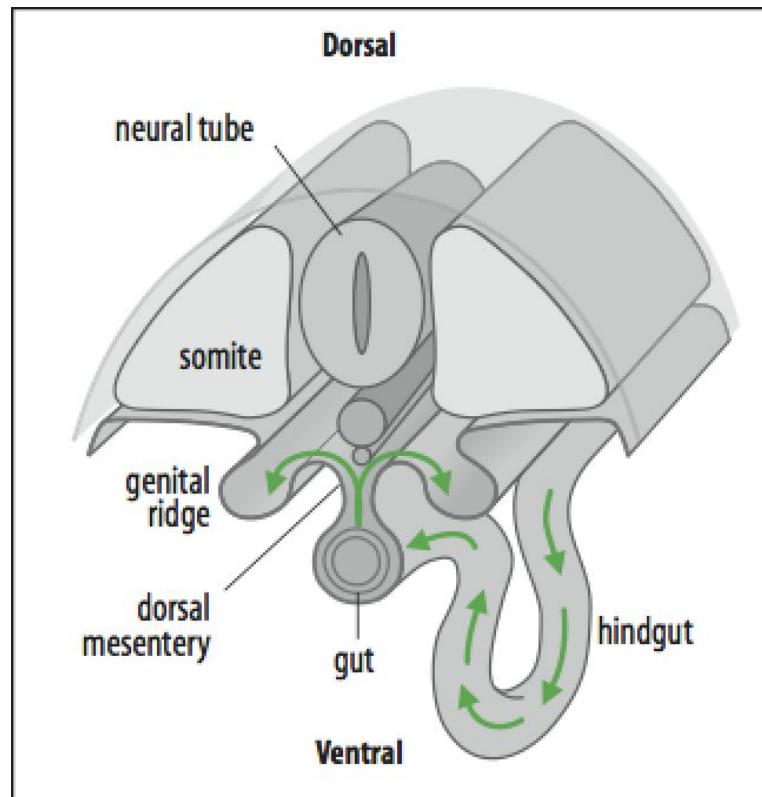
In mammals germ cells are induced by cell-cell interactions

- There is no evidence for germ plasm in the mouse or other mammals or in the chick.
- Mammalian germ cells have high concentration of the enzyme alkaline phosphatase.
- The earliest detectable primordial germ cells can be identified in the mouse before the beginning of gastrulation. The cluster of 6 to 8 cells expressing Blimp1.

Germ cells migrate from their site of origin to the gonad



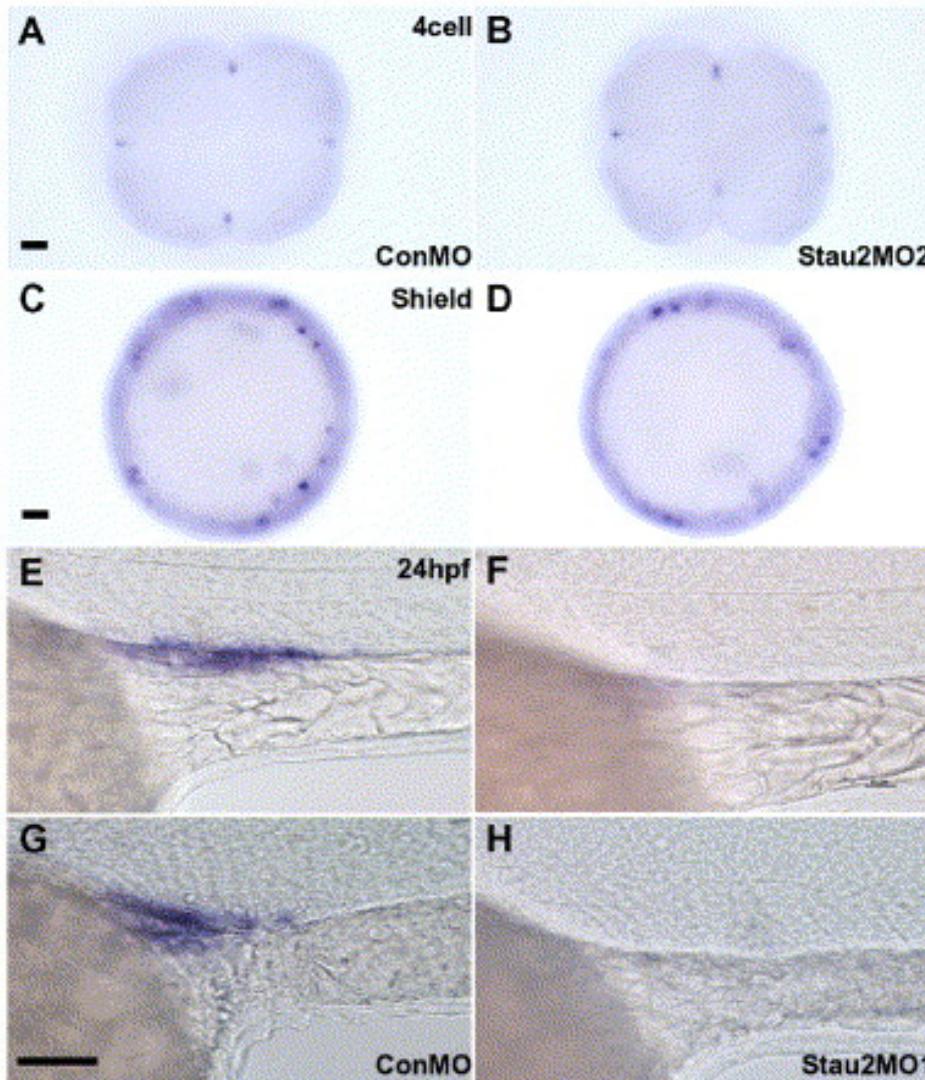
Pathway of primordial germ-cell migration in the mouse embryo



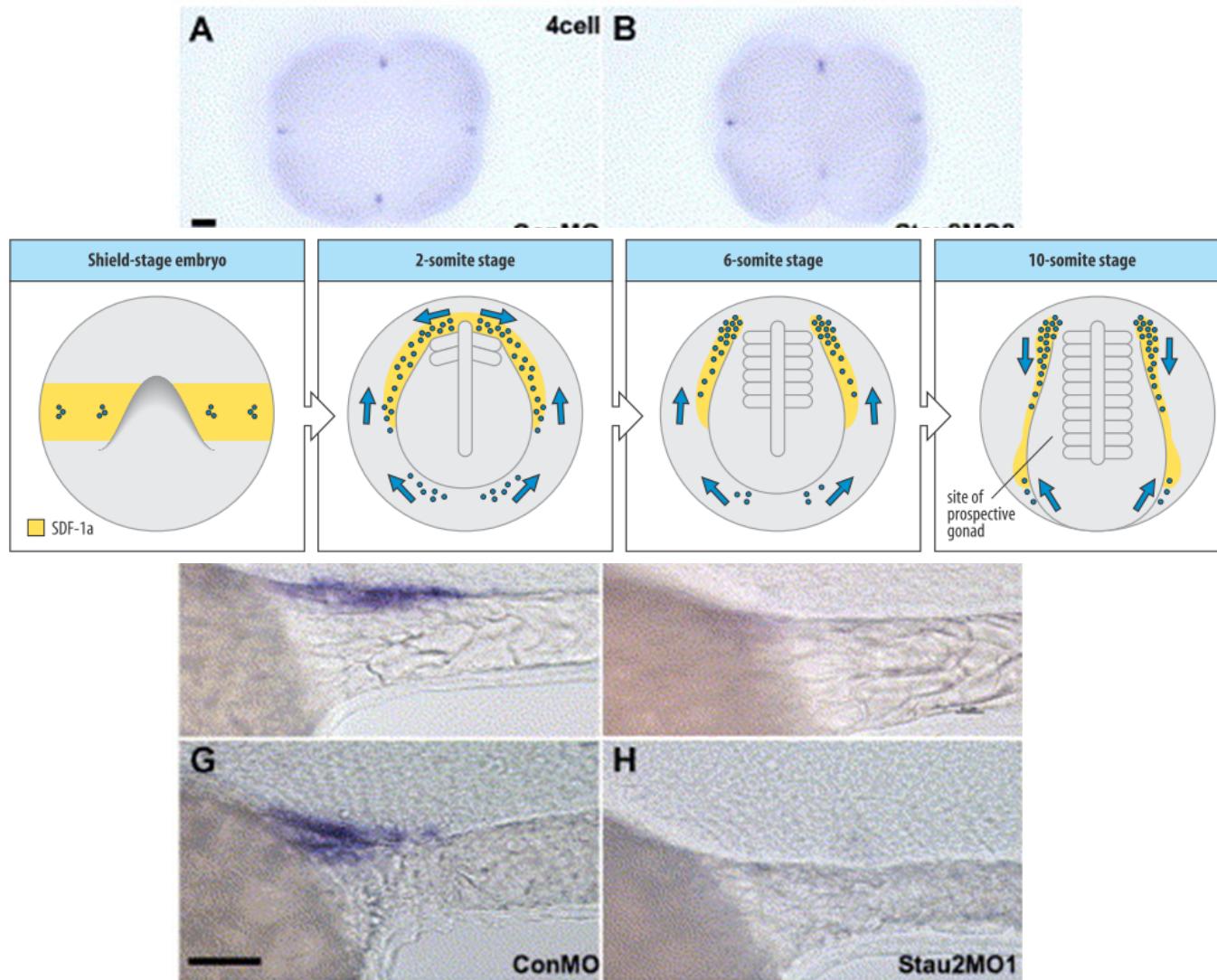
Chick

- The germ cells originate in the epiblast.
- Then migrate to the head end of the embryo.
- Enter blood circulation.
- Exit at the hindgut and migrate along an epithelial sheet to the gonad.

Zebrafish germ plasm contains a number of maternal mRNAs



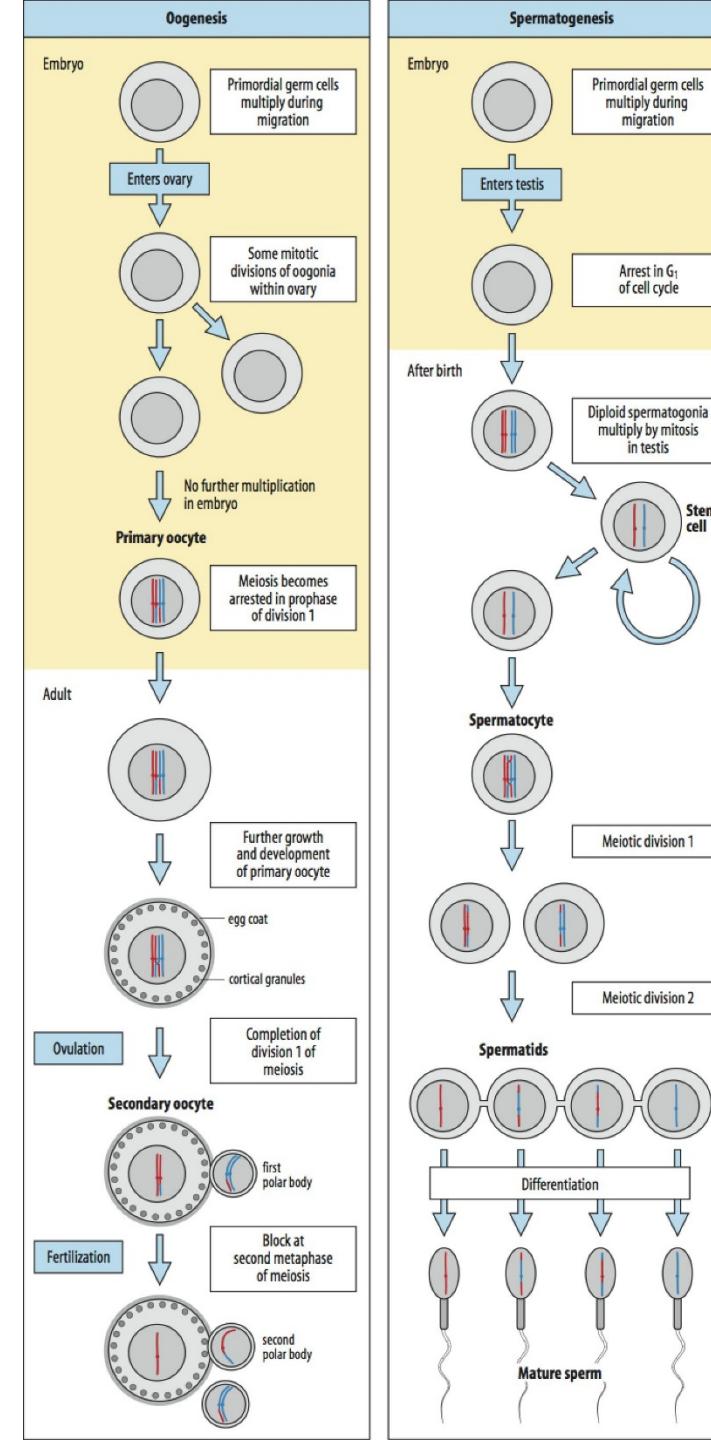
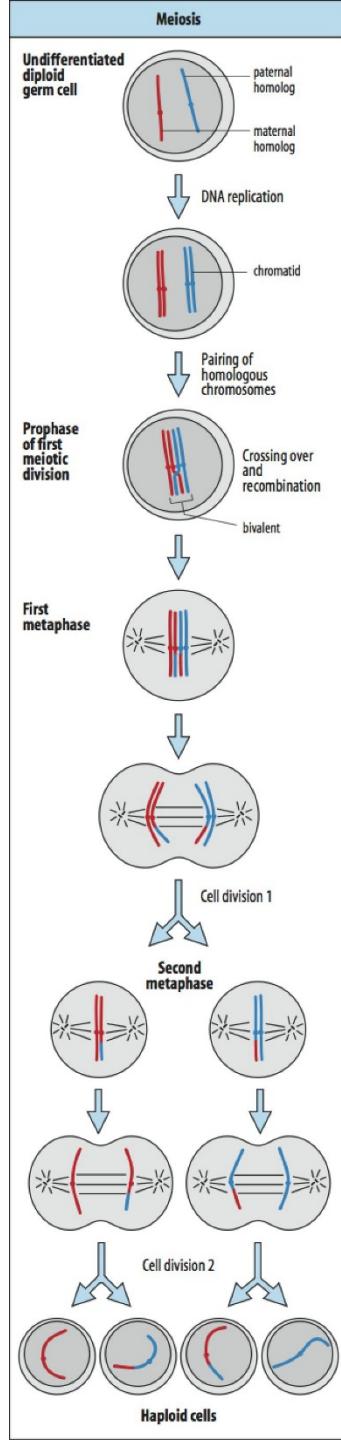
Zebrafish



SDF-1 is a chemokine

- Chemokines are a family of small signaling proteins secreted by cells. Their name is derived from their ability to induce directed chemotaxis in nearby responsive cells.
- MW is 8~10 kD. Chemokines have been classified into four main subfamilies : CXC, CC, CX3C and XC.
- The stromal cell-derived factor 1 (SDF-1) is also known as C-X-C motif chemokine 12 (CXCL12)

Oogenesis and spermatogenesis in mammals



Synaptonemal complex

MEIOTIC DRIVE

Spindle asymmetry drives non-Mendelian chromosome segregation

Takashi Akera,¹ Lukáš Chmátl,¹ Emily Trimm,¹ Karren Yang,¹ Chanat Aonbangkhen,² David M. Chenoweth,² Carsten Janke,^{3,4} Richard M. Schultz,¹ Michael A. Lampson^{1*}

Genetic elements compete for transmission through meiosis, when haploid gametes are created from a diploid parent. Selfish elements can enhance their transmission through a process known as meiotic drive. In female meiosis, selfish elements drive by preferentially attaching to the egg side of the spindle. This implies some asymmetry between the two sides of the spindle, but the molecular mechanisms underlying spindle asymmetry are unknown. Here we found that CDC42 signaling from the cell cortex regulated microtubule tyrosination to induce spindle asymmetry and that non-Mendelian segregation depended on this asymmetry. Cortical CDC42 depends on polarization directed by chromosomes, which are positioned near the cortex to allow the asymmetric cell division. Thus, selfish meiotic drivers exploit the asymmetry inherent in female meiosis to bias their transmission.

Genetic conflict is inherent in any haploid-diploid life cycle because genetic elements compete for transmission through meiosis. Mendel's law of segregation states that alleles of a gene are transmitted with equal probability, but this law can be violated by selfish genetic elements through meiotic drive—for example, by eliminating competing gametes (e.g., sperm killing or spore killing) or by exploiting the asymmetry in female meiosis to increase transmission to the egg. Despite the impact of meiotic

drive on evolution and genetics (1–4), the underlying mechanisms are largely unknown.

Female meiosis provides a clear opportunity for selfish elements to cheat because only chromosomes that segregate to the egg can be transmitted to offspring, whereas the rest are degraded in polar bodies. Conceptually, female meiotic drive depends on three conditions: asymmetry in cell fate, a functional difference between homologous chromosomes that influences their segregation, and asymmetry within the meiotic spindle (5).

The asymmetry in cell fate is well established (6), and chromosomal rearrangements and amplifications of repetitive sequences (e.g., centromeres) are associated with biased segregation (7–10). Asymmetry within the meiotic spindle was noted in grasshopper in 1976 (11) but not studied further.

Oocyte spindles are positioned close to the cortex and oriented perpendicular to the cortex so that cytokinesis produces a large egg and a small polar body. A selfish element drives by preferentially attaching to the egg side of the spindle, implying some difference in microtubules (MTs) between the egg and cortical sides. To determine how such spindle asymmetry is regulated, using mouse oocytes as a model for meiotic drive (10, 12), we tested for asymmetry in posttranslational modifications that functionally diversify MTs (fig. S1A) (13–15). Only tyrosinated (Tyr) and detyrosinated (dTyr) α -tubulin showed asymmetry, with the cortical side enriched for Tyr α -tubulin and the egg side for dTyr α -tubulin (Fig. 1, A and C, and fig. S1B). Furthermore, we found that spindles were asymmetric late in metaphase of meiosis I (MI)

¹Department of Biology, School of Arts and Sciences, University of Pennsylvania, Philadelphia, PA 19104, USA.

²Department of Chemistry, School of Arts and Sciences, University of Pennsylvania, Philadelphia, PA 19104, USA.

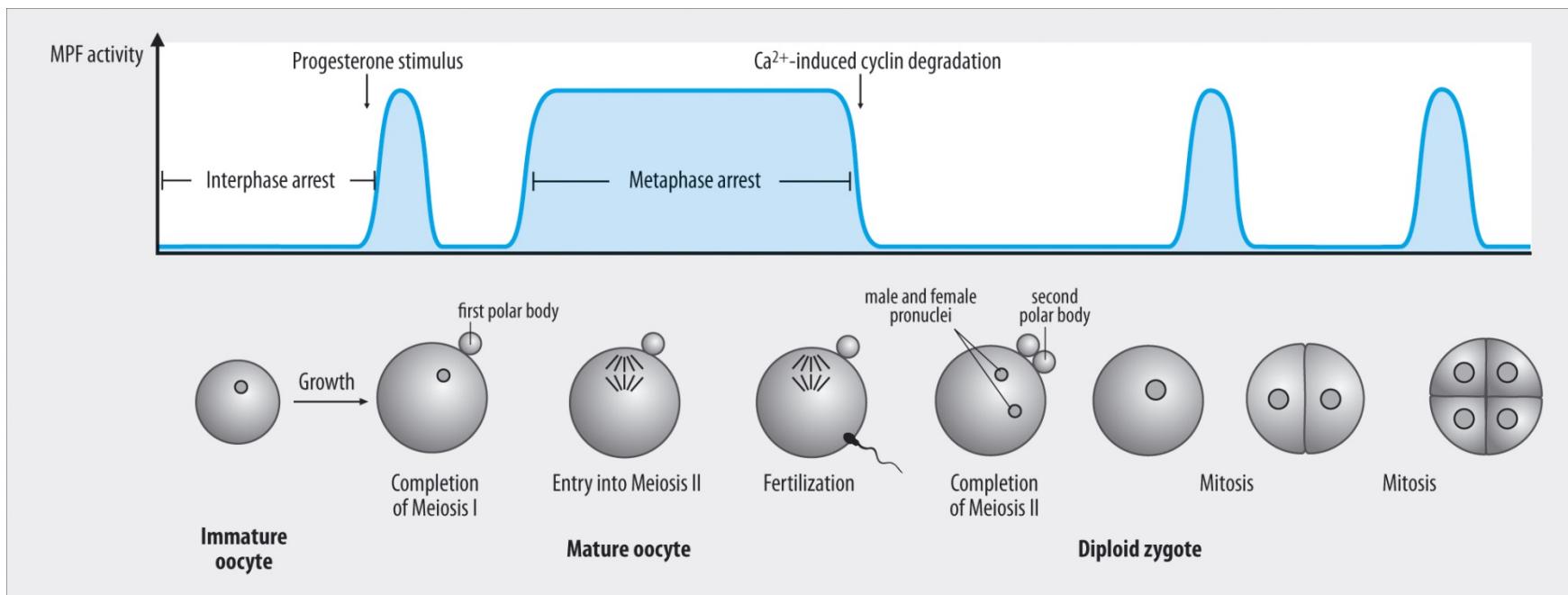
³Institut Curie, Paris Sciences & Lettres (PSL) Research University, CNRS UMR3348, Centre Universitaire, Bâtiment 110, F-91405 Orsay, France. ⁴Université Paris Sud, Université Paris-Saclay, CNRS UMR3348, Centre Universitaire, Bâtiment 110, F-91405 Orsay, France.

*Corresponding author. Email: lampson@sas.upenn.edu

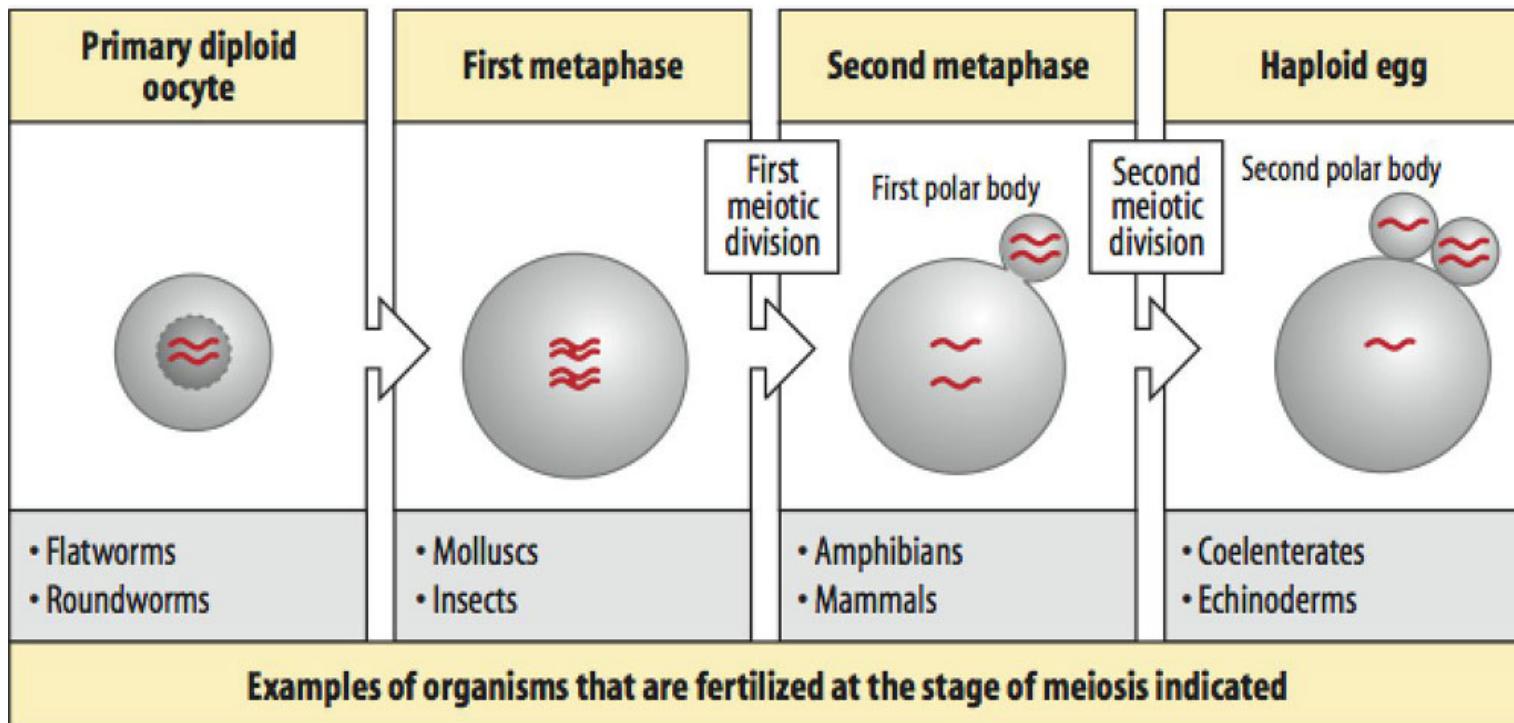
Oogenesis

- Oogonia, diploid germ cell.
卵母细胞
- Primary oocyte, which enters into meiosis and becomes arrested.
卵泡
- Follicle, somatic ovarian cells.
- Oocytes (primary oocytes) never proliferate again after entry into meiosis.
- In mammals, at the time of ovulation, the oocyte completes the first meiotic division and proceeds to the metaphase of the second meiotic division. Here, meiosis is arrested again.
- Meiosis is only completed after fertilization.

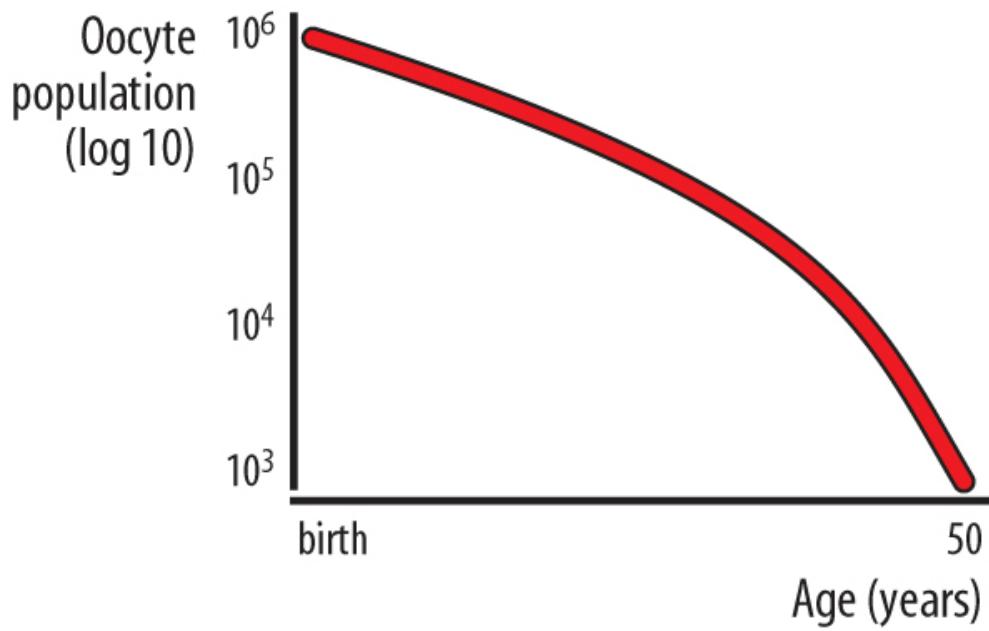
Profile of maturation-promoting factor (MPF) activity in early Xenopus development



Polar bodies



Decline of human oocyte numbers with age



- At the beginning, there are 6~7 M oocyte.

青春期

- After puberty, there remain ~ 4M.
- Decreasing by apoptosis.

Oocyte development can involve gene amplification and contributions from other cells

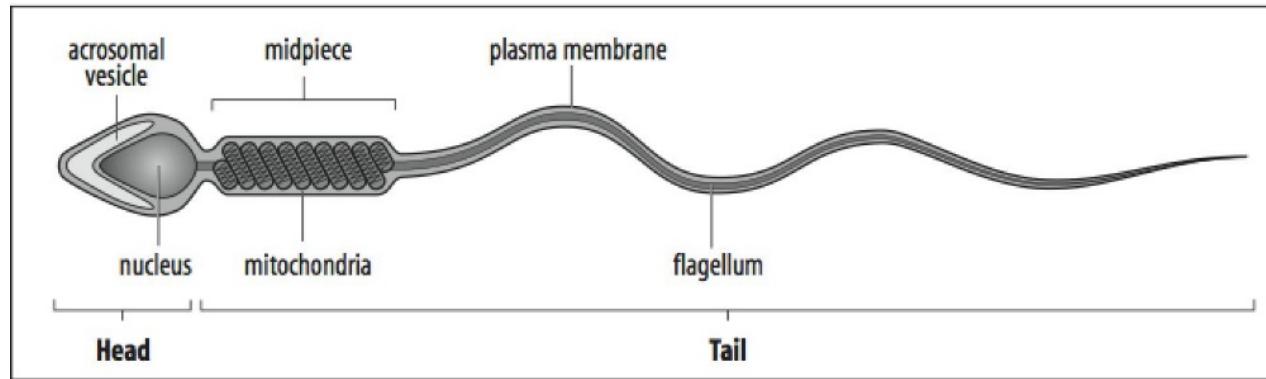
- Eggs are usually larger than the somatic cells.
- Vertebrate oocytes are arrested in prophase of the first meiotic division and so have double the normal diploid number of genes.
- Insects and amphibians produce many extra copies of selected genes which products are needed in very large amounts. For example, rRNA genes.
- Oocyte also relies on the synthetic activities of other cells. For example, nurse cells and yolk proteins.

Spermatogenesis

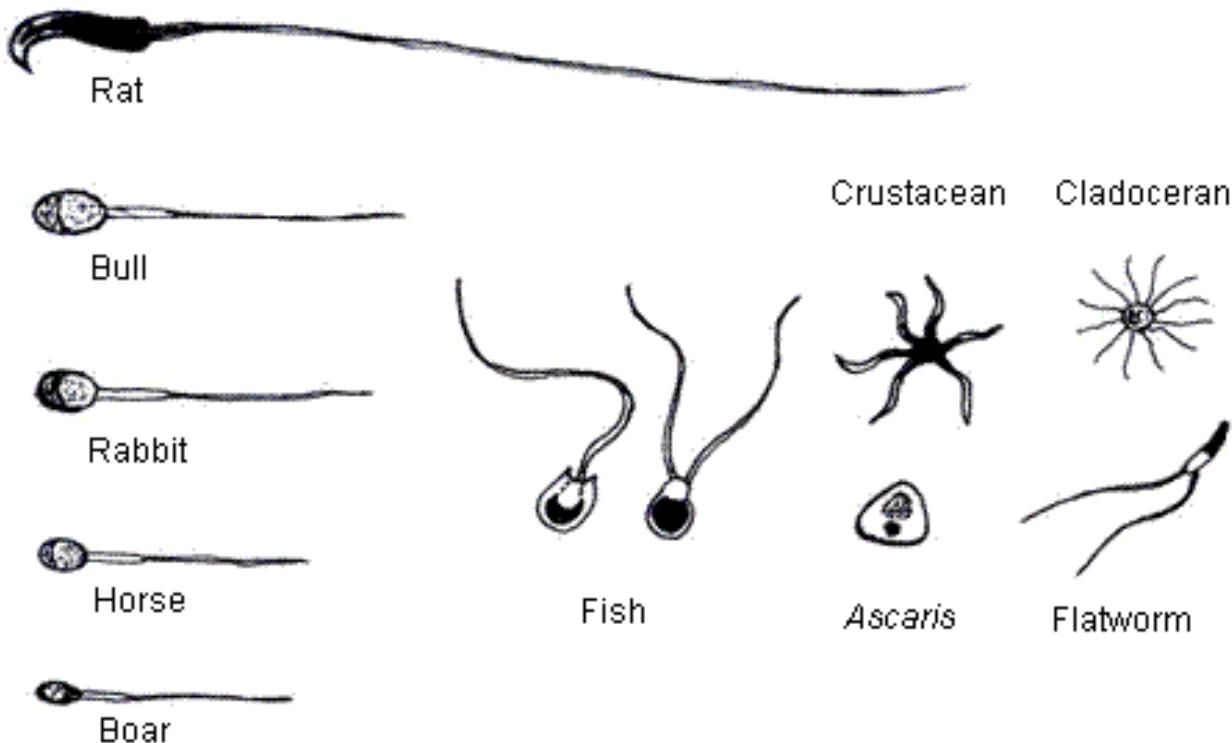
- Primordial germ cells enter testis, and are arrested in G1 of cell cycle during embryogenesis.
- After birth, spermatogonia (diploid) multiply by mitosis and produce spermatocyte in a stem cell manner.
- Spermatocyte undergoes meiosis and forms four spermatids. Then spermatids differentiate to sperm.

Fertilization

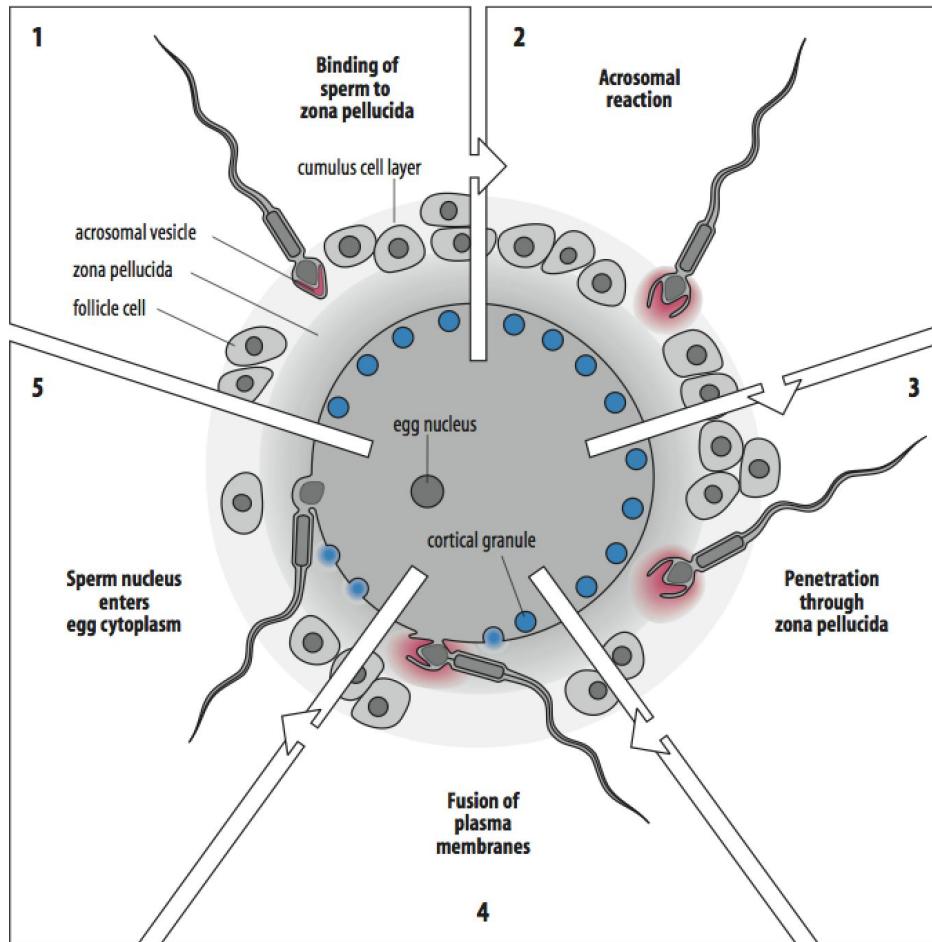
A human sperm



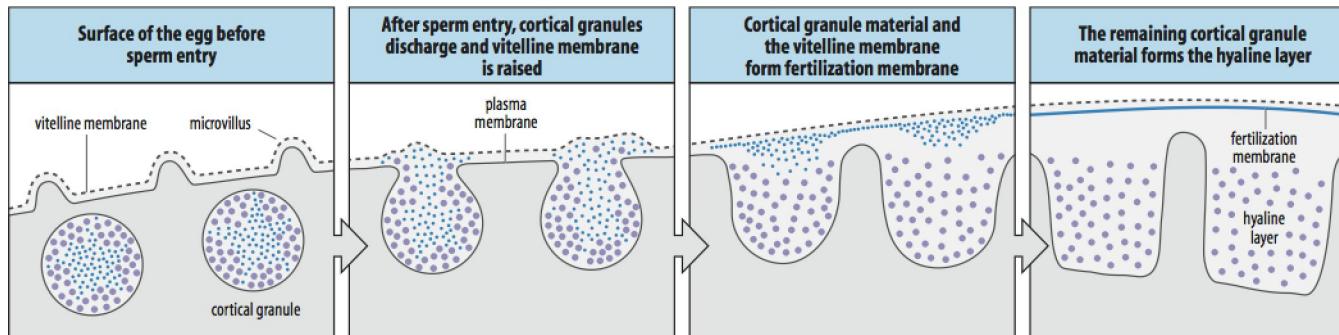
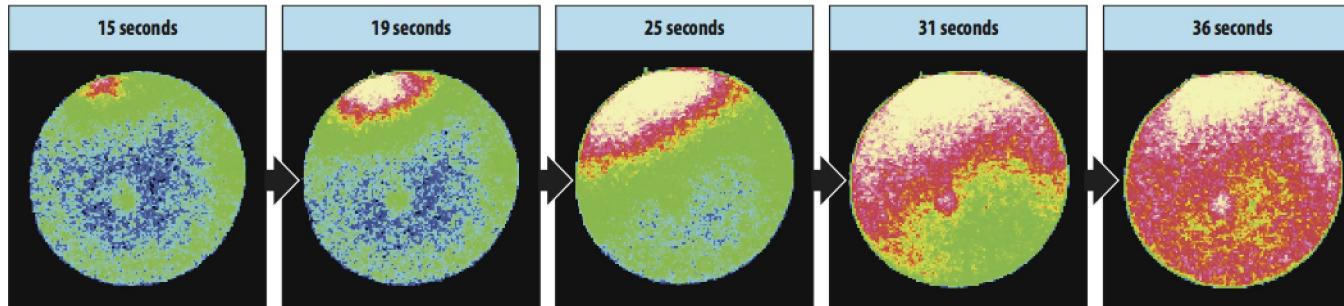
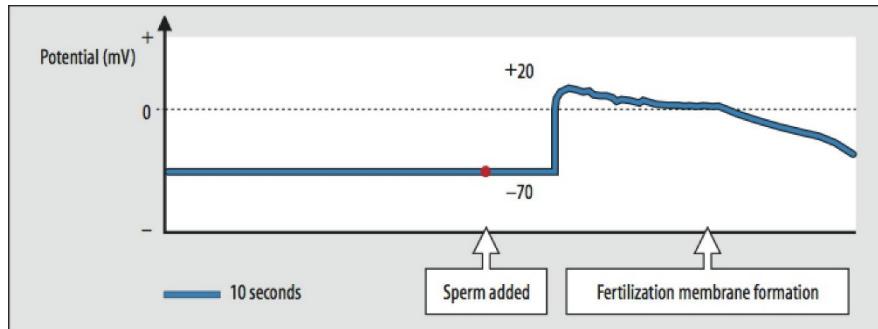
Sperm of different animal species



Fertilization



Changes in the egg envelop at fertilization block polyspermy



It takes more than one sperm to make a baby bird

PROCEEDINGS B

rsb.royalsocietypublishing.org

Research



Cite this article: Hemmings N, Birkhead TR. 2015 Polyspermy in birds: sperm numbers and embryo survival. *Proc. R. Soc. B* **282**: 20151682.

<http://dx.doi.org/10.1098/rspb.2015.1682>

Received: 13 July 2015

Accepted: 22 September 2015

Polyspermy in birds: sperm numbers and embryo survival

N. Hemmings and T. R. Birkhead

Department of Animal and Plant Sciences, University of Sheffield, Sheffield S102TN, UK

Polyspermy is a major puzzle in reproductive biology. In some taxa, multiple sperm enter the ovum as part of the normal fertilization process, whereas in others, penetration of the ovum by more than one sperm is lethal. In birds, several sperm typically enter the germinal disc, yet only one fuses with the female pronucleus. It is unclear whether supernumerary sperm play an essential role in the avian fertilization process and, if they do, how females regulate the progression of sperm through the oviduct to ensure an appropriate number reach the ovum. Here, we show that when very few sperm penetrate the avian ovum, embryos are unlikely to survive beyond the earliest stages of development. We also show that when the number of inseminated sperm is limited, a greater proportion than expected reach and penetrate the ovum, indicating that females compensate for low sperm numbers in the oviduct. Our results suggest a functional role for supernumerary sperm in the processes of fertilization and early embryogenesis, providing an exciting expansion of our understanding of sperm function in birds.

Thanks!