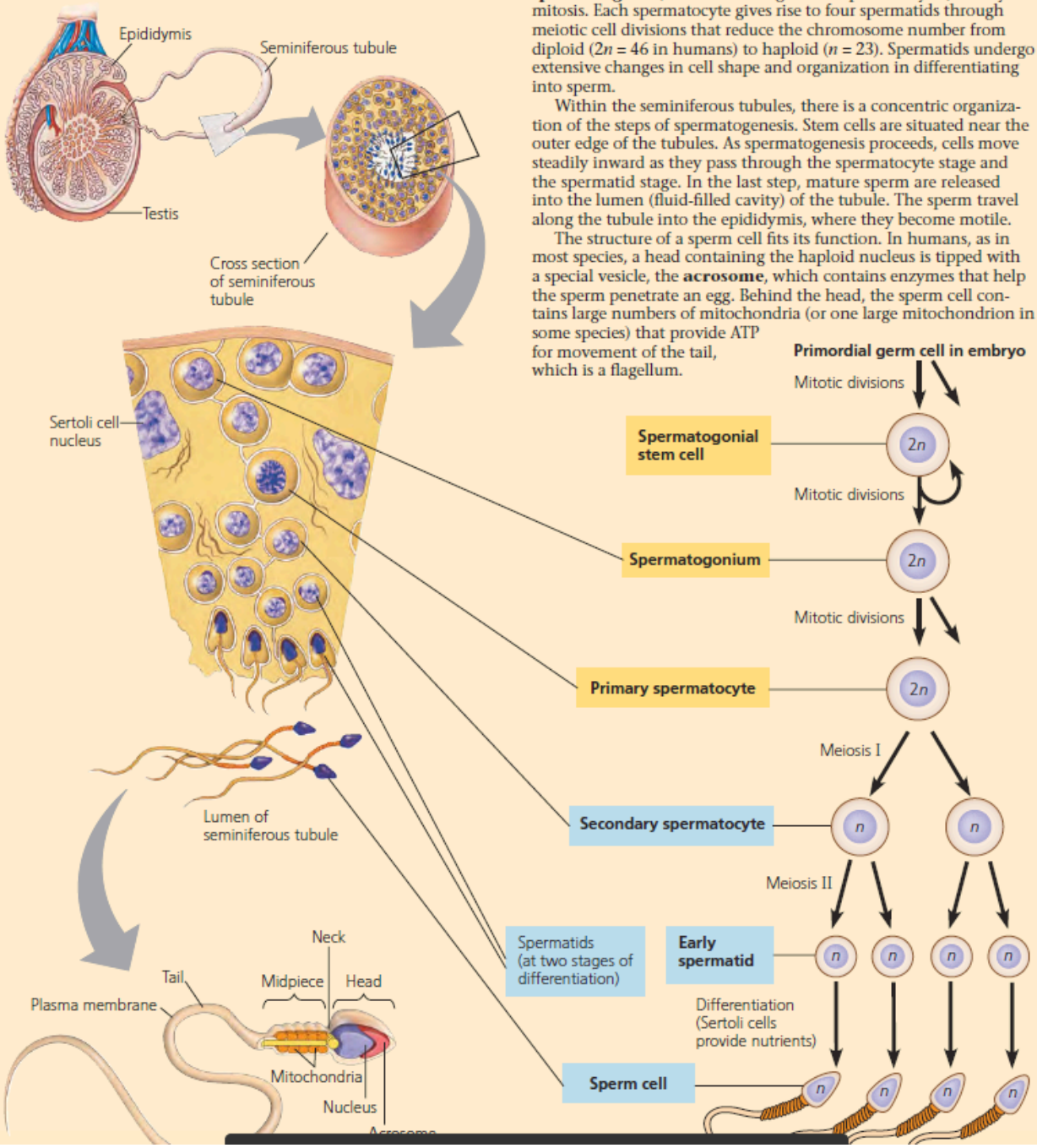
Cheat Sheet

Spermatogenesis

These drawings correlate the mitotic and meiotic divisions in sperm development with the microscopic structure of seminiferous tubules.



The initial or *primordial* germ cells of the embryonic testes divide and differentiate into stem cells that divide mitotically to form **spermatogonia**, which in turn generate spermatocytes, also by mitosis. Each spermatocyte gives rise to four spermatids through meiotic cell divisions that reduce the chromosome number from diploid ($2n = 46$ in humans) to haploid ($n = 23$). Spermatids undergo extensive changes in cell shape and organization in differentiating into sperm.

Within the seminiferous tubules, there is a concentric organization of the steps of spermatogenesis. Stem cells are situated near the outer edge of the tubules. As spermatogenesis proceeds, cells move steadily inward as they pass through the spermatocyte stage and the spermatid stage. In the last step, mature sperm are released into the lumen (fluid-filled cavity) of the tubule. The sperm travel along the tubule into the epididymis, where they become motile.

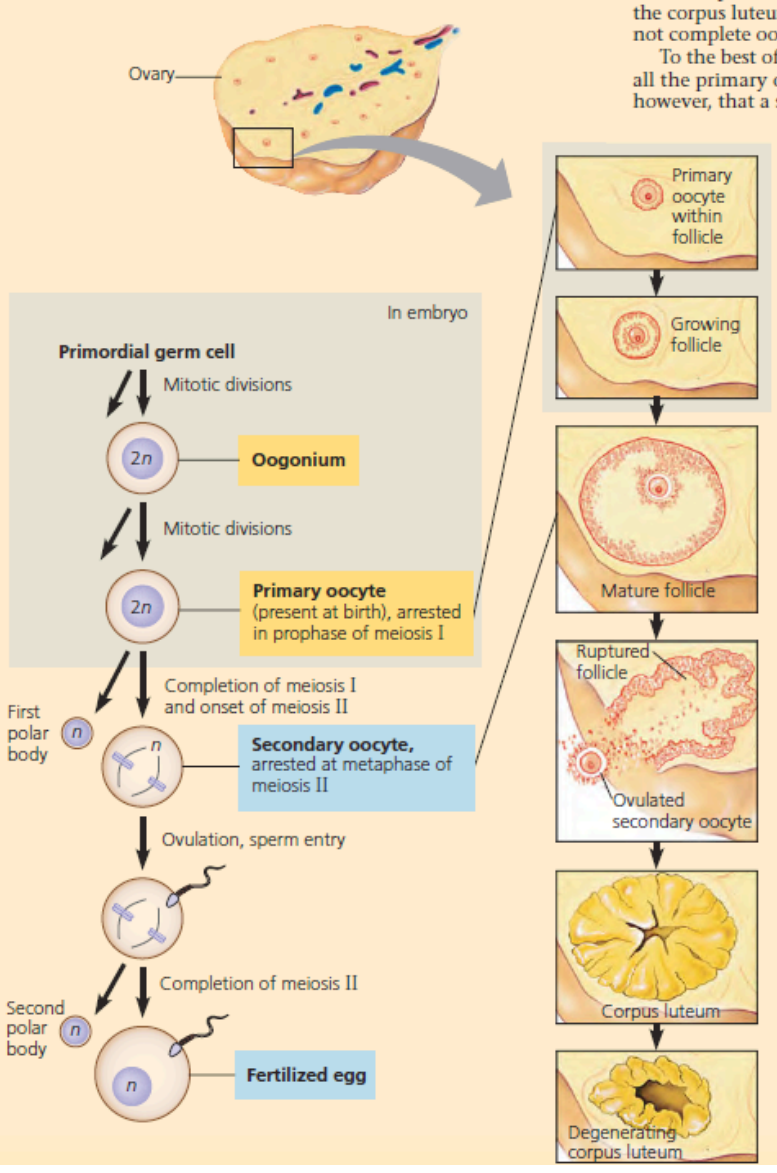
The structure of a sperm cell fits its function. In humans, as in most species, a head containing the haploid nucleus is tipped with a special vesicle, the **acrosome**, which contains enzymes that help the sperm penetrate an egg. Behind the head, the sperm cell contains large numbers of mitochondria (or one large mitochondrion in some species) that provide ATP for movement of the tail, which is a flagellum.

Oogenesis

Oogenesis begins in the female embryo with the production of **oogonia** from primordial germ cells. The oogonia divide by mitosis to form cells that begin meiosis, but stop the process at prophase I before birth. These developmentally arrested cells, called **primary oocytes**, each reside within a small follicle, a cavity lined with protective cells. Beginning at puberty, follicle-stimulating hormone (FSH) periodically stimulates a small group offollicles to resume growth and development. Typically, only one follicle fully matures each month, with its primary oocyte completing meiosis I. The second meiotic division begins, but stops at metaphase. Thus arrested in meiosis II, the **secondary oocyte** is released at ovulation, when its follicle breaks open. Only if a sperm penetrates the oocyte does meiosis II resume. (In other animal species, the sperm may enter the oocyte at the same stage, earlier, or later.) Each of the two meiotic divisions involves unequal cytokinesis, with the smaller cells becoming polar bodies that eventually degenerate (the first polar body may or may not divide again). Thus, the functional product of complete oogenesis is a single mature egg already containing a sperm head; fertilization is defined strictly as the fusion of the haploid nuclei of the sperm and secondary oocyte, although we often use it loosely to mean the entry of the sperm head into the egg.

The ruptured follicle left behind after ovulation develops into the corpus luteum. If the released oocyte is not fertilized and does not complete oogenesis, the corpus luteum degenerates.

To the best of our current knowledge, women are born with all the primary oocytes they will ever have. It is worth noting, however, that a similar conclusion regarding most other mammals was overturned by the discovery in 2004 of multiplying oogonia in the ovaries of adult mice that develop into oocytes. If the same turned out to be true of humans, it might be that the marked decline in fertility that occurs as women age results from both a depletion of oogonia and the degeneration of aging oocytes.



WHAT IF? Suppose you are analyzing the DNA from the polar bodies formed during human oogenesis. If the mother has a mutation in a known disease gene, would analyzing the polar body DNA allow you to infer whether the mutation is present in the mature oocyte? Explain.

Chapter 46 Questions

1. **What is sexual reproduction?**
2. **What is asexual reproduction?**
3. **What is budding?**
4. **What is fission?**
5. **What is fragmentation and regeneration?**
6. **What is parthenogenesis?**
7. **Describe parthenogenesis in honey bees.**
8. **What is hermaphroditism?**
9. **Describe the reproduction of bluehead wrasse.**
10. **Describe reproduction of oysters.**
11. **What is ovulation?**
12. **Describe the reproduction of *Aspidoscelis* lizards.**
13. **What is fertilization?**
14. **What is external fertilization?**
15. **What is internal fertilization?**
16. **Why is a moist habitat required for external fertilization?**
17. **What is spawning?**
18. **Describe the reproduction of the palolo worm?**
19. **What are pheromones?**
20. **What are gonads?**
21. **What are spermatheca?**
22. **What is the cloaca?**
23. **What are the testes?**
24. **What are seminiferous tubules?**
25. **What do the testes require to produce sperm properly?**
26. **What is the scrotum?**
27. **What is a testicle?**
28. **What occurs to rodent testes between breeding seasons?**
29. **What mammals retain testes in abdominal cavity at all times?**
30. **What is the epididymis?**
31. **What is ejaculation?**
32. **What is the urethra?**
33. **What is semen?**
34. **What are seminal vesicles?**
35. **What is the prostate gland?**
36. **What are the bulbourethral glands?**
37. **What is the penis?**
38. **What prevents a penis from achieving an erection (erectile dysfunction)?**
39. **What is the baculum?**
40. **What is the glans?**

41. What is the prepuce?
42. What are ovaries?
43. What are follicles?
44. What are oviducts (fallopian tubes)?
45. What is the uterus?
46. How is egg conveyed to uterus?
47. What is endometrium?
48. What is the cervix?
49. What is the vagina?
50. What is the vulva?
51. What are the labia majora?
52. What are the labia minora?
53. What is the hymen?
54. What is the clitoris?
55. What happens in females during sexual arousal?
56. What are the vestibular glands?
57. What are the mammary glands?
58. What tissues do breasts contain?
59. What is gametogenesis?
60. What is spermatogenesis?
61. What is oogenesis?
62. What are the three main differences between spermatogenesis and oogenesis?
63. Describe spermatogenesis in detail.
64. Describe oogenesis in detail.
65. How do the gonadotropins follicle-stimulating hormone (FSH) and luteinizing hormone (LH) support gametogenesis?
66. Describe the relative concentrations of sex hormones in males and females.
67. What organ secretes sex hormones (other than gonads)?
68. What are secondary sex characteristics?
69. What do androgens stimulate during puberty?
70. What do estrogens stimulate during puberty?
71. How do FSH and LH direct spermatogenesis?
72. Describe the two negative feedback mechanisms that control sex hormone production in males.
73. What is the ovarian cycle?
74. What is the uterine cycle?
75. What is the menstrual cycle?
76. What is menstruation?
77. Describe the ovarian cycle.
78. Describe the proliferative phase of the uterine cycle.
79. Describe the secretory phase of the uterine cycle.
80. Describe the menstrual flow phase of the uterine cycle.
81. What is endometriosis?

82. What is menopause?
83. How do humans/primates differ from other mammals in terms of uterine cycle?
84. What is vasocongestion?
85. What is myotonia?
86. Describe the sexual response cycle.
87. Describe what happens during copulation.
88. What is conception?
89. What occurs after fertilization?
90. What is pregnancy (gestation)?
91. What is the average pregnancy of humans?
92. What is the average pregnancy of rodents, cows, and elephants?
93. What occurs in the first trimester?
94. What is a tubal/ectopic pregnancy?
95. What is the trophoblast?
96. What is the umbilical cord?
97. What are identical (monozygotic) twins?
98. What are fraternal (dizygotic) twins?
99. What occurs during the second trimester?
100. What occurs during third trimester?
101. Describe labor.
102. What is lactation?
103. What is the relationship between autoimmune disorders and pregnancy?
104. What is contraception?
105. What is natural family planning?
106. What is the IUD?
107. What is progestin?
108. What effects can hormonal contraceptives have?
109. What is sterilization?
110. What is tubal ligation?
111. What is vasectomy?
112. What is abortion?
113. What is mifepristone (RU486)?
114. What is in vitro fertilization (IVF)?

Chapter 46 Answers

1. Fusion of haploid gametes to form diploid cell (zygote), male gamete (sperm) motile, female gamete (egg) nonmotile
2. New individuals generated without fusion of egg and sperm
3. Asexual reproduction where new individuals arise from outgrowths of existing ones, in stony corals
4. Splitting and separation of parent organism into two individuals of approx. equal size
5. Asexual reproduction where body breaks into several pieces and then regrows lost body parts, in annelids, sponges, cnidarians, tunicates
6. Egg develops without being fertilized, occurs in bees, wasps, ants, thought to be response to low population density in vertebrates (e.g. Komodo dragon/hammerhead shark)
7. Males (drones) are fertile haploid adults that arise by parthenogenesis. females (sterile workers and fertile queens) are diploid adults, result from fertilized eggs
8. Individual has male and female reproductive system, common in sessile animals and burrowing animals
9. Harems consist of male and many females, when male dies biggest female becomes male and produces sperm instead of eggs
10. Individuals switch to females (start as males) when they are big enough, size more significant for females than males
11. release of mature eggs at midpoint of reproductive cycle
12. Only females, asexual, have courtship behaviors where one acts as male when progesterone high, other acts as female when estradiol high
13. Union of sperm and egg
14. Female releases eggs into environment, male fertilizes them
15. Sperm deposited in or near female reproductive tract, fertilizes eggs within tract
16. Prevents gametes from drying out and allows sperm to swim to eggs
17. Individuals release gametes into water at same time
18. Times spawning to season and lunar cycle. In spring, last quarter moon, breaks in half and releases tail segments filled with sperm or eggs
19. Chemicals released by one organism that can influence physiology/behavior of other individuals of same species, small, volatile, or water-soluble
20. Organs that produce gametes, found in many (not all) animals. Most polychaete worms have separate sexes but lack gonads, gametes develop from cells lining coelom
21. In female reproductive system of insects, sacs in which sperm may be kept alive for extended periods
22. Common opening to outside in many nonmammalian vertebrates (digestive, excretory, reproductive), gametes released by turning cloaca inside out
23. Male gonads, produce sperm
24. Highly coiled tubes in testes that produce sperm
25. Lower temperature than rest of body (2^{o}C in most mammals below)

26. Fold in body wall that maintains testis temperature
27. Testis within scrotum, formed after testes develop in abdominal cavity and descend into scrotum just before birth
28. Drawn back into cavity
29. Whales and elephants/ other animals whose body temperature is low enough
30. Coiled duct that sperm passes into after production in seminiferous tubules, 6 m long, takes 3 weeks for sperm to travel, sperm complete maturation and become motile
31. Sperm propelled from both epididymis through vas deferens (muscular duct, extends around and behind urinary bladder, joins duct from seminal vesicle to form the short ejaculatory duct)
32. Outlet tube for both excretory and reproductive system
33. Fluid that is ejaculated
34. Two, contribute 60% of semen volume, fluid is thick, yellowish, alkaline, contains mucus, fructose, a coagulating enzyme, ascorbic acid, and prostaglandins
35. Secretes products into urethra through small ducts. Thin and milky fluid with anticoagulant enzymes and citrate
36. Pair of small glands along urethra below prostate, secrete clear mucus before ejaculation to neutralize urine
37. Contains urethra and three cylinders of spongy erectile tissue (fills with blood from arteries, increasing pressure seals off veins that drain it)
38. Alcohol, drugs, emotional issues, aging
39. Bone in some mammals (e.g. dogs, raccoons, walruses) that stiffens penis
40. Head of penis, has thinner outer layer
41. Foreskin, fold of skin removed if male is circumsized
42. Pair of gonads, flank uterus, held in abdominal cavity by ligaments
43. Packed in outer layer of ovary, consist of oocyte (partially developed egg) and surrounded by support cells
44. Extends from uterus towards funnel like opening at each ovary, very thin near uterus (human hair thickness)
45. Womb, thick, muscular organ that can expand during pregnancy
46. Cilia of oviduct and contractions of oviduct
47. Inner lining of uterus, richly supplied by blood vessels
48. Neck of uterus, opens into vagina
49. Muscular, elastic chamber, site for deposition of sperm
50. Term for external female genitalia, opening of vagina
51. Pair of thick, fatty ridges, enclose and protect vulva
52. Pair of slender skin folds that border opening of vagina and urethra
53. thin tissue, Partly covers vaginal opening at birth, becomes thinner over time and with activity
54. At top of labia minora, consists of erectile tissue supporting glans, covered by prepuce
55. Clitoris, vagina, and labia minora engorge with blood
56. Near vaginal opening, secrete lubricating mucus to facilitate intercourse

57. Present in both sexes, produce milk only in females, small sacs of epithelial tissue within secrete milk
58. Connective and adipose tissue + mammary glands
59. Production of gametes
60. Formation and development of sperm, continuous and prolific in adult human males, takes seven weeks for single sperm
61. Development of mature oocytes (eggs), prolonged, immature eggs form in ovary of embryo but do not complete dev until decades later
62. Spermat: All 4 products of meiosis develop into mature gametes, occurs throughout life, continuous
    Oogen - Cytokinesis during meiosis unequal, almost all cytoplasm segregated into single cell. (smaller cells = polar bodies, degenerate). Mitotic divisions complete before birth, production ceases at 50. Long interruptions
63. See picture
64. See picture
65. Stimulate sex hormone production by gonads
66. Male testosterone levels 10 times higher than females, female estradiol 10 times higher than males, peak progesterone levels higher in females
67. Adrenal glands (cortex), but in small amounts
68. Physical and behavioral differences that are not directly related to reproductive system
69. Deeper voice, facial and pubic hair, muscle growth, sexual behaviors/drive, aggressiveness
70. Breast and pubic hair development, sexual behavior, fat deposition in breasts/hips, water retention, alters calcium metabolism
71. FSH stimulates Sertoli cells (in seminiferous tubules, nourish developing sperm), LH causes Leydig cells (scattered in connective tissue between tubules that secrete many hormones and local regulators) to produce androgens
72. Testosterone inhibits hypothalamic and anterior pituitary release of GnRH, FSH, and LH. Sertoli cells produce inhibin (hormone that reduces FSH secretion by anterior pituitary)
73. Cyclic events in ovaries, follicle matures and oocyte released once per
74. Changes in uterus
75. In humans/other primates is uterine cycle, endometrium thickens and develops rich blood supply before being shed through cervix if pregnancy doesn't occur, if oocyte not fertilized, lining sloughed off and cycles restart (avg 28, 20-40 days)
76. Cyclic shedding of blood-rich endometrium from uterus, occurs through cervix
77. Begins when hypothalamus releases GnRH, stimulates anterior pituitary to secrete little FSH and LH, follicle growth stimulated, follicles make estradiol (concentration slowly rises during follicular phase, when follicles grow and oocytes mature). Several follicles grow, only one matures, others disintegrate. Low levels of estradiol inhibit pituitary secretion. When follicle estradiol secretion rises steeply, FSH/LH levels rise (high levels of estradiol stimulates GnRH secretion and increases GnRH sensitivity of pituitary). Folicle enlarges to form bulge. One day after LH surge, ovulation occurs when follicle/ovary wall rupture to release oocyte. Luteal phase follows, LH stimulates follicular

tissue to form corpus luteum (glandular structure stimulated by LH to secrete progesterone and estradiol that together exert negative feedback on hypothalamus and pituitary to prevent maturation of another egg. If pregnancy doesn't occur, low gonadotropin levels cause corpus luteum to disintegrate, freeing up hypothalamus/pituitary to initiate next cycle

78. OVarian steroid hormones stimulate uterus to prepare for embryo, estradiol secreted by follicles signals endometrium to thicken.
79. Estradiol and progesterone from corpus luteum stimulate maintenance and development of uterine lining, including enlargement of arteries/growth of glands. Glands secrete nutrient fluid for early embryo
80. If embryo not implanted, ovarian hormone lvls drop, causes arteries of endometrium to constrict, lining disintegrates, blood released and shed with endometrial tissue and fluid, lasts few day. First day of flow designated day 1 of new uterine cycle.
81. Disorder in 7% of reproductive women, cells of uterine lining migrate to ectopic (abnormal) abdominal location, responds to blood stream hormones and swells/breaks down, resulting in pelvic pain/abdominal bleeding
82. cessation of ovulation and menstruation after approx. 500 cycles, occurs between 46 and 54.
83. Other mammals don't have menstrual cycle since reabsorb endometrium in absence of pregnancy (cyclic changes of uterus called estrous cycle, controls sexual receptivity of females). During estrus, right after ovulation, female is receptive to mating (only at this time)
84. The filling of a tissue with blood
85. Increased muscle tension
86. Excitement - Prepares organs for coitus, enlargement of testicles, labia, and breast, vagina becomes lubricated, myotonia may occur (nipple erection/limb tension)
    Plateau - Responses continue as result of stimulation of genitalia. Outer third of vagina vasocongested, inner ⅔ expands slightly, forms depression for receiving sperm. Breathing/heart rate quickens (150 bpm).
    Orgasm - Rhythmic, involuntary contractions of reproductive structures. In males, emission occurs when glands and ducts of tract contract, sending semen into urethra, expulsion occurs when urethra contracts. In females, uterus/outer vagina contract
    Resolution - Completes cycle, reverses responses of earlier stages
87. Semen coagulates, keeping ejaculate in place. Anticoagulants liquefy semen to allow sperm to swim.
88. Fertilization of humans
89. 24 hrs after, zygote begins series of cell divisions (cleavage), after 4 days produces blastocyst (sphere of cells). Embryo implants in endometrium.
90. Condition of carrying embryos in uterus
91. 266 days from fertilization, 40 weeks from start of menstrual cycle
92. 12 days, 280 days, 600 days
93. Implanted embryo secretes hormones. Human chorionic gonadotropin (hCG) maintains progesterone/estrogen secretion by corpus luteum through first few months, can be

detected in urine. During first 2-4 weeks, obtains nutrients from endometrium. Trophoblast grows outward and mingles with endometrium to form placenta (can weigh 1 kg at birth). Main period of organogenesis, embryo particularly susceptible to damage (alcohol can cause fetal alcohol syndrome that results in mental retardation). Heart starts beating by 4th week, can be detected at 8-10 wks. 8 weeks all major structures present in rudimentary form, embryo called fetus (5 cm at end of trimester). Mother has mucus in cervix to protect against infection, placenta grows, breasts/uterus become larger, ovulation/menstrual cycling stop. ¾ pregnant women experience nausea ("morning sickness")

94. Fertilized egg lodges in oviduct, cannot be sustained without rupturing oviduct, risk increased if scarred by bacterial infections, medical procedures, or STDs
95. Outer layer of blastocyst.
96. Cord that connects embryo to placenta, has veins/arteries that circulate blood to embryo
97. When embryo splits during first month of development
98. Two follicles mature and are independently fertilized/implanted
99. Fetus grows to 30 cm in length, development continues (formation of fingernails, external sex organs, outer ears), mother may feel fetal movements as early as one month into this trimester, fetal activity visible through abdominal wall 1-2 months later. hCG secretion declines, corpus luteum deteriorates, placenta takes over production of progesterone
100. grows to 3-4 kg, 50 cm in length, activity may decrease, abdominal organs of mom compressed/displaced (digestive blockages/frequent urination).
101. Series of strong, rhythmic uterine contractions that starts childbirth. Prostaglandins, estradiol, and oxytocin induce/regulate contractions of uterus (positive feedback loop, oxytocin induces more contractions induces more oxytocin). First stage = thinning/opening(dilation) of cervix. Second = expulsion (delivery) of baby, third = delivery of placenta
102. Production of mother's milk
103. Autoimmune disorder severity reduced during pregnancy
104. Deliberate prevention of pregnancy
105. temporary abstinence, depends on refraining from intercourse when conception likely
106. Intrauterine device, placed in uterus by doctor, interferes with fertilization/implantation
107. Synthetic progesterone-like hormone used in hormonal contraceptives to stop release of GnRH by hypothalamus
108. Increase risk for cardiovascular disorders, eliminate dangers of pregnancy, decrease risk of ovarian/endometrial cancer
109. Permanent prevention of gamete production/release
110. Sealing shut or tying off (ligating) section of each oviduct
111. Cutting and tying off each vas deferens
112. Termination of pregnancy in progress. Spontaneous (miscarriage) very common)
113. Drug, terminates pregnancy nonsurgically within first 7 weeks. Blocks progesterone receptors in uterus, taken with prostaglandin to induce uterine contractions

114. Combining oocytes and sperm in lab.