Primordial Germ Cells

• Produce gametes (egg and sperm)

• How are primoridal germ cells determined?
  • Cytoplasmic determinants in egg
    – Proteins and mRNA are localized in region called the germ plasm
    – Nematodes, flies, frogs
  • Interactions between neighboring cells
    – Salamander, mammals
Nematodes

Parascaris

C. elegans
Nematode germ cells

- Animal pole
  - No yolk
  - Produces most cells
- Vegetal pole
  - Yolk
- Equatorial cleavage plane
- Chromosome diminution
  - DNA fragments and only part of the DNA is present in somatic cells
Boveri's experiments on *Parascaris*
C. elegans

- P-granules migrate to P4 blastomere
  - Alters transcription
- PIE-1 protein activated
  - Blocks most gene transcription
Drosophila melanogaster

Help me!
Germ cell determination in *Drosophila*

- Pole granules (A) form at posterior pole
- Pole cells (B) migrate to posterior of developing embryo (ninth division)
Cystocyte development in *Drosophila*
Genes involved in pole cell formation in *Drosophila*

- Germ cell-less
- Polar granule component
- Posterior group
  - Oscar
  - Nanos
  - Vasa
  - Piwi and Augergine
Localization of the germ cell-less gene in *Drosophila*
Germ cell-less (gcl))

- mRNA produced by nurse cells and deposited into egg
- mRNA transported to posterior pole of egg (pole plasm)
- Transcribed into protein early in development
- gcl protein enters nuclei and alters gene transcription
- Necessary for pole cell production
- Human homologues necessary for spermatogenesis
Polar granule component (Pgc)

- Non-coding RNA
- Inhibits transcription by blocking RNA polymerase II phosphorylation
- When mutated pole cells develop into somatic cells
Oskar

- Involved in localizing factors (proteins and mRNA) necessary for pole cell formation to the posterior end of developing egg
- Expressing abnormal expression of Oskar causes production of extra pole cells
Nanos

- Prevents development of somatic cells
- Blocks translation
- Localized by oskar
Vasa, Piwi, Aubergine

• Vasa – initiates germ cell differentiation and meiosis
  • RNA binding protein
• Piwi, Aubergine – necessary for germ cells to develop into stem cells in gonad
  • Repress transcription
Germ cell migration in *Drosophila*
Germ Cell Determination in Vertebrates

- Frogs
- Zebrafish
- Mammals
Frogs

- Vegetal region contains *Drosophila* pole plasm homologue
  - For example: *Xcat2* homologue of *Nanos*
  - Germ plasm granules are present in unfertilized egg
    - Tethered to yolk
    - After fertilization microtubules position germ plasm granules in vegetal pole
Zebrafish

- Germ plasm polar granules containing *Drosophila* pole plasm homologue
  - For example: *Nanos* and *Vasa*
- Maternally supplied
- Associated with cleavage furrow
- At 1000 cell stage only four cells have germ plasm
  - 4 clusters of primordial germ cells form
Mammals

• Eggs do not contain germ plasm
• Induction causes germ cell production
Testis and Associated Structures

Figure 27.9b

- **Spermatic cord**
- **Blood vessels and nerves**
- **Head of epididymis**
- **Ductus deferens**
- **Efferent ductule**
- **Rete testis**
- **Body of epididymis**
- **Tail of epididymis**
- **Seminiferous tubule**
- **Septum**
- **Lobule**
- **Tunica vaginalis**
- **Tunica albuginea**
Endocrine Control

As hypothalamus matures it produces gonadotropin-releasing hormone (GnRH)
  – GnRH stimulates anterior pituitary cells (gonadotropes) to secrete:
    • follicle stimulating hormone (FSH)
      – stimulates Sertoli cells to secrete androgen-binding protein that binds testosterone keeping it in the seminiferous tubule lumen to stimulate spermatogenesis and raising sperm count
    • luteinizing hormone (LH)
      – stimulates interstitial cells to produce testosterone
Primordial germ cell
PGC

Fig. 46.11

Primordial germ cell in embryo

Differentiation

Mitotic division, producing large numbers of spermatogonia

Differentiation and onset of meiosis I

2n

Spermatogonium

Primary spermatocyte (in prophase of meiosis I)

Meiosis I completed

n

Secondary spermatocyte

Meiosis II

n

Early spermatids

Spermatids (at two stages of differentiation)

Differentiation (Sertoli cells provide nutrients)

n

Sperm cells (spermatozoa)

Lumen of seminiferous tubule

Fig. 46.11
Spermatogenesis

Cross section of seminiferous tubules

Lumen of seminiferous tubule

Sperm

Spermatid

Secondary spermatocyte

Blood–testis barrier
Primary spermatocyte
Sustentacular cell

Type B spermatogonium

Tight junction
Type A spermatogonium
Basement membrane of seminiferous tubule

Figure 27.15

27-24
Histology of Testis

Figure 27.10 a-b

Interstitial cells
Blood vessel
Germ cells
Sustentacular cell
Tails of spermatozoa

(a)

Interstitial cells
Blood vessel
Seminiferous tubule
Spermatids
Sustentacular cell nuclei
Tubule lumen
Germ cells
Connective tissue wall of tubule
Interstitial cells

(b) 50 µm

a: Copyright by R.G. Kessel and R.H. Kardon, Tissues and Organs: A Text-Atlas of Scanning Electron Microscopy, 1979, W.H. Freeman, All rights reserved; b: © Ed Reschke
Sperm structure:
Haploid nucleus.
Tipped with an **acrosome**.
Contains enzymes that help the sperm penetrate to the egg.
A large number of mitochondria provide ATP to power the flagellum.

---

**Spermatozoon**

![Diagram of a sperm](image)

- **Head**
- **Midpiece of tail**
- **Principal piece of tail**
- **Endpiece of tail**

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(a) Visuals Unlimited
Anatomy of Ovary

Primordial follicles
Primary follicles
Secondary follicle
Mature follicle
Oocyte
Suspensory ligament and blood vessels

Ovarian ligament
Medulla
Cortex
Tunica albuginea
Corpus albicans
Corpus luteum
Fimbriae of uterine tube

Ovulated oocyte

Figure 28.2
Oogenesis and Follicle Development

**Figure 28.11**

Development of egg (oogenesis)

<table>
<thead>
<tr>
<th>Before birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitosis</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Adolescence to menopause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meiosis I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>If not fertilized</th>
<th>If fertilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second polar body (dies)</td>
<td>Ovulation of mature (graafian) follicle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>If fertilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ooocyte Nucleus Follicular cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Granulosa cells</th>
<th>Zona pellucida</th>
<th>Theca folliculi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antrum</td>
<td>Cumulus oophorus</td>
<td>Theca interna</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Theca externa</th>
<th>Bleeding into antrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovulated oocyte</td>
<td>Follicular fluid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corpus luteum</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Primordial follicle</th>
</tr>
</thead>
</table>

| Primordial & Primary follicle: © Ed Reschke; (Secondary follicle): © The McGraw-Hill Companies, Inc./Photo by Dr. Alvin Telser; (Tertiary follicle): Manfred Kage/Peter Arnold, Inc.; (Graafian): Landrum Dr. Shettles; (Corpus luteum): © The McGraw-Hill Companies, Inc./Photo by Dr. Alvin Telser |
Folliculogenesis

• folliculogenesis – the development of the follicles around the egg than undergoes oogenesis

  – primordial follicles
    • consists of a primary oocyte in early meiosis
    • surrounded by a single layer of squamous follicular cells
    • most wait 13 to 50 years before they develop further
    • adult ovary has 90% to 95% primordial follicles

  – primary follicles
    • have larger oocytes and follicular cells that still form a single layer

  – secondary follicles
    • still larger oocytes and follicular cells now stratified (granulosa cells)
    • zona pellucida – layer of glycoprotein gel secreted by granulosa cells around the oocyte
    • theca folliculi – connective tissue around the granulosa cells condenses to form a fibrous husk
Folliculogenesis

- tertiary follicles
  - granulosa cells begin secreting follicular fluid
  - fluid-filled cavity, the antrum
  - cumulus oophorus – a mound of granulosa cells on one side of the antrum that covers the oocyte and secures it to the follicular wall

- mature (graafian) follicles
  - normally only one follicle from each month’s cohort becomes a mature follicle destined to ovulate
  - remainder degenerate
Histology of Ovarian Follicles

Figure 28.12b

Granulosa cells
Oocyte (egg)
Oocyte nucleus
Zona pellucida
Cumulus oophorus
Antrum
Theca folliculi

(b) 100 µm

Manfred Kage/Peter Arnold, Inc

Figure 28.12b
Endoscopic View of Ovulation

Figure 28.15

Infundibulum of uterine tube  Fimbriae

Cumulus oophorus
Oocyte
Stigma
Ovary

0.1 mm

© Landrum B. Shettles, MD
**Pituitary-Ovarian Axis**

1. Maturing follicle secretes estradiol
2. Estradiol stimulates hypothalamus and anterior pituitary
3. Hypothalamus secretes GnRH
4. GnRH and estradiol stimulate pituitary to secrete LH and FSH
5. Oocyte completes meiosis I; follicle rapidly enlarges and then ovulates

Figure 28.13
Growth of Primary Oocyte

Increase in Gene Expression
Lampbrush Chromosomes
  Increased number of Nucleoli
gene amplification

Increased number of Organelles

Yolk Production
Egg Types
  Isolecithal – mammals, echinoderms
  Mesolecithal – amphibians
  Telolecithal – birds, fish, reptiles
  Centrolecithal – arthropods

Isolecithal
Egg Envelopes

I. Produced within the ovary
   Vitelline Membrane  sea urchin, frog, bird
   Zona pellucida  mammal

II. Produced outside of the ovary
   jelly
   albumin & shell membranes