# STUDY GUIDE AND SELF-EXAMINATION REVIEW

FOR

LANGMAN'S

# MEDICAL EMBRYOLOGY

FIFTH EDITION

**T. W. Sadler, Ph.D.**

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# Preface

This study guide has been written for medical students, physicians, and others who require a review of medical embryology. As such, it is designed to highlight essential facts and provide an overview of development from gamete formation to birth, including separate chapters directed toward understanding the morphogenesis of organ systems. The National Board format of questions is employed, but the redundancy of enlisting large numbers of questions to illustrate each point has been avoided. Instead, emphasis is placed on the specific topics to be learned. In this regard, the guide is specifically designed to correlate with *Langman's Medical Embryology* and the points made by each question are referred by page number to this text for further study. However, it should be noted that the guide will serve its purpose well when used in combination with other textbooks of medical embryology.

The author is indebted to his sister, who provided the drawings, and to his wife, who assisted in preparation of the manuscript.

# Contents

# 1

# Gamete Formation and Fertilization

LANGMAN CHAPTERS 1 and 2

## Objectives

After completing this period of study, be able to:

1. Describe the processes of spermatogenesis and oogenesis including differences between the two during germ cell maturation.
2. Compare the ovarian cycle with the endometrial cycle.
3. Describe the process of fertilization and discuss at least four results accomplished by union of the gametes.
4. Define the normal site of implantation and list the more common sites of ectopic pregnancy.
5. Trace the period of development from zygote to blastocyst formation.

# Questions

**DIRECTIONS:** Each question or incomplete statement listed below is followed by five suggested responses or completions. Select the one best answer in each case.

**1.1.** In contrast to mitosis, the first meiotic division is characterized by:

A. cytokinesis
B. synthesis of DNA
C. pairing of homologous chromosomes
D. separation of chromatids into daughter cells
E. none of the above

**1.2.** The exchange of genetic material via crossover occurs:

A. between maternal and paternal chromosomes after fertilization
B. during the second meiotic division
C. during mitosis
D. during the pairing of homologous chromosomes in meiosis
E. after the first meiotic division has occurred

**1.3.** The normal allocation of chromosomes in a sperm is

A. 23 autosomes
B. 23 autosomes plus a sex chromosome
C. 22 autosomes plus a sex chromosome
D. 22 paired autosomes plus a pair of sex chromosome
E. 22 autosomes

**1.4.** Primordial germ cells migrate to the gonads from the

A. intermediate mesoderm
B. wall of the yolk sac
C. lateral plate mesoderm
D. endoderm of the bilaminar disc
E. splanchnic mesoderm

**1.5.** Oogonia divide by mitosis during

A. their migration to the gonadal ridges
B. late fetal life
C. postnatal life
D. puberty to menopause
E. the 2nd to the 5th month of prenatal life

**1.6.** The secondary oocyte undergoes completion of the second maturation division

A. before ovulation
B. at fertilization
C. after ovulation
D. prenatally
E. at puberty

**1.7.** During penetration of the follicle by sperm, passage through which layer(s) initiates a reaction that blocks polyspermy

A. zona pellucida
B. oocyte plasma membrane
C. corona radiata
D. nuclear membrane of the oocyte
E. all of the above

**1.8.** Which portion of the blastocyst will give rise to the embryo?

A. inner cell mass
B. ectoderm
C. endoderm
D. cytotrophoblast
E. none of the above

**1.9.** Ectopic pregnancies occur most frequently in the

A. abdomen
B. uterine tube
C. ovary
D. mesentery of the intestines
E. internal os of the uterus

# Answers

**1.1. The answer is C** (*Langman*, pp. 5 and 6) Pairing of homologous chromosomes occurs only during meiosis and is the time when each chromosome pair can exchange genetic material (crossover). Both processes require synthesis of DNA and include cytokinesis, but chromatids are separated in mitosis, whereas homologous chromosomes separate in meiosis I.

**1.2. The answer is D** (*Langman*, pp. 5 and 6) Crossover occurs during the first meiotic division when homologous chromosomes pair and permits exchange of genetic material.

**1.3. The answer is C** (*Langman*, pp. 6 and 7) The normal number of chromosomes in a sperm is 23: 22 autosomes and 1 sex chromosome (either X or Y). A normal oocyte also has 22 autosomes and 1 sex chromosome which is always an X. Sometimes during meiosis separation of homologous chromosomes (meiosis I) or chromatids (meiosis II) fails to occur. This event is known as nondisjunction and results in one germ cell with too many chromosomes and one with too few.

**1.4. The answer is B** (*Langman*, pp. 8 and 9) The germ cells are clearly visible among the endoderm cells of the yolk sac near the allantois. They migrate by ameboid movement along the dorsal mesentery of the hindgut and arrive at the gonads at the end of the 4th or beginning of the 5th week.

**1.5. The answer is E** (*Langman*, pp. 8–10) By the 5th month the total number of germ cells, oogonia and primary oocytes, has reached a maximum estimated at 7,000,000. Many of the cells now begin to die, such that at birth only 700,000 to 2,000,000 primary oocytes remain. During childhood most of these will become atretic and only approximately 40,000 will be present at puberty.

**1.6. The answer is B** (*Langman*, p. 13) The secondary oocyte is ovulated the moment that spindle formation occurs, but completes its second maturation division without DNA replication only at the time of fertilization. If fertilization fails to occur the cell degenerates approximately 24 hours after ovulation.

**1.7. The answer is A** (*Langman*, pp. 24–26) Permeability of the zona pellucida changes when the head of the sperm penetrates this layer (by means of acrosomal enzymes) and makes contact with the oocyte surface. This contact results in the zona reaction rendering the zona pellucida impermeable to other sperm.

**1.8. The answer is A** (*Langman*, p. 30) The inner cell mass, or embryoblast, is located at one pole of the blastocyst and will give rise to the embryo. This region is responsible for the formation of the three germ layers including the ectoderm, endoderm, and mesoderm.

**1.9. The answer is B** (*Langman*, pp. 34–36) Fertilization normally occurs in the ampullary region of the uterine tube, while implantation normally takes place along the anterior or posterior wall of the body of the uterus. The most common site of ectopic pregnancy is in the uterine tube due to a lack of movement of the fertilized ovum to the uterus. Usually the tube ruptures during the 2nd month resulting in severe internal hemorrhaging by the mother.

# Questions

**DIRECTIONS:** For each of the incomplete statements below, *one* or *more* of the completions given is correct. Choose answer:

A. if only **1, 2,** and **3** are correct
B. if only **1** and **3** are correct
C. if only **2** and **4** are correct
D. if only **4** is correct
E. if all are correct

**1.10.** Meiosis
1. reduces the amount of DNA and the number of chromosomes by one half in the resulting daughter cells
2. sometimes results in nondisjunction where one cell receives 24 chromosomes and another 22
3. serves as a means of exchange of genetic material between homologous chromosomes during the first meiotic division
4. produces four mature gametes from a single cell in both the male and female

**1.11.** Primary oocytes
1. are arrested in prophase of the first meiotic division
2. suffer from atretion until only approximately 40,000 are left at puberty
3. together with surrounding epithelial cells form a primordial follicle
4. continue to form after birth

**1.12.** During spermiogenesis spermatids undergo changes including
1. formation of a neck, mid-piece, and tail
2. formation of the acrosome
3. loss of cytoplasm
4. nuclear condensation

**1.13.** Prior to fertilizing an egg, a sperm must
1. penetrate the corona radiata and zona pellucida
2. undergo a second meiotic division
3. undergo capacitation and the acrosomal reaction
4. secrete fluids that promote its motility

**1.14.** Immediately after a spermatozoon enters the oocyte the egg responds by
1. undergoing cortical and zona reactions
2. completing the second meiotic division
3. undergoing metabolic activity
4. discarding the zona pellucida

**1.15.** As a result of fertilization:
1. sex of the offspring is determined
2. the diploid number of chromosomes is restored
3. cleavage divisions are initiated
4. genetic heterogeneity is maintained

**1.16.** After 3–4 cell divisions the zygote
1. consists of 12–16 cells and is about 3 days old
2. has the appearance of a mulberry and is known as the morula
3. consists of an inner cell mass and an outer cell mass
4. contains trophoblastic cells which have contacted the endometrium

**1.17.** During the secretory (progestational) phase the uterine endometrium is composed of which of the following layers:
1. compact layer
2. basal layer
3. spongy layer
4. muscle layer

# Answers

**1.10. The answer is A** (*Langman*, pp. 5–7) The purpose of meiosis is to reduce the chromosome number and amount of DNA by one half and to provide a means of exchange of genetic material between homologous chromosomes. As a result of meiosis in the germ cells, four gametes are formed from a single cell in the male, whereas only one is formed in the female. Each gamete contains 23 chromosomes unless an improper distribution (nondisjunction) has occurred during one of the meiotic divisions.

**1.11. The answer is A** (*Langman*, pp. 8–11) Primary oocytes form from oogonia and are arrested in prophase of the first meiotic division. The number of germ cells in the ovary reaches its maximum of 7,000,000 by the 5th month of development. Thereafter, oogonia and primary oocytes become atretic and by puberty only a total of 40,000 remain. Primary oocytes, together with their surrounding flat epithelial cells, are known as primordial follicles. No new oocytes are formed after birth.

**1.12. The answer is E** (*Langman*, p. 15) Spermatids undergo a series of changes resulting in the production of spermatozoa. These include: 1) formation of the acrosome which covers the upper portion of the nucleus; 2) formation of a midpiece, neck, and tail; 3) loss of cytoplasm; and 4) nuclear condensation. In man, the process of developing a mature spermatozoon from a spermatogonium requires 61 days.

**1.13. The answer is B** (*Langman*, pp. 24–26) In order to fertilize an ovum a sperm must undergo capacitation and the acrosomal reaction. The latter results in the release of enzymes which disperse the corona radiata and digest the zona pellucida, thereby permitting penetration of these layers. Fluids secreted by the female reproductive tract assist in sperm motility and may aid in dispersal of the corona radiata. Sperms do not undergo cell division, but instead are transformed into mature cells during spermiogenesis.

**1.14. The answer is A** (*Langman*, pp. 26 and 27) Penetration of the egg by the sperm results in the cortical and zona reactions which render the egg impermeable to other sperm. The head and tail of the sperm enter the egg, but the cell membrane remains outside. The egg now completes the second meiotic division to form the definitive oocyte whose chromosomes become arranged in a vesicular nucleus known as the female pronucleus. Metabolic activation also occurs and may be considered to include the initial cellular and molecular events associated with early embryogenesis. The zona pellucida is not discarded until the early blastocyst stage at approximately 4½ days of gestation.

**1.15. The answer is E** (*Langman*, pp. 26–28) The main results of fertilization include: 1) determination of the sex of the offspring, XX being female; XY being male; 2) restoration of the diploid number of chromosomes; 3) initiation of cleavage as opposed to degeneration of the ovum 24 hours after ovulation if fertilization does not occur; and 4) maintenance of genetic heterogeneity, since the offspring receives a complement of chromosomes from each parent.

**1.16. The answer is A** (*Langman*, pp. 29) At approximately 3 days of age, the zygote has undergone 3–4 cell divisions resulting in the 12–16-cell stage with the shape of a mulberry, known as the morula. This structure contains a group of centrally located cells forming the inner cell mass, which will give rise to embryonic tissues, and a surrounding layer known as the outer cell mass, which will form the trophoblast. Implantation has not yet occurred, although the zygote is beginning to enter the uterine cavity.

**1.17. The answer is A** (*Langman*, pp. 31–33) The wall of the uterus consists of three layers including the endometrium (inner mucosa), myometrium (smooth muscle), and perimetrium (peritoneal covering). At implantation the mucosal layer (endometrium) has responded to the influence of progesterone and is composed of three layers including an inner compact layer, a spongy layer, and a basal layer. The muscle layer lies outside the basal layer and is not part of the endometrium.

# Questions

**DIRECTIONS:** Questions 1.18–1.22 refer to Figure 1.1 (*Langman*, p. 25); 1.23–1.27 refer to Figure 1.2 (*Langman*, p. 32). For each numbered word or phrase select the lettered part of each figure that matches it correctly. Each letter may be used more than once.

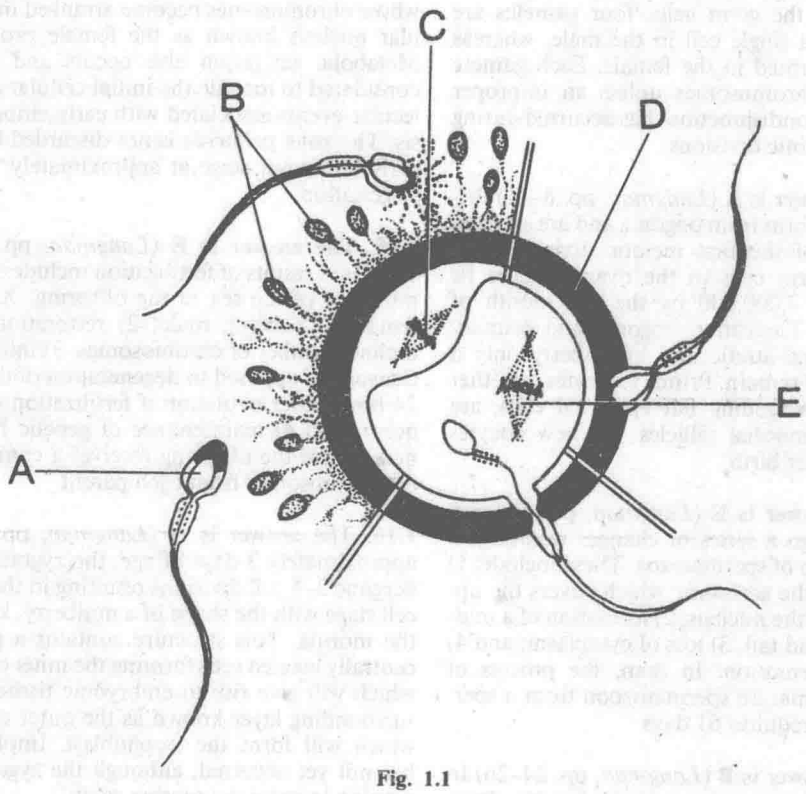


Fig. 1.1

**1.18.** Secondary oocyte meiotic spindle
**1.19.** Zona pellucida
**1.20.** Polar body
**1.21.** Haploid cell
**1.22.** Follicular cells

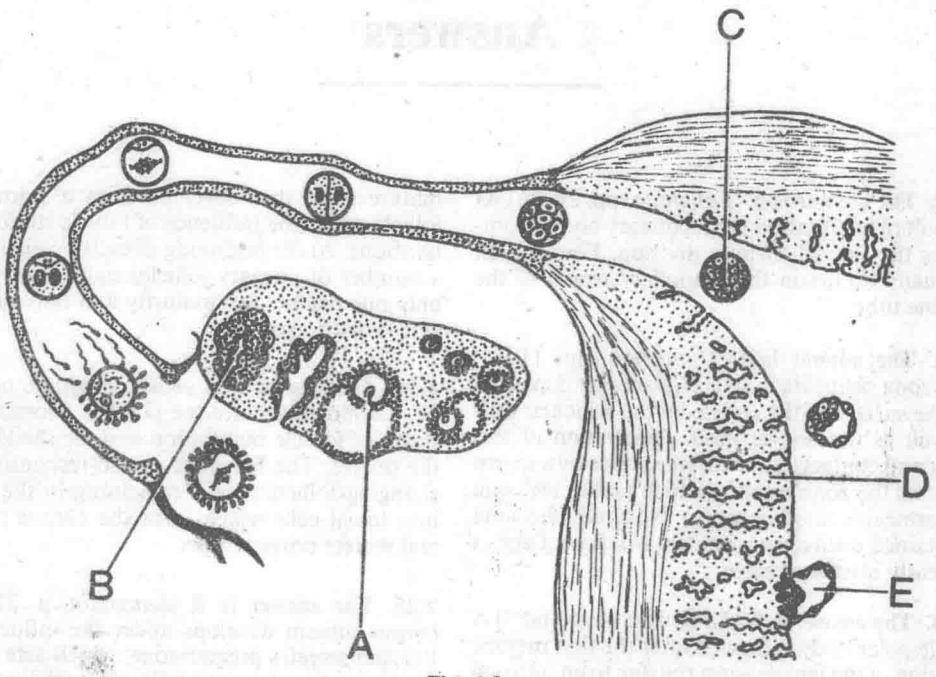


Fig. 1.2

1.23. Graafian follicle
1.24. Develops under the influence of LH
1.25. Secretes progesterone
1.26. Approximately 6-day-old conceptus
1.27. Maintained by progesterone

# Answers

**1.18. The answer is E** (*Langman*, pp. 24–26) As a result of fertilization the secondary oocyte completes the second meiotic division. Fertilization normally occurs in the ampullary region of the uterine tube.

**1.19. The answer is D** (*Langman*, pp. 11–13) The zona pellucida is an acellular layer deposited on the surface of the oocyte by the follicular cells as well as the oocyte itself. Penetration of this layer and contact of the oocyte surface by a sperm initiates the zona reaction which makes the zona impermeable to other sperm. Normally the zona is retained until approximately 4½ days of age at the early blastocyst stage.

**1.20. The answer is C** (*Langman*, pp. 6 and 7) A single polar body is formed after the first meiotic division of the female germ cell due to an unequal distribution of cytoplasm. Two additional polar bodies are formed after the second meiotic division such that one primary oocyte gives rise to only one mature gamete.

**1.21. The answer is A** (*Langman*, pp. 6 and 7) The sperm is a haploid cell containing 22 autosomes and an X or Y chromosome. Thus, the sperm determines the sex of the offspring since normal oocytes contain a single X chromosome and 22 autosomes. Neither the polar body nor the oocyte are haploid at this stage.

**1.22. The answer is B** (*Langman*, pp. 13 and 22) Cells surrounding the oocyte outside the zona pellucida are known as the corona radiata which is composed of one or more layers of follicular cells. Follicular cells remaining in the wall of the ruptured follicle are stimulated by luteinizing hormone to form the corpus luteum and secrete progesterone.

**1.23. The answer is A** (*Langman*, pp. 19 and 20) The Graafian or vesicular follicle represents a mature stage that develops from a primordial follicle under the influence of follicle stimulating hormone. At the beginning of each ovarian cycle, a number of primary follicles start to grow, but only one reaches full maturity and only one oocyte is discharged.

**1.24. The answer is A** or **B** (*Langman*, pp. 19–22) Luteinizing hormone (LH) is necessary for stages of follicle maturation and for shedding of the oocyte. The hormone is also responsible for changing follicular cells remaining in the ovary into luteal cells which form the corpus luteum and secrete progesterone.

**1.25. The answer is B** (*Langman*, p. 22) The corpus luteum develops under the influence of LH and secretes progesterone, which acts on the uterine endometrium to bring about the secretory phase. If fertilization occurs the corpus luteum enlarges and increases its hormone production. If fertilization fails to occur, the corpus luteum degenerates, forming a fibrotic scar known as the corpus albicans.

**1.26. The answer is E** (*Langman*, pp. 30–32) At approximately 6 days after fertilization, the blastocyst begins to implant in the uterine wall. Penetration is initiated by cells covering the embryoblast known as trophoblast cells.

**1.27. The answer is D** (*Langman*, pp. 31–34) The uterine endometrium is maintained by progesterone. First, this hormone is secreted by the corpus luteum which, after fertilization, continues to grow to form the corpus luteum of pregnancy. By the end of the 4th month, secretion of progesterone by the trophoblastic component of the placenta becomes adequate for maintenance of pregnancy and the corpus luteum regresses. Removal of the corpus luteum prior to the 4th month usually leads to abortion.

# 2

# Bilaminar and Trilaminar Disc Formation

LANGMAN CHAPTERS 3 and 4

## Objectives

After completing this period of study, be able to:

1. Describe the process of implantation.
2. Describe villus formation in the placenta and the role of the cytotrophoblast and syncytiotrophoblast.
3. Describe the formation of the amnion, primitive and secondary yolk sacs, intra- and extra-embryonic coeloms.
4. Describe the process of gastrulation and define primitive streak, primitive knot (Hensen's node), notochordal process, and intra-embryonic mesoderm.

# Questions

**DIRECTIONS:** Each question or incomplete statement listed below is followed by five suggested responses or completions. Select the one best answer in each case.

**2.1.** Which germ layers are present at the beginning of the second week of development?

A. epiblast
B. mesoderm
C. hypoblast
D. epiblast and mesoderm
E. epiblast and hypoblast

**2.2.** The amniotic cavity

A. is formed from the inner cell mass
B. lies between the epiblast layer and the syncytiotrophoblast
C. is formed in the extra-embryonic mesoderm
D. is part of the chorionic cavity
E. contains the primitive yolk sac

**2.3.** The space between the somatopleuric and splanchnopleuric extraembryonic mesoderm is known as

A. the primitive yolk sac
B. the secondary yolk sac
C. the blastocoele
D. the amniotic cavity
E. the extra-embryonic coelom

**2.4.** Primary stem villi consist of

A. columns of syncytiotrophoblast
B. columns of cytotrophoblast
C. spiral arteries and surrounding endometrial tissue
D. columns of cytotrophoblast surrounded by syncytium
E. none of the above

**2.5.** The chorionic cavity

A. is equivalent to the intra-embryonic coelom
B. is lined by extra-embryonic mesoderm
C. is formed by a coalition of exocoelomic cysts
D. contains the free-floating conceptus
E. communicates with the uterine endometrium via the chorionic plate

**2.6.** The initial morphological change preparatory to gastrulation is

A. formation of the prochordal plate
B. migration of laterally placed ectoderm cells toward the midline
C. formation of the primitive streak
D. formation of the notochordal process
E. delamination of the epiblast from the hypoblast

**2.7.** The mesodermal layer and the notochordal process separate the ectoderm from the endoderm in the trilaminar disc embryo except in the region of

A. the cloacal membrane
B. the prochordal plate
C. both A and B
D. neither A nor B

# Answers

**2.1. The answer is E** (*Langman*, pp. 39–41) At the beginning of the 2nd week of development the blastocyst is partially embedded in the endometrial stroma and the embryoblast has differentiated into two layers. One is formed of small cuboidal cells, the hypoblast layer; the other consists of tall columnar cells, the epiblast layer. Together they form the bilaminar germ disc.

**2.2. The answer is A** (*Langman*, pp. 40 and 41) The amniotic cavity forms within the epiblast of the inner cell mass and those epiblast cells adjacent to the cytotrophoblast are known as amnioblasts. The syncytiotrophoblast lies outside the cytotrophoblast and thus is not in direct contact with the amnioblasts or amnion.

**2.3. The answer is E** (*Langman*, pp. 42 and 43) Extra-embryonic mesoderm fills the space between the exocoelomic membrane (delimiting the primitive yolk sac) and amnion internally and the cytotrophoblast externally. Eventually, this mesoderm splits into two layers: One forms the extra-embryonic somatopleuric mesoderm lining the cytotrophoblast and amnion, while the other forms the extra-embryonic splanchnopleuric mesoderm. The space between these two layers is known as the extra-embryonic coelom.

**2.4. The answer is D** (*Langman*, pp. 44 and 45) By the 13th day of development the trophoblast is characterized by the first appearance of villous structures, the primary stem villi. These villi consist of a central core of cytotrophoblastic tissue surrounded by the syncytiotrophoblast.

**2.5. The answer is B** (*Langman*, p. 46) The extra-embryonic coelom or chorionic cavity is lined by extra-embryonic mesoderm. The mesoderm layer lining the inside of the cytotrophoblast (somatopleuric mesoderm) is known as the chorionic plate. The only place where the extra-embryonic mesoderm traverses the chorionic cavity is in the region of the connecting stalk, which eventually will become the umbilical cord.

**2.6. The answer is C** (*Langman*, pp. 48 and 49) The most characteristic structure formed during the 3rd week is the primitive streak in preparation for gastrulation or establishment of the third germ layer. The cephalic end of the streak is known as the primitive node (Hensen's node), while caudally the streak forms a narrow groove. Epiblast cells in the proximity of the streak and node turn inward and migrate between the remaining epiblast and hypoblast, thereby establishing the intra-embryonic mesoderm and endoderm.

**2.7. The answer is C** (*Langman*, pp. 50 and 51) By the 17th day of development, the intra-embryonic mesoderm and the notochordal process separate the endoderm and ectoderm layers entirely except in the regions of the prochordal plate cranially and the cloacal membrane caudally.