

Sexual maturity, breeding season and development of gametes



Sexual maturity

- Maturation of fish gonads (gonadal maturation) is a process by which minute sex cells (germ cells) develop, with accessory tissues, into large organs, microscopic-large 25-30% b.w. (testis and ovary) which finally lead to the maturation and release of gametes (sperm and eggs)
- Age at sexual maturity in fish varies with climatic and ecological /environmental conditions
- It varies between species and between sexes; In general, males mature earlier than females
- Size at first sexual maturity also varies with species and between sexes

Breeding season:

- The cultivated carps (with the exception of common carp) attain maturity at the end of second year or the beginning of third year, depending upon the temperature
- Majority of the major carps breed during south-west monsoon
- The common carp attains maturity at 4-6 months
- Tilapia matures at 4-5 months and spawns through out the year

Breeding season:

- Medium carps, catfishes, murrels, etc. mature during pre-monsoon and with the onset of south-west monsoon and breed in ponds, tanks, paddy fields, etc.
- Brackish-water and marine fishes attain maturity during pre-monsoon and with the onset of south-west monsoon and have prolonged breeding season
- Maturation has various stages and different sex steroids are involved at each stage, but gonadotropins influence the production of all of them

Gamete maturation and release in females

- Gamete development has series of stages:

A. Oogenesis:

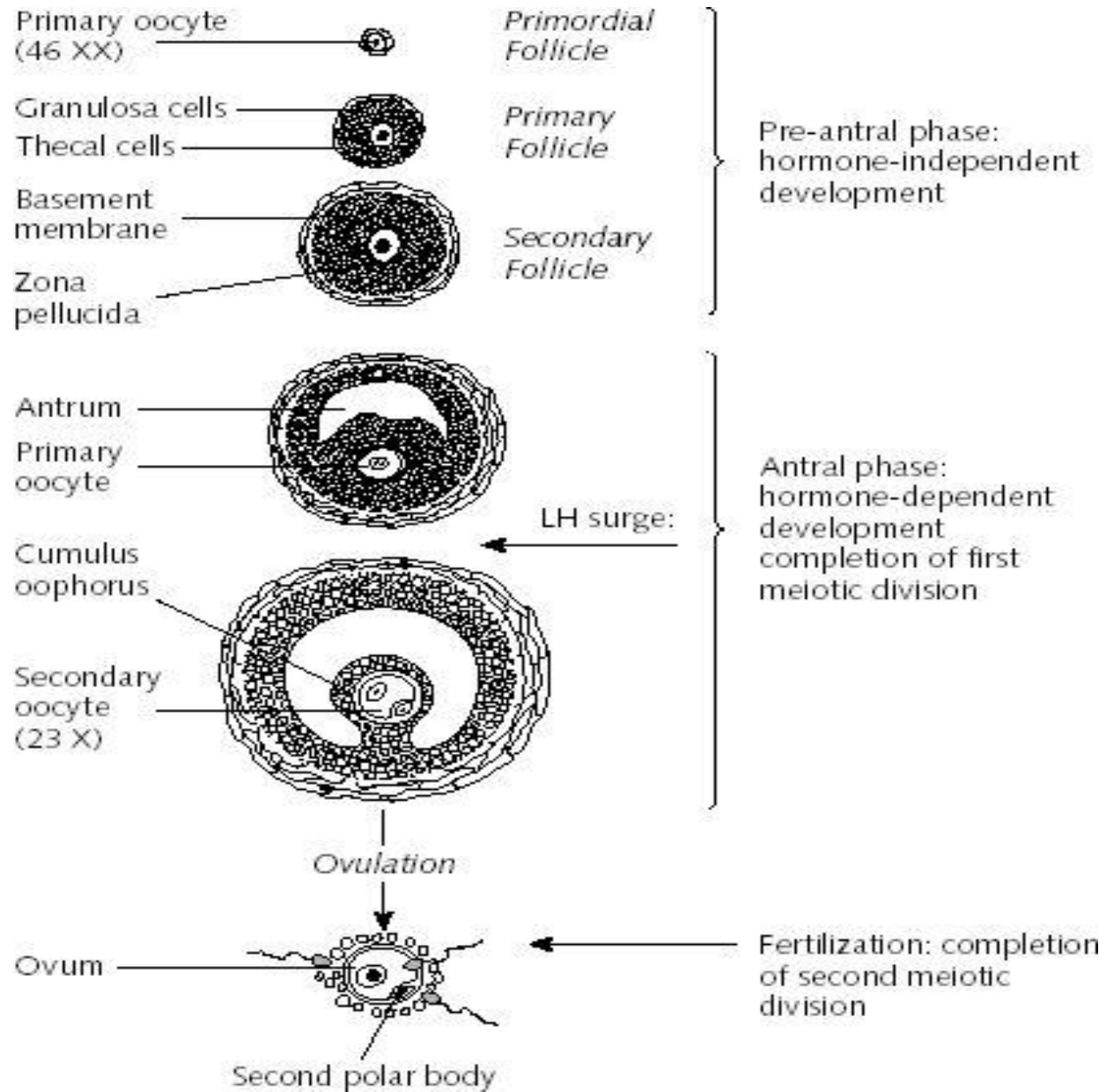
- Oogonia are the cells that give rise to oocytes through a continuous process called oogenesis and are found throughout the life of a fish
- Oocytes are produced from oogonia as a result of meiosis (reduction division)
- After the first meiosis the oocytes become surrounded by a layer of epithelial cells called the follicle
- After this the oocyte enters a long stage of cytoplasmic growth
- In fish that breed more than once, oogenesis goes on at various rates throughout the fishes life and is not under the control of hormones (GtH).



Figure: Mature female with orange/yellow ovary

B. Primary oocytes growth:

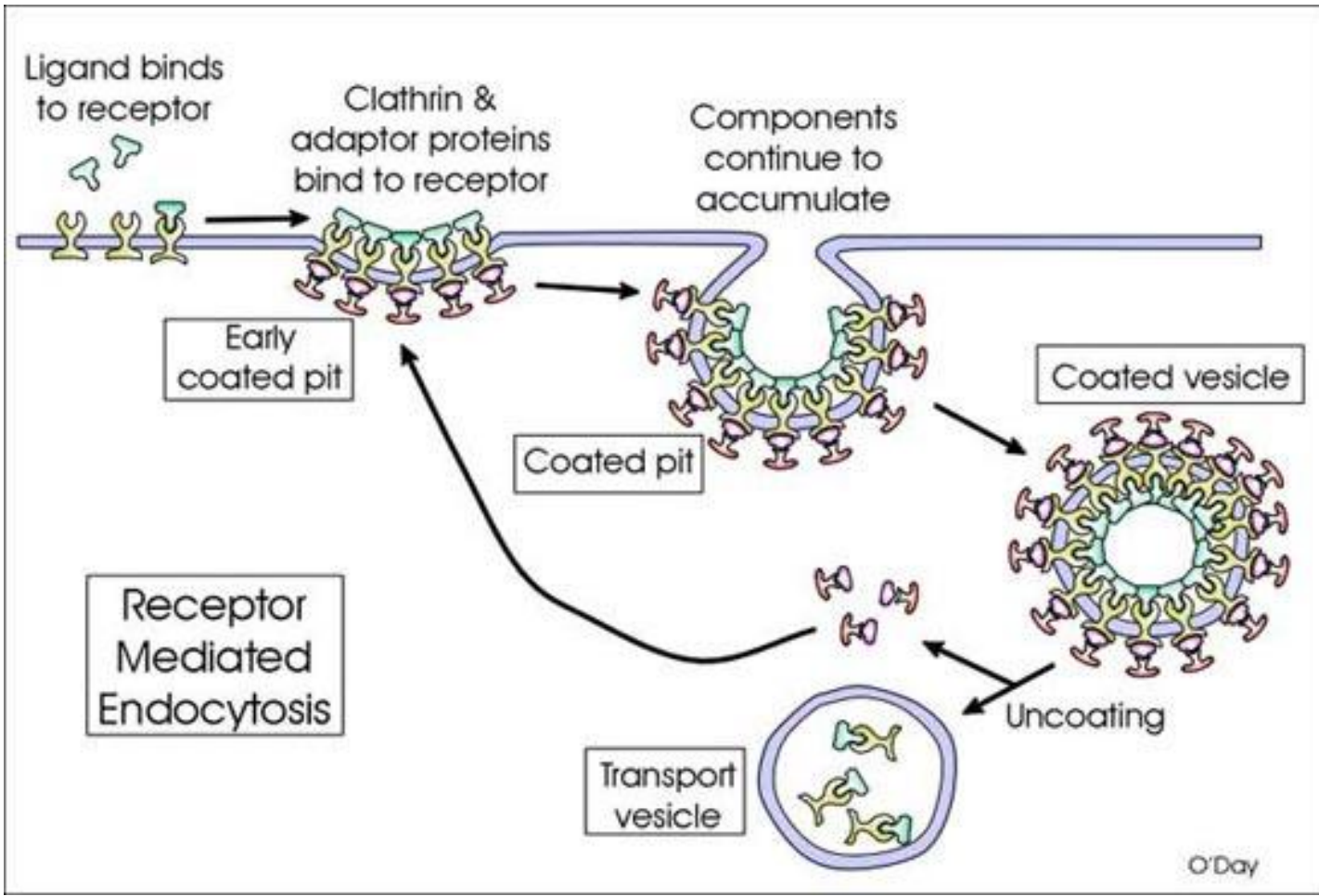
- The early development of the follicle and its oocyte is independent of pituitary GtH
- The growth is due mainly to proliferation of cellular components
- By the end of this stage, the typical teleost oocyte increases several hundred times in size to a diameter of 100-200 μ m and is called pre-vitellogenic oocyte
- During the growth period, the follicle cells differentiate to form glandular granulosa, separated from oocyte by a zona pellucida and surrounded by an outer theca



- These cells play an important role in steroidogenesis
- The primary growth process continues throughout the life of fish that are multiple spawners and previtellogenic oocytes are present in the ovary year round
- If only the previtellogenic oocytes are present, the ovary is considered immature, which may be because of age or season

C. Yolk vesicle formation:

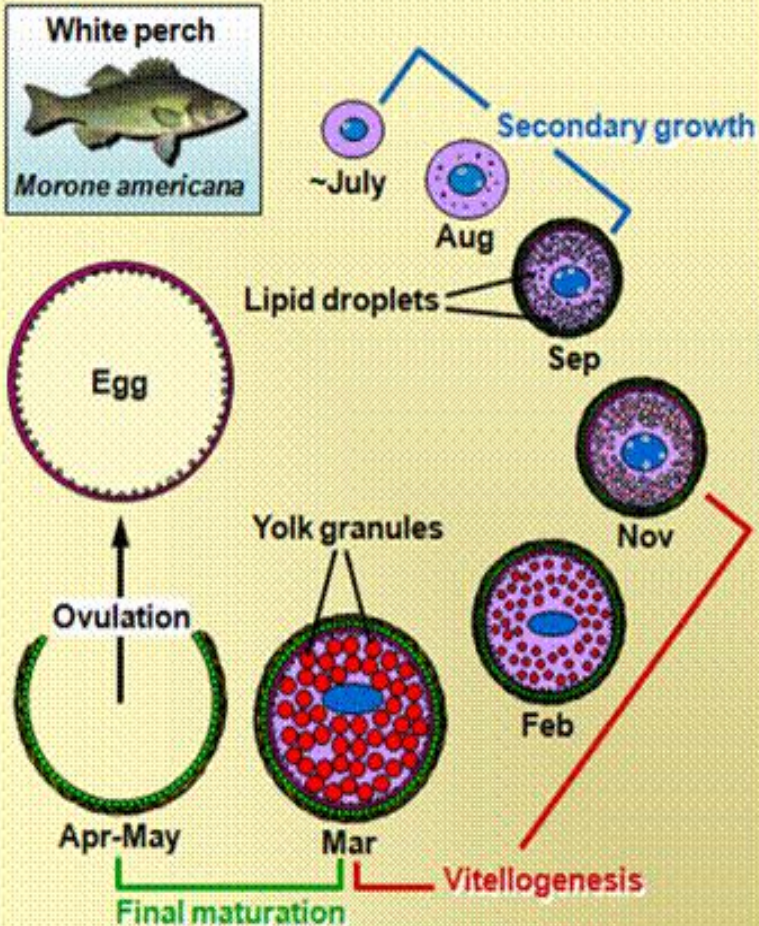
- In response to environmental cues- change in day length, temperature or rainfall, there will be a surge in the GtH levels that induce previtellogenic oocyte to develop further
- The first sign - the appearance of yolk vesicles in the oocyte cytoplasm
- There contains glycoproteins formed within the oocyte and will eventually become cortical alveoli (may be a source of energy for the embryo) that will be expelled into the previtline space around the egg after fertilization
- This process is some times referred to as “endogenous vitellogenesis.”
- Since there oocytes contain neither true yolk nor vitellogenin, it is better known as “yolk vesicle formation” which is triggered by GtH.



D. Vitellogenesis:

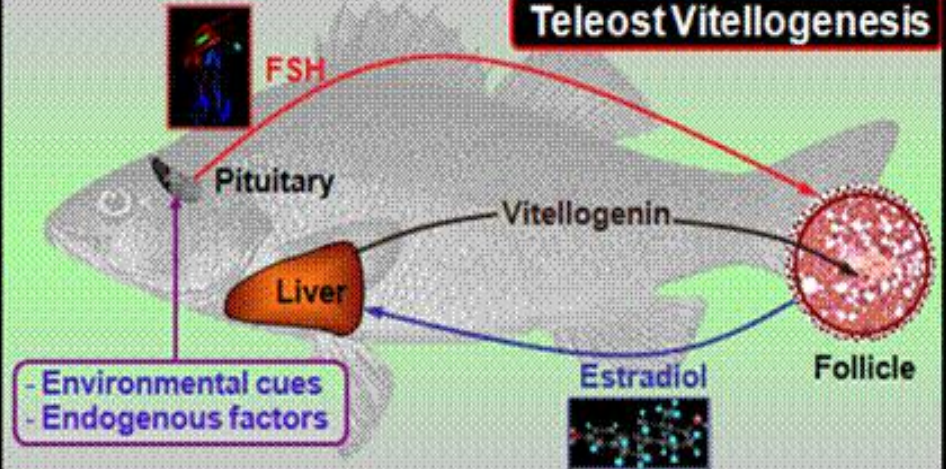
- Sequestration of the phospholipids, vitellogenin (Vg) from the blood stream and accumulation of true yolk in yolk globules takes place after yolk vesicle formation this represents the major growth of the oocytes and is known as vitellogenesis
- Involves synthesis of vitellogenin (yolk protein precursor) in the liver, delivery of vitellogenin to the oocytes via bloodstream and uptake and chemical alterations to form yolk protein
- GtH induces the thecal cells of the follicle to produce T, which in turn converted to an estrogen, $17\beta E_2$, in the granulosa cells

"Oogenesis"



Jackson and Sullivan, 1995 Trans. Am. Fish. Soc.

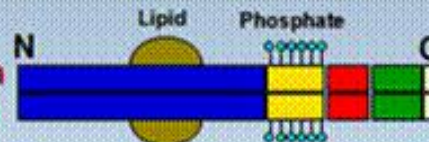
Teleost Vitellogenesis



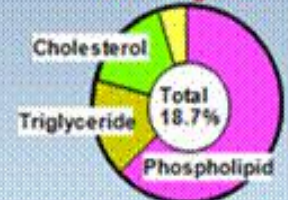
Vitellogenin (Vtg) and yolk proteins

Blood

Vitellogenin (complete)



Vitellogenin

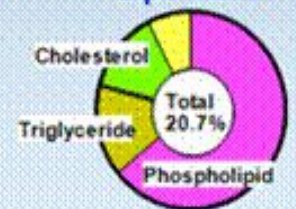


Oocyte

Lipovitellin



Lipovitellin



Phosvitin



β' -component



C-terminal component



- E_2 travels to the liver in the blood and stimulates production of Vg, which travels to the oocyte, also by the blood stream
- Oocytes sequester Vg as yolk protein in yolk globules and increase in size and this is facilitated by GtH
- The plasma levels of GtH is high during this phase of maturation. T and E_2 act on the pituitary in “feed back loops” to regulate GtH release
- Vitellogenesis can be triggered and accelerated by environmental manipulation and hormonal manipulation

E. Steroid switch and final maturation:

- Final oocyte maturation in many warm water species - rapid-takes less than 24hrs
- Involves resumption of meiosis, migration of GV (nucleus) to the edge of the oocyte and GVBD- useful in inducing the oocyte maturity
- Meiosis then stops again and the oocyte is now mature, ready for expulsion from the follicle (ovulation)
- During this stage, the level of GtH increases and GtH stimulates the follicle to produce maturation inducing steroid (MIS) instead of estradiol

- MIS is a form of progesterone called 17-OHP or 17 α -20 β -diOH P
- At this stage the enzyme responsible for the production of estradiol is inhibited
- The MIS induces a number of visible changes in the oocyte during final maturation
- In addition to GV migration and breakdown, it causes an increase in oocyte diameter due to the uptake of water (hydration) in to the cytoplasm and changes in the appearance of the yolk

F. Ovulation:

- Final maturation is followed by ovulation- the release of egg from its follicle into the ovarian lumen and is ready to be expelled into the surrounding water for fertilization. Ovulation is controlled by prostaglandin (PG) under the influence of GtH
- PG -produced by the follicle and the oviduct; cyclopentane fatty acids
- Once ovulated the eggs of different species remain fertile within the ovary or body cavity for periods of <1 hr to several days
- After this time the eggs become “overripe” and start to disintegrate
- Over ripening of eggs held in the body after Ovulation - temperature dependent
- In hormone induced spawning, final maturation and spawning are the most important stages of reproduction



Figure: Ripe ovary and testis

Gamete maturation and release in males

- The three important stages of reproduction- vitellogenesis, final maturation and ovulatory- biases endocrinologist
- Gonadal development in the male goes ahead on its own even in captivity
- Male remains mature over a much longer period than the females and spermatozoa can remain fertile in the testis or outside for much longer periods
- The testis of fish is sac-like and folded
- Like the oocyte, male gametes (sperm cells) develop and mature in the male fish through a series of stages



Figure: Mature male with creamy white testis

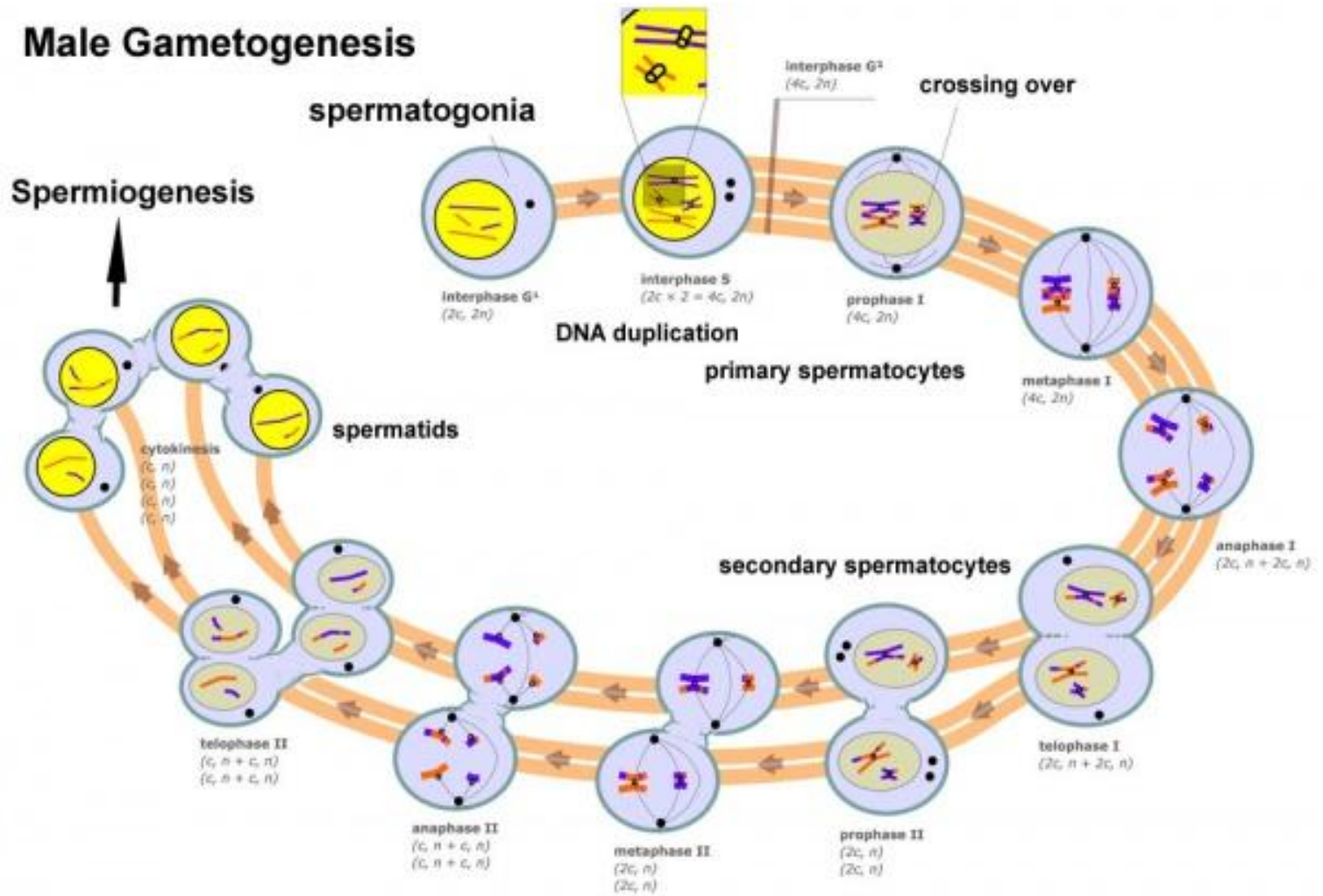
A. Spermatogenesis:

- Spermatogonia are cells that give rise to spermatocytes through a process called spermatogenesis.
- The spermatocytes produced by meiosis (I) are enveloped by sertoli cells until their liberation as mature spermatozoa within the lumen of the testis
- GtH induces the Leydig cells to produce Testosterone (T), which causes spermatogonia to divide into spermatocytes within cysts of sertoli cells

B. Spermogenesis:

- Development of spermatocytes into spermatids (spermogenesis) may continue and occurs through 2nd meiosis in the absence of GtH
- The growth of spermatids takes place within the cyst of sertoli cells and at this stage the spermatids possess flagellum

Male Gametogenesis



C. Spermiation:

- Mature spermatids are liberated into the lumen as spermatozoa through a process called spermiation
- 11-ketotestosterone (11-KT), produced by the Leydig cells under GtH stimulation, initiates this process. 17α - 20β -DiOH P, also produced by the Leydig cells (and possibly by mature spermatozoa), maintains continuous low level spermiation

D. Hydration:

- The last step before release of spermatozoa is hydration i. e. dilution of spermatozoa with seminal fluid produced from the walls of the sperm duct under the influence of 17α - 20β -DiOH P
- This diluted sperm suspension - milt - released during spawning
- Spermiation and sperm hydration increase rapidly when the appropriate environmental cues are present and are often synchronized with final maturation in females
- Males generally are mature even in captivity, if not, environmental/hormonal manipulation can induce spermiation
- Males need less hormone than females to induce 'final maturation'

