GAMATOGENESIS

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WHAT IS THE BASIC DIFFERENCES BETWEEN

SPERMATOGENESIS AND OOGENESIS


One of the fundamental differences concerns the timing of meiosis onset.

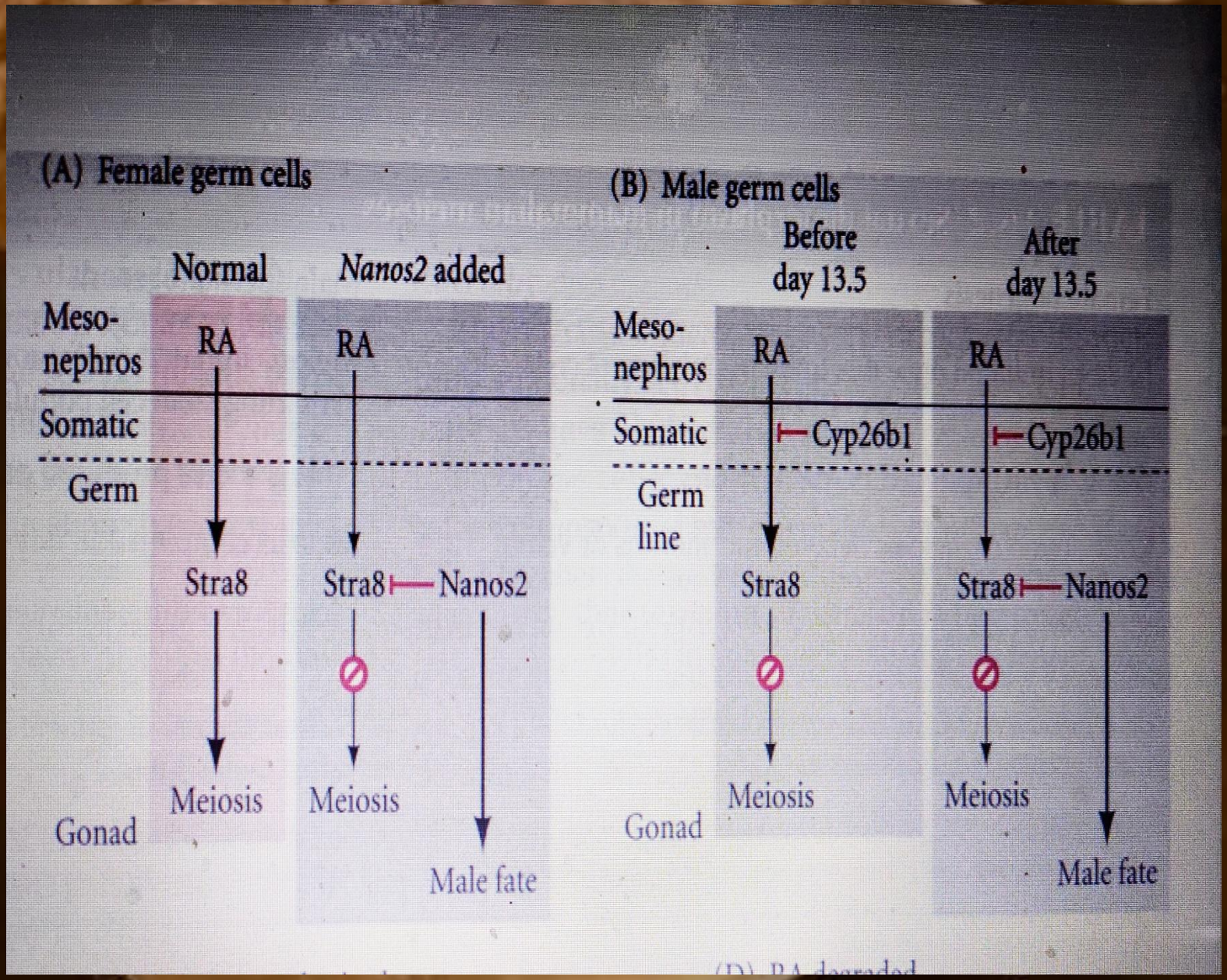

SO HOW TIMING IS DIFEERENT ??

In females, meiosis begins in the embryonic gonads BUT in males, meiosis is not initiated until puberty. HOW IT POSSIBLE ???

- This critical difference in timing is due to **Retinoic Acid (RA)** produced by the mesonephric kidneys .

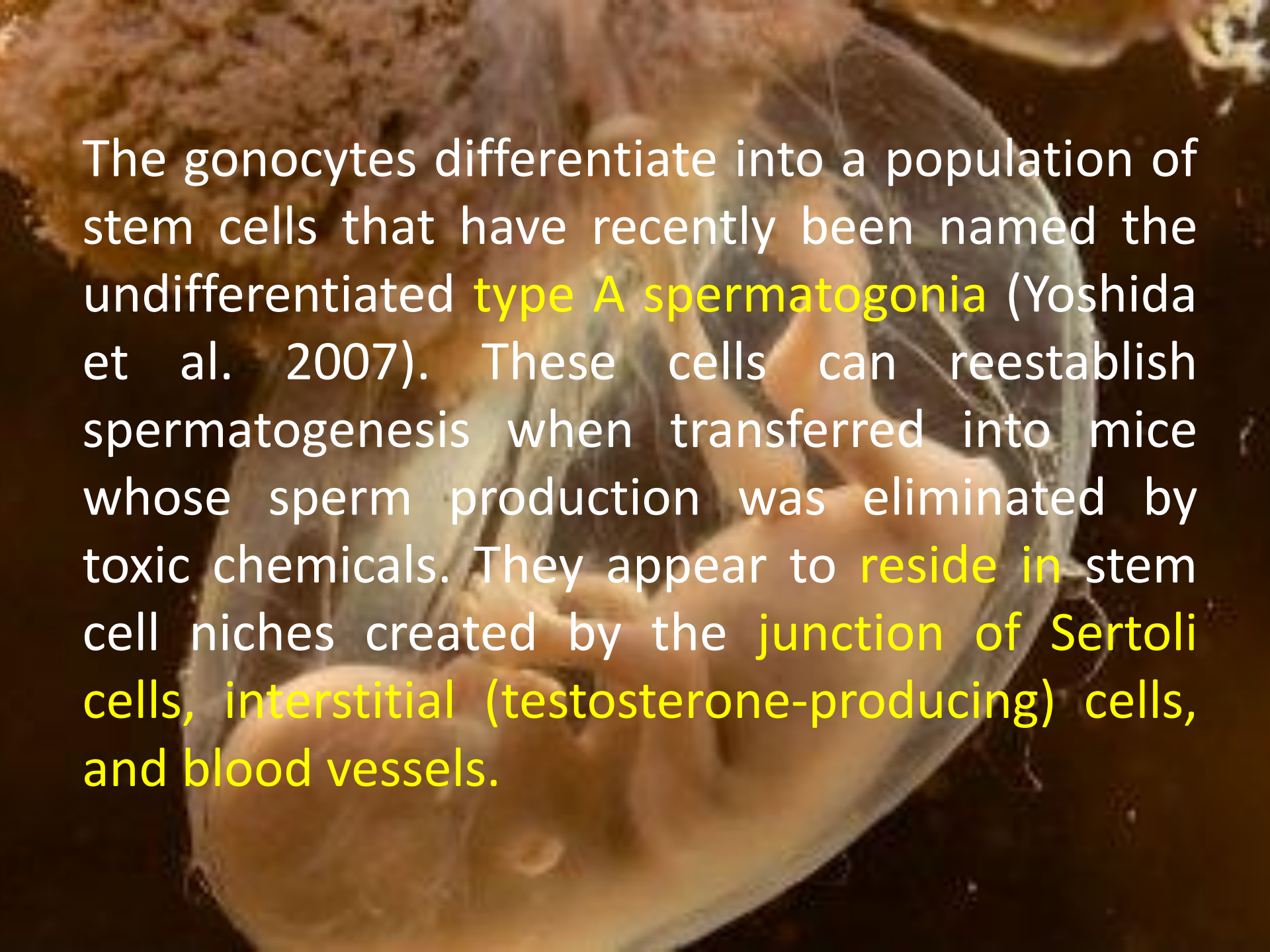
- This RA stimulates the germ cells to undergo a new round of DNA replication and initiate meiosis (Baltus et al. 2006; Bowles et al. 2006; Lin et al. 2008).

- In males, however, the embryonic testes secrete the **RA-degrading enzyme Cyp26b1**. This prevents RA from promoting meiosis. Later, **Nanos2** will be expressed in the male germ cells, and this will also prevent meiosis and ensure that the cells follow the pathway to become sperm (Koubova et al. 2006; Suzuki and Saga 2008).


(A) Female germ cells
Normal
Nanos2 added
Meso-
nephros
RA
RA
Somatic
Germ
Stra8
Stra8
Nanos2
Meiosis
Meiosis
Gonad
Male fate
(B) Male germ cells
Before
day 13.5
After
day 13.5
Meso-
nephros
RA
RA
Somatic
Cyp26b1
Cyp26b1
Germ
line
Stra8
Stra8
Nanos2
Meiosis
Meiosis
Gonad
Male fate

SPERMATOGENESIS

Once mammalian PGCs arrive at the genital ridge of a male embryo, they are called gonocytes and become incorporated into the sex cords (Culty 2009). They remain there until maturity, at which time the sex cords hollow out to form the seminiferous tubules. The epithelium of the tubules differentiates into the Sertoli cells that will nourish and protect the developing sperm cells.



The gonocytes differentiate into a population of stem cells that have recently been named the undifferentiated type A spermatogonia (Yoshida et al. 2007). These cells can reestablish spermatogenesis when transferred into mice whose sperm production was eliminated by toxic chemicals. They appear to reside in stem cell niches created by the junction of Sertoli cells, interstitial (testosterone-producing) cells, and blood vessels.

The decision to proliferate or differentiate may involve interactions between to pathways –
Wnt and BMP pathways.

Wnt signalling appears to promote proliferation of stem cells, and the spermatogonia appear to have receptors for both Wnts and BMPs (Golestaneh et al. 2009). The initiation of spermatogenesis during puberty is probably regulated by the synthesis of BMPs by the spermatogenic germ cells, the spermatogonia.

HOW BMPS INITIATES SPERMATOGENESIS ??

- When BMP8b reaches a critical concentration, the germ cells begin to differentiate.
- The differentiating cells produce high levels of BMP8b, which can then further stimulate their differentiation. Mice lacking BMP8b do not initiate spermatogenesis at puberty (Zhao et al. 1996).
- The spermatogenic germ cells are bound to the Sertoli cells by N-cadherin molecules on the surfaces of both cell types, and by galactosyltransferase molecules on the spermatogenic cells that bind a carbohydrate receptor on the Sertoli cells (Newton et al. 1993; Pratt et al. 1993).
- SpermatogenesiS occurs in the recesses between the Sertoli cells.

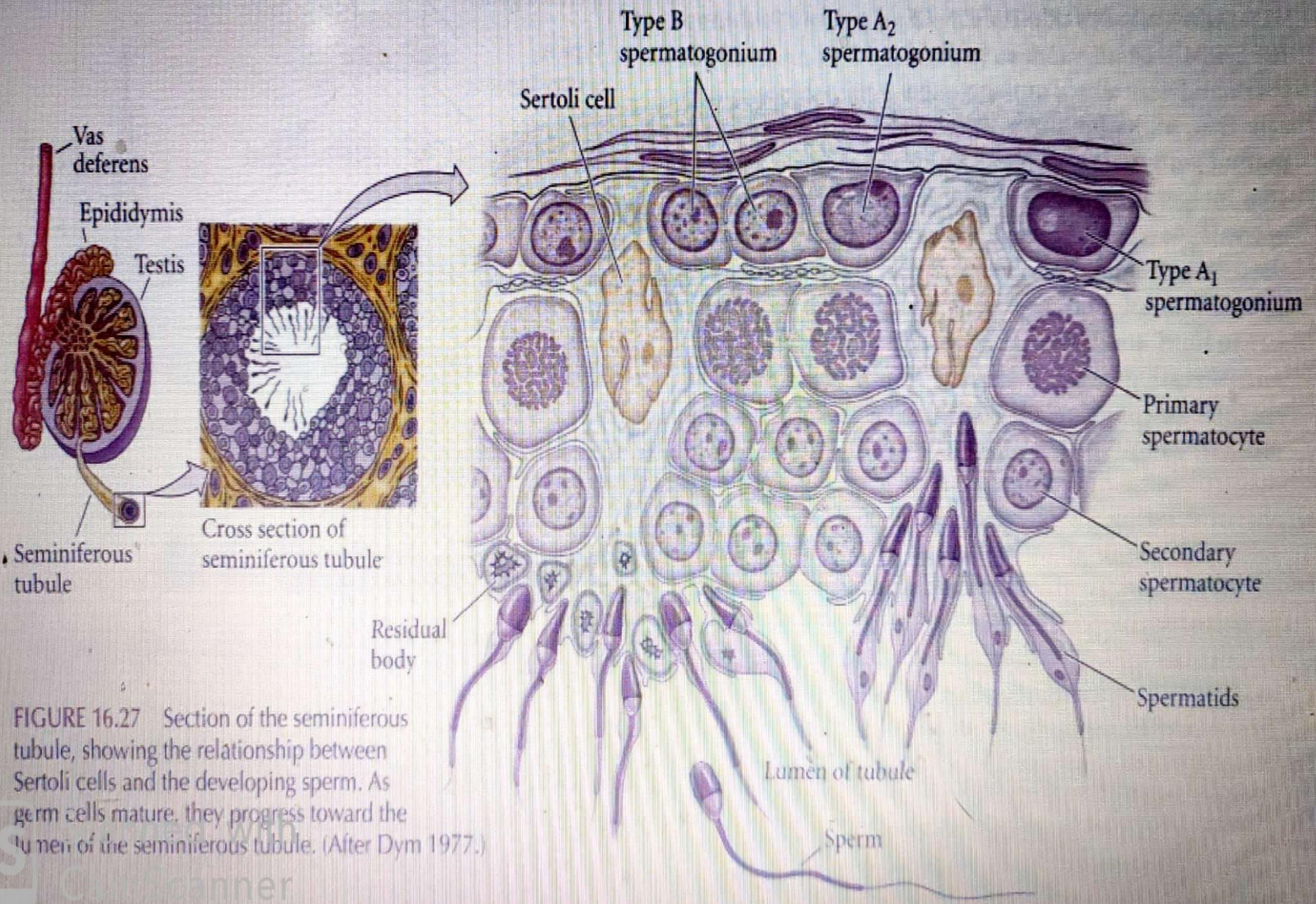


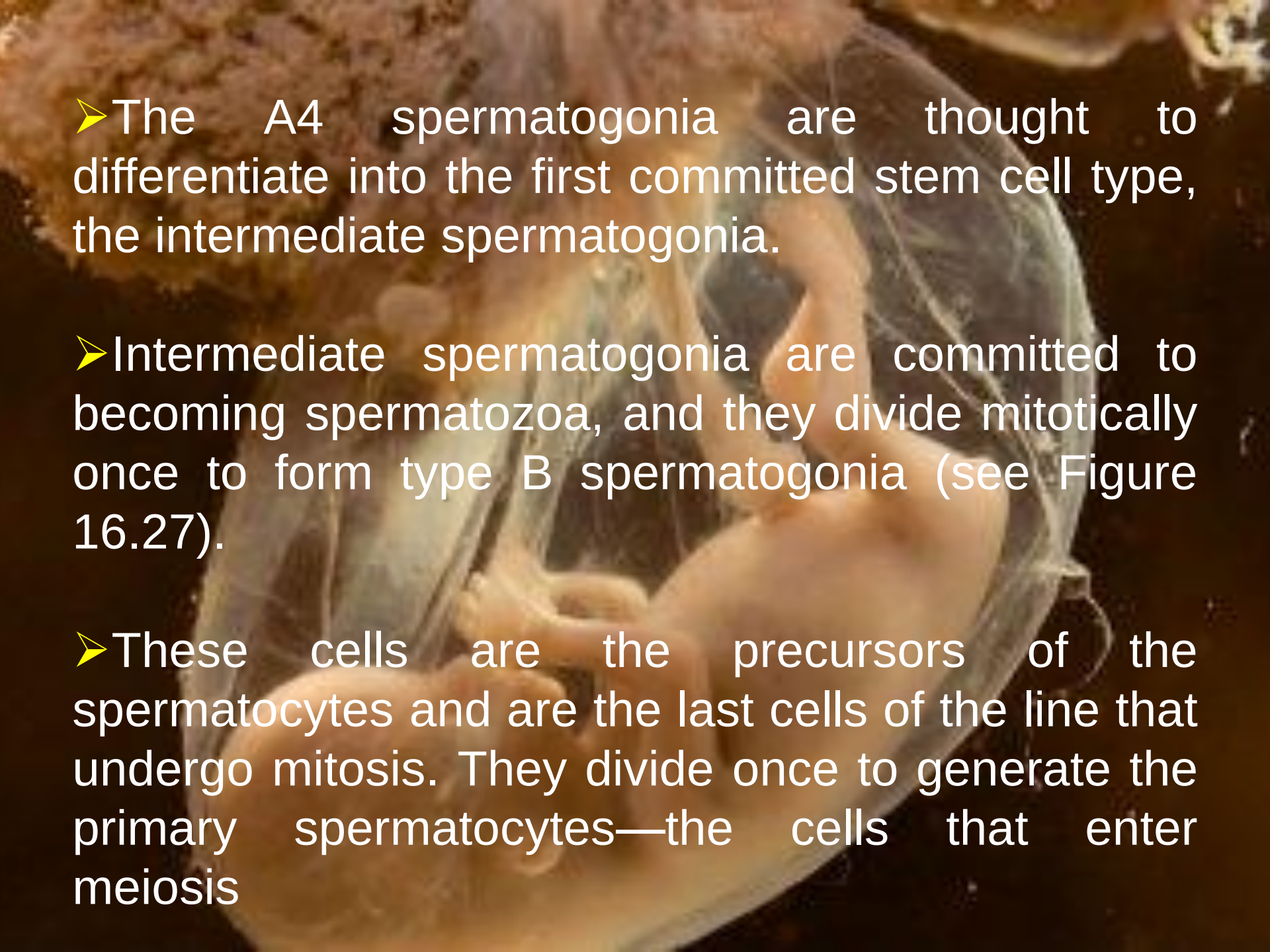
FIGURE 16.27 Section of the seminiferous tubule, showing the relationship between Sertoli cells and the developing sperm. As germ cells mature, they progress toward the lumen of the seminiferous tubule. (After Dym 1977.)

FORMING THE HAPLOID SPERMATID

- The undifferentiated type A1 spermatogonia (sometimes called the dense type A spermatogonia) are found adjacent to the outer basal lamina of the sex cords.

- They are stem cells, and upon reaching maturity are thought to divide to make another type A1 spermatogonium as well as a second,the type A2 spermatogonia.

- The A2 spermatogonia divide to produce type A3 spermatogonia, which then beget type A4 spermatogonia..



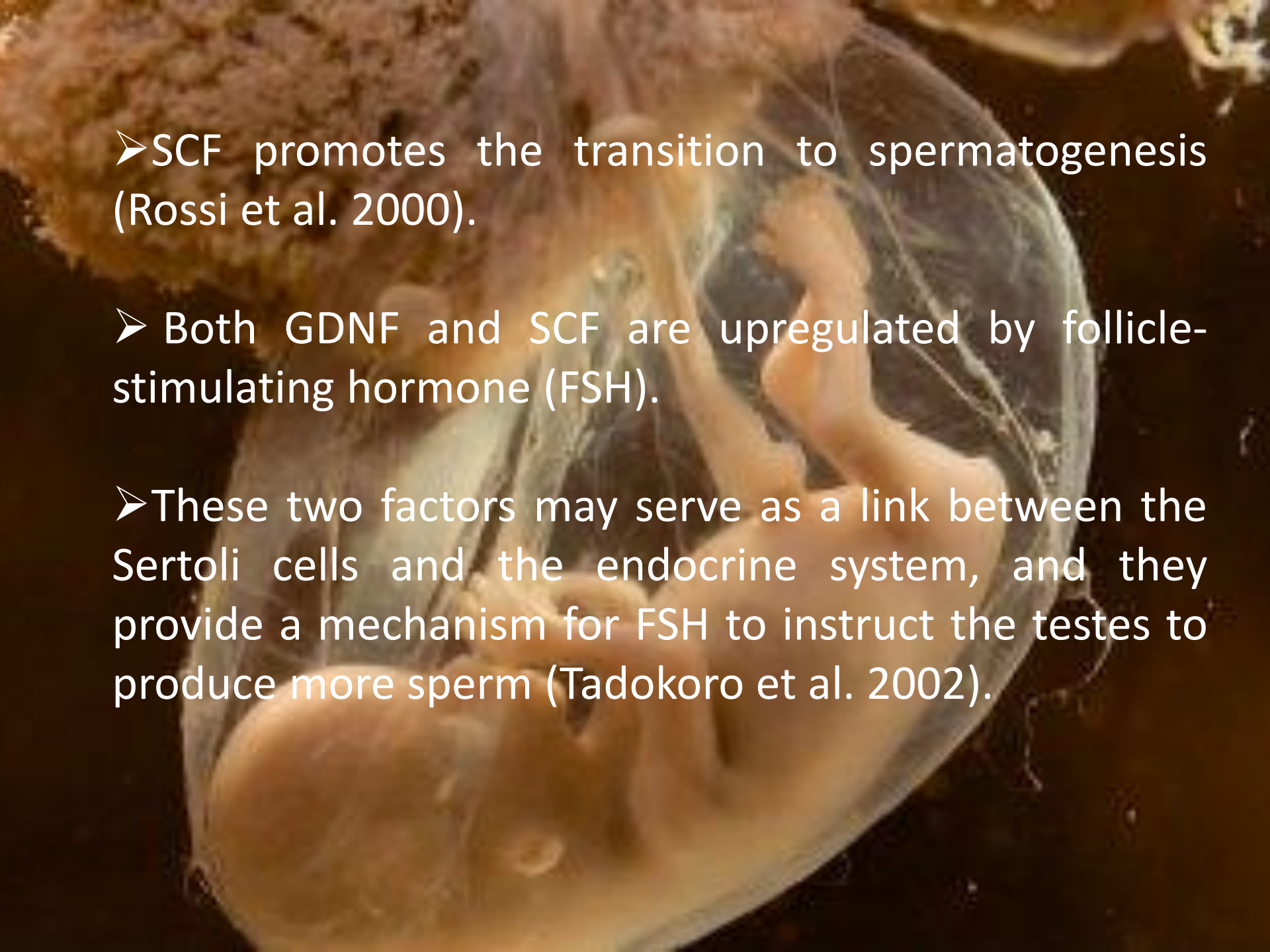
- The A4 spermatogonia are thought to differentiate into the first committed stem cell type, the intermediate spermatogonia.

- Intermediate spermatogonia are committed to becoming spermatozoa, and they divide mitotically once to form type B spermatogonia (see Figure 16.27).

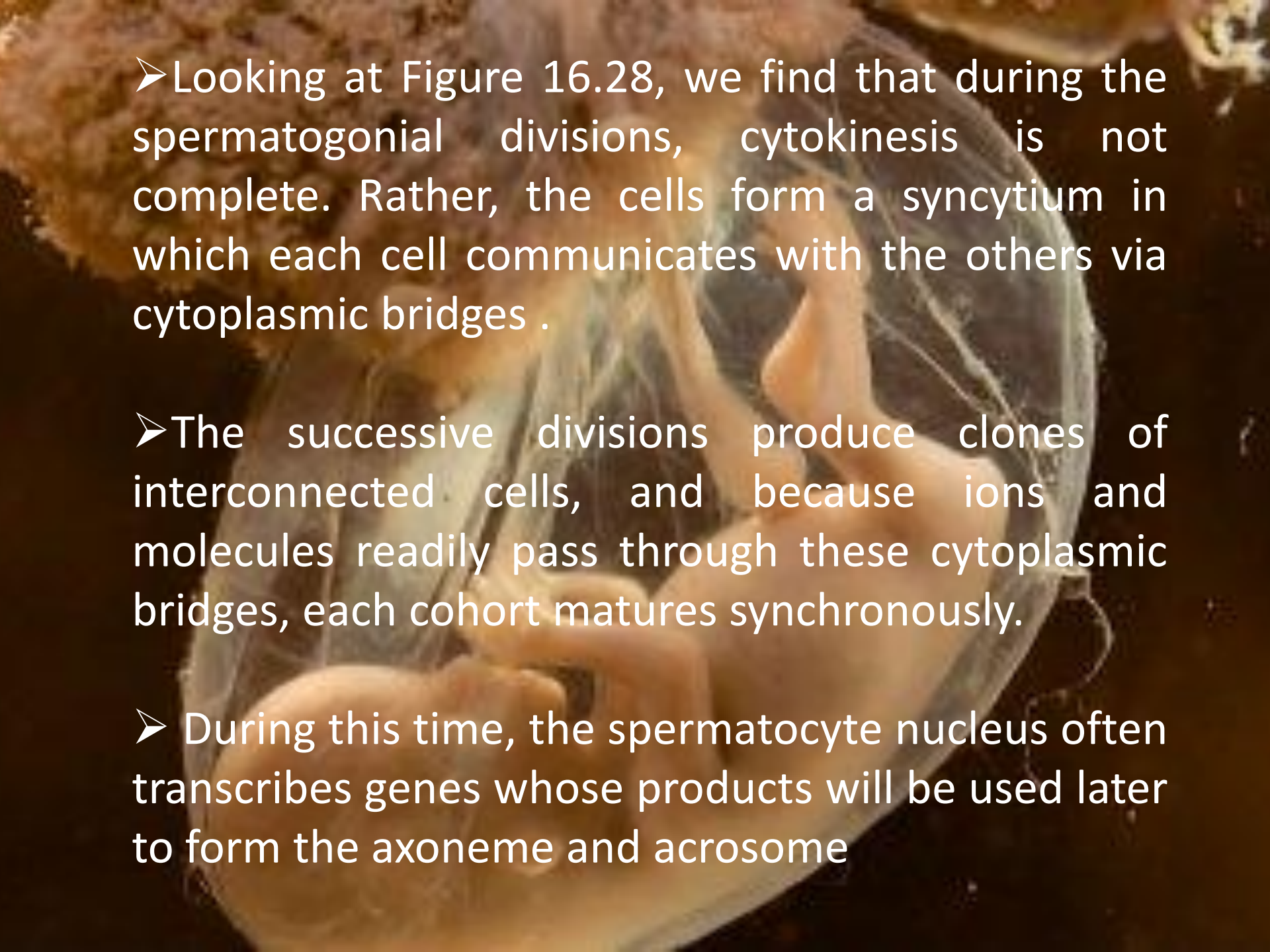
- These cells are the precursors of the spermatocytes and are the last cells of the line that undergo mitosis. They divide once to generate the primary spermatocytes—the cells that enter meiosis

The transition between spermatogonia and spermatocytes appears to be mediated by the opposing influences of two factors- glial cell line-derived neurotrophic factor (GDNF) and stem cell factor (SCF), both of which are secreted by the Sertoli cells.

- GDNF levels determine whether the dividing spermatogonia remain spermatogonia or enter the pathway to become spermatocytes. Low levels of GDNF favor the differentiation of the spermatogonia, whereas high levels favor self-renewal of the stem cells (Meng et al. 2000)



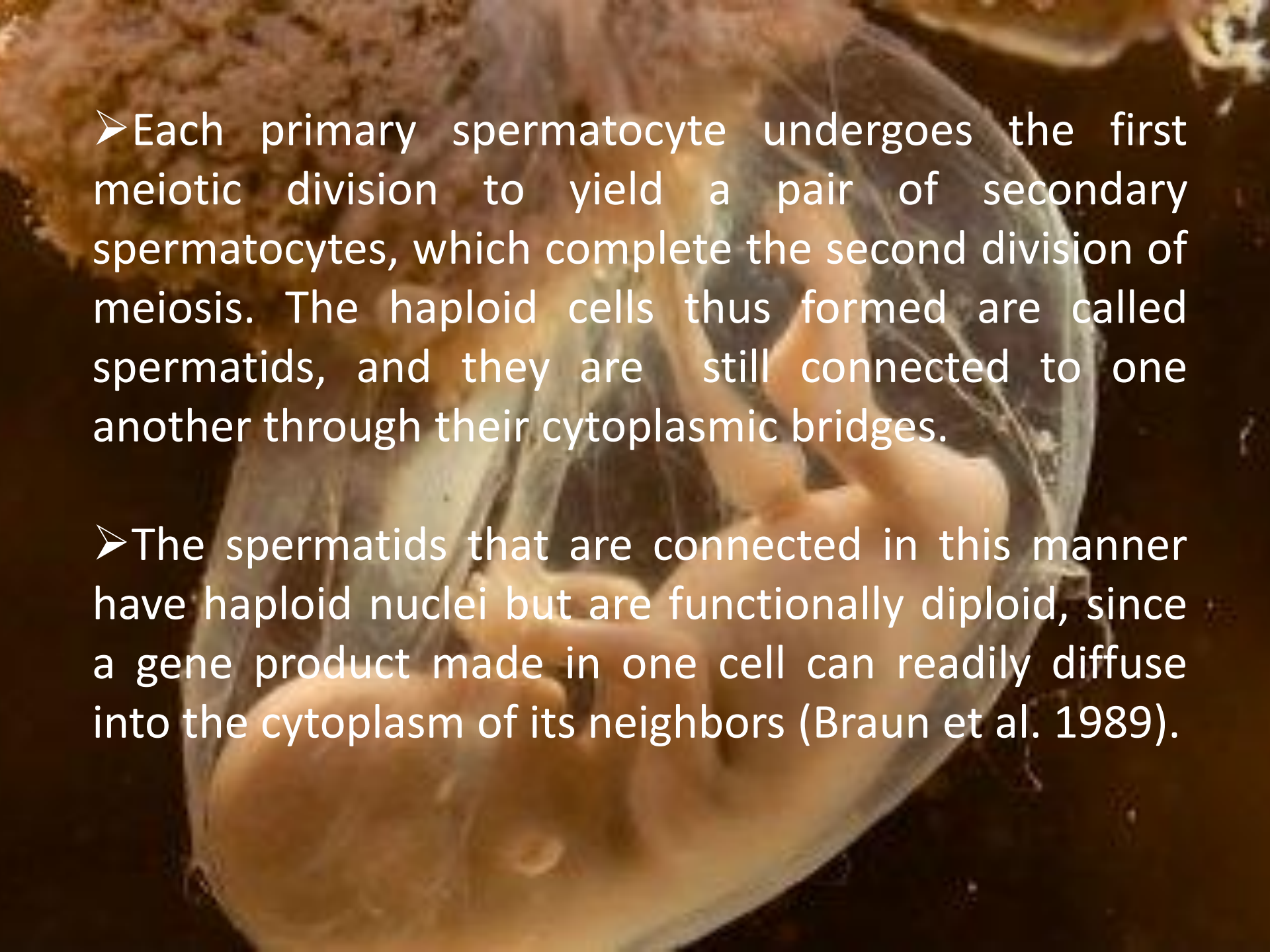
- SCF promotes the transition to spermatogenesis (Rossi et al. 2000).
- Both GDNF and SCF are upregulated by follicle-stimulating hormone (FSH).
- These two factors may serve as a link between the Sertoli cells and the endocrine system, and they provide a mechanism for FSH to instruct the testes to produce more sperm (Tadokoro et al. 2002).



- Looking at Figure 16.28, we find that during the spermatogonial divisions, cytokinesis is not complete. Rather, the cells form a syncytium in which each cell communicates with the others via cytoplasmic bridges .

- The successive divisions produce clones of interconnected cells, and because ions and molecules readily pass through these cytoplasmic bridges, each cohort matures synchronously.

- During this time, the spermatocyte nucleus often transcribes genes whose products will be used later to form the axoneme and acrosome



- Each primary spermatocyte undergoes the first meiotic division to yield a pair of secondary spermatocytes, which complete the second division of meiosis. The haploid cells thus formed are called spermatids, and they are still connected to one another through their cytoplasmic bridges.

- The spermatids that are connected in this manner have haploid nuclei but are functionally diploid, since a gene product made in one cell can readily diffuse into the cytoplasm of its neighbors (Braun et al. 1989).

- During the divisions from type A1 spermatogonia to spermatids, the cells move farther and farther away from the basal lamina of the seminiferous tubule and closer to its lumen (see Figure 16.27; Siu and Cheng 2004).

- Thus, each type of cell can be found in a particular layer of the tubule.

- The spermatids are located at the border of the lumen, and here they lose their cytoplasmic connections and differentiate into spermatozoa. In humans, the progression from spermatogonial stem cell to mature spermatozoa takes 65 days (Dym 1994).

OOGENESIS

- In the human embryo, the thousand of oogonia divide rapidly from the second to the seventh month of gestation to form roughly 7 million germ cells.
- After the seventh month of embryonic development, however, the number of germ cells drops precipitously.
- Most oogonia die during this period, while the remaining oogonia enter the first meiotic division (Pinkerton et al. 1961).
- These latter cells, called primary oocytes, progress through the first meiotic prophase until the diplotene stage, at which point they are maintained until the female matures.

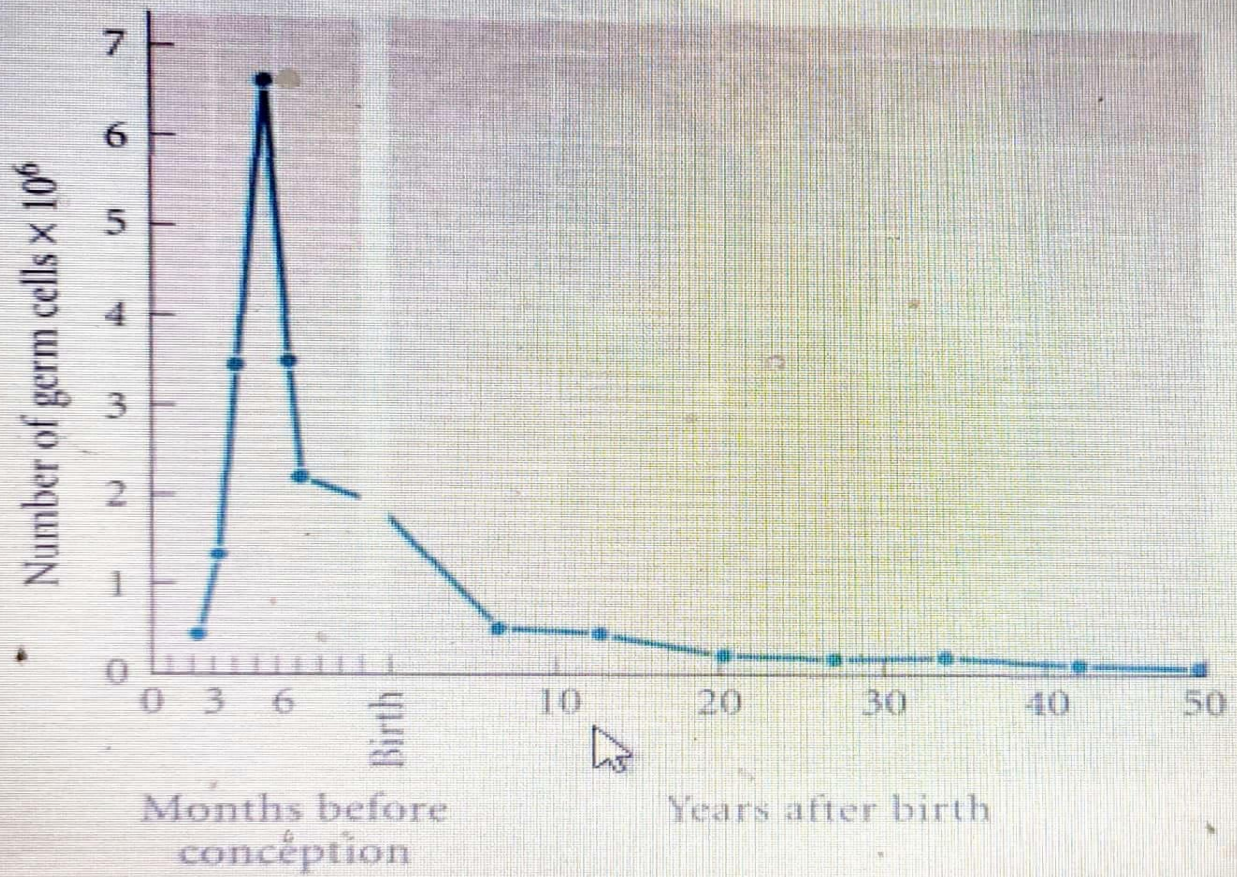
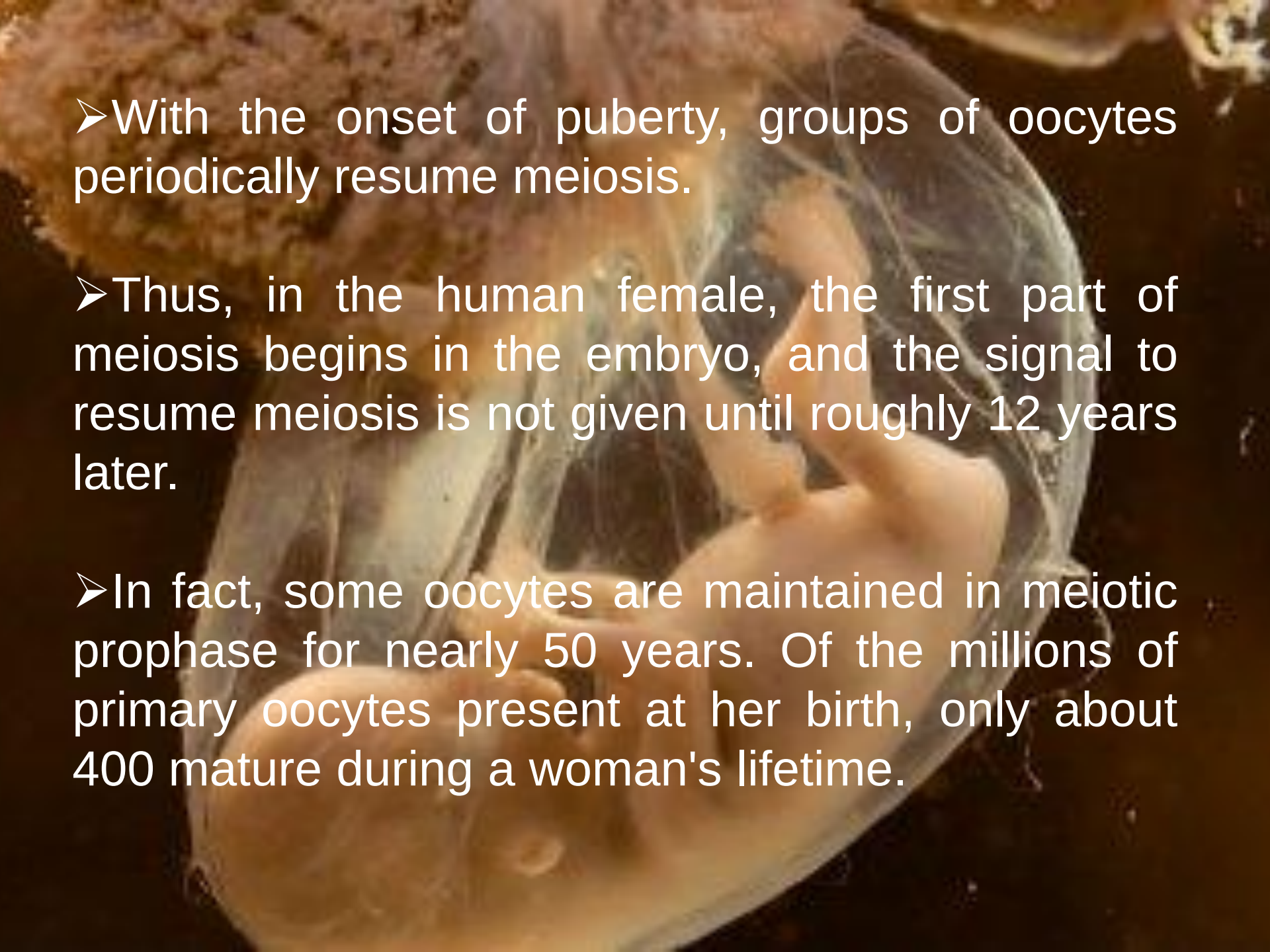


FIGURE 16.29 The number of germ cells in the human ovary changes over the life span. (After Baker 1970.)



- With the onset of puberty, groups of oocytes periodically resume meiosis.

- Thus, in the human female, the first part of meiosis begins in the embryo, and the signal to resume meiosis is not given until roughly 12 years later.

- In fact, some oocytes are maintained in meiotic prophase for nearly 50 years. Of the millions of primary oocytes present at her birth, only about 400 mature during a woman's lifetime.

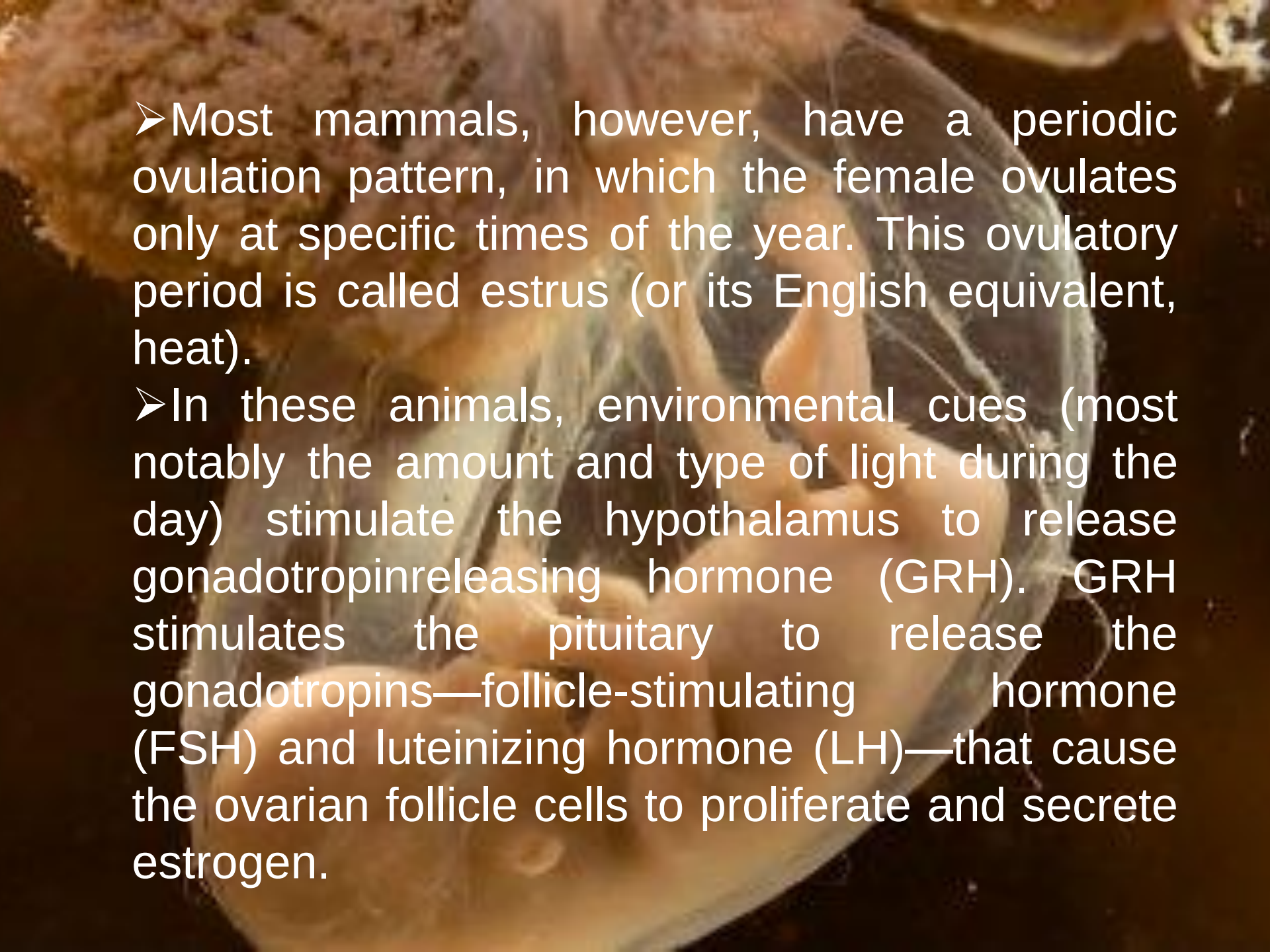
OOGENIC MEIOSIS

Oogenic meiosis differs from spermatogenic meiosis in its placement of the metaphase plate. When the primary oocyte divides, its nucleus, called the germinal vesicle, breaks down, and the metaphase spindle migrates to the periphery of the cell. At telophase, one of the two daughter cells contains hardly any cytoplasm, whereas the other cell retains nearly the entire volume of cellular constituents (Figure 16.30). The smaller cell is called the first polar body, and the larger cell is referred to as the secondary oocyte.

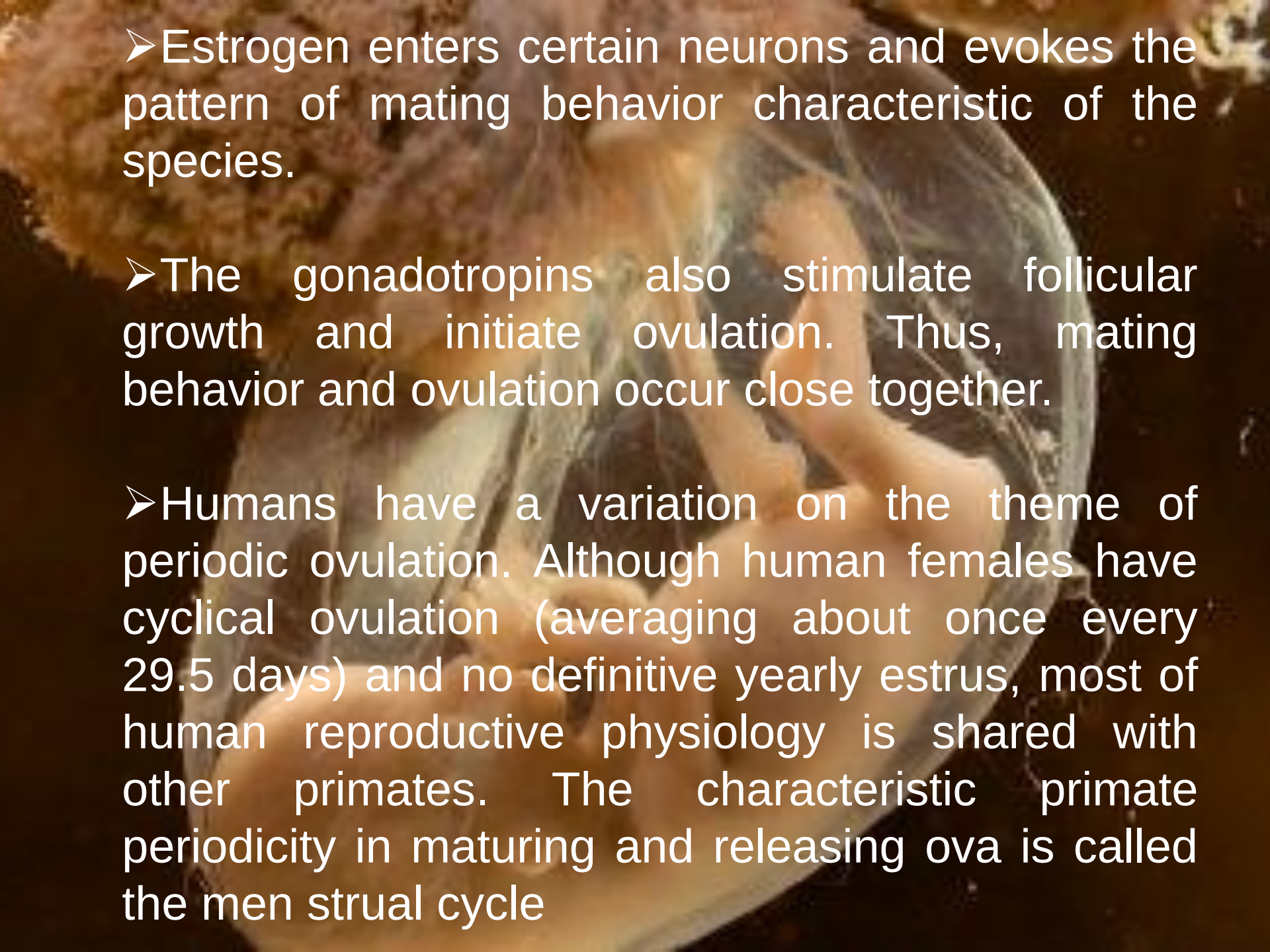
During the second division of meiosis, a similar unequal cytokinesis takes place. Most of the cytoplasm is retained by the mature egg (the ovum), and a second polar body receives little more than a haploid nucleus. (The first polar body usually does not divide.) Thus, oogenic meiosis conserves the volume of oocyte cytoplasm in a single cell rather than splitting it equally among four progeny.

MATURATION OF THE MAMMALIAN OOCYTE

Ovulation in mammals follows one of two patterns, depending on the species. One type of ovulation is stimulated by the act of copulation. Physical stimulation of the cervix triggers the release of gonadotropins from the pituitary. These gonadotropins signal the egg to resume meiosis and initiate the events that will expel it from the ovary. This mechanism ensures that most copulations will result in fertilized ova, and animals that utilize this method of ovulation—such as rabbits and minks—have a reputation for procreative success.



- Most mammals, however, have a periodic ovulation pattern, in which the female ovulates only at specific times of the year. This ovulatory period is called estrus (or its English equivalent, heat).
- In these animals, environmental cues (most notably the amount and type of light during the day) stimulate the hypothalamus to release gonadotropinreleasing hormone (GRH). GRH stimulates the pituitary to release the gonadotropins—follicle-stimulating hormone (FSH) and luteinizing hormone (LH)—that cause the ovarian follicle cells to proliferate and secrete estrogen.



- Estrogen enters certain neurons and evokes the pattern of mating behavior characteristic of the species.

- The gonadotropins also stimulate follicular growth and initiate ovulation. Thus, mating behavior and ovulation occur close together.

- Humans have a variation on the theme of periodic ovulation. Although human females have cyclical ovulation (averaging about once every 29.5 days) and no definitive yearly estrus, most of human reproductive physiology is shared with other primates. The characteristic primate periodicity in maturing and releasing ova is called the men strual cycle

The menstrual cycle represents the integration of three very different cycles:

1. The ovarian cycle, the function of which is to mature and release an oocyte.
2. The uterine cycle, the function of which is to provide the appropriate environment for the developing blastocyst.
3. The cervical cycle, the function of which is to allow sperm to enter the female reproductive tract only at the appropriate time. These three functions are integrated through the hormones of the pituitary, hypothalamus, and ovary.

- The majority of the oocytes in the adult huma n ovary are maintained in the diplotene stage of the first meiotic prophase, often referred to as the dictyate state.
- Each oocyte is enveloped by a primordial follicle consisting of a single layer of epithelial granulosa cells and a less organized layer of mesenchymal thecal cells (Figure 16.31).
- Periodically, a group of primordial follicles enters a stage of follicular growth. During this time, the oocyte undergoes a 500-fold increase in volume (corresponding to an increase in oocyte diameter from 10 um in a primordial follicle to 80 um in a fully developed follicle).

Books used as References to prepare the presentation:

1. DEVELOPMENTAL BIOLOGY: 9TH ED. BY GILBERT