Pregnancy and Human Development
Outline

28.1 Fertilization is the joining of sperm and egg chromosomes to form a zygote (pp. 1075–1077; Figs. 28.1–28.3; Focus Figure 28.1)

A. Fertilization occurs when a sperm's chromosomes combine with those of an egg to form a zygote. (p. 1075; Fig. 28.1)

B. Sperm Transport and Capacitation (p. 1076; Figs. 28.1–28.2; Focus Figure 28.1)

1. Millions of sperm ejaculated into the female reproductive tract are lost due to leakage from the vaginal canal, destruction by the acidic environment of the vagina, inability to pass the cervical mucus, or destruction by defense cells of the uterus.
2. In order to fertilize an egg, sperm must be capacitated, a process involving weakening of the sperm cell membrane in order to allow release of acrosomal hydrolytic enzymes.

C. Acrosomal Reaction and Sperm Penetration (p. 1076; Figs. 28.1–28.2; Focus
Figure 28.1)

1. A sperm cell must breach both the corona radiata and zona pellucida in order to penetrate the oocyte.
2. Once a sperm cell binds to a receptor on the zona, Ca^{++} channels open, leading to a rise in intracellular Ca++ in the sperm cell that causes the release of acrosomal enzymes: Hundreds of sperm cells must undergo the acrosomal reaction before fertilization can occur.
3. Once a sperm cell binds to membrane receptors on the oocyte membrane, its nucleus is pulled into the cytoplasm of the oocyte, where the gametes fuse.

D. Blocks to Polyspermy (pp. 1076–1077; Fig. 28.2; Focus Figure 28.1)

1. Polyspermy, entry by more than one sperm cell, leads to a lethal number of chromosomes and is prevented in several ways.
   a. The oocyte membrane block occurs when the oocyte sheds the rest of its sperm-binding receptors following the binding of a sperm cell.
   b. The zona reaction (slow block to polyspermy) involves entry of a sperm cell into the oocyte, which causes waves of Ca^{++} to be released into the oocyte's cytoplasm, which activates the oocyte to prepare for the second meiotic division.
   c. The cortical reaction (slow block to polyspermy), triggered by the Ca^{++} surge in the cytoplasm, results in destruction of sperm-binding receptors, while enzymes released from granulocytes inside the plasma membrane form a swollen, hardened membrane.

E. Completion of Meiosis II and Fertilization (p. 1077; Fig. 28.2)

1. Following the entry of the sperm pronucleus into the oocyte, the oocyte completes meiosis II, forming the ovum pronucleus, and the second polar body: male and female pronuclei fuse and produce a zygote.

28.2 Embryonic development begins as the zygote undergoes cleavage and forms a blastocyst en route to the uterus (pp. 1077–1081; Fig. 28.3)

A. Early embryonic development begins with fertilization and continues with the movement of the embryo to the uterus, where it implants in the uterine wall. (p. 1077)

B. Cleavage is a period of rapid mitotic divisions of the zygote without cell growth, so that cells become progressively smaller. (pp. 1080–1081; Fig. 28.3)

1. After 36 hours, cleavage forms two blastomeres; by 72 hours, continued division will have produced a ball of 16 or more cells, called a morula.
2. After 4–5 days, the embryo has formed about 100 cells, becoming a blastocyst, and breaks free of the zona pellucida.
   a. The blastocyst is a fluid-filled ball of cells that separate into trophoblast cells, that produce the placenta, and the inner cell mass, which will become the embryonic disc.

28.3 Implantation occurs when the embryo burrows into the uterine wall, triggering placenta formation (pp. 1081–1085; Figs. 28.4–28.7)

A. Implantation (pp. 1081–1083; Figs. 28.4–28.5)

1. Implantation occurs after 6–7 days; the trophoblast adheres to the endometrium and produces enzymes and growth factors to the endometrium, which takes on characteristics of an inflammatory response.
   a. Uterine capillaries become permeable and leaky, and the trophoblast proliferates, forming the inner cytotrophoblast and the outer syncytiotrophoblast that erodes the endometrium to allow the blastocyst to embed.
   b. Trophoblast cells secrete human chorionic gonadotropin (hCG), which acts on the corpus luteum to maintain its presence until the placenta can adequately support the developing fetus.

B. Placentation (pp. 1083–1085; Figs. 28.6–28.7)

1. Placentation is the process of proliferation of the trophoblast, giving rise to the chorion which, along with the endometrial decidua basalis, becomes the placenta.
   a. The placenta is fully functional as a nutritive, respiratory, excretory, and endocrine organ by the end of the third month of gestation.

28.4 Embryonic events include gastrula formation and tissue differentiation, which are followed by rapid growth of the fetus (pp. 1085–1092; Figs. 28.8–28.14; Table 28.1)

A. Extraembryonic Membranes (p. 1085)

1. While implantation is occurring, the blastocyst is being converted into a gastrula, in which three primary germ layers form and embryonic membranes develop.
   a. The amnion forms the transparent sac ultimately containing the embryo and provides a buoyant environment that protects the embryo from physical trauma.
   b. The yolk sac forms part of the gut, and produces the earliest blood cells and blood vessels.
   c. The allantois is the structural base for the umbilical cord that links the embryo to the placenta and becomes part of the urinary bladder.

d. The chorion helps to form the placenta and encloses the embryonic body and all other membranes.

B. Gastrulation: Germ Layer Formation (pp. 1085–1086; Fig. 28.8)

1. Gastrulation is the process of transforming the two-layered embryonic disc to a three-layered embryo containing three germ layers: ectoderm, mesoderm, and endoderm.
2. Gastrulation begins with the appearance of the primitive streak, which establishes the long axis of the embryo.
   a. The endoderm gives rise to epithelial linings of the gut, respiratory, and urogenital systems, and associated glands.
   b. The mesoderm gives rise to all types of tissues not formed by ectoderm or endoderm, such as muscle tissue.
   c. The ectoderm gives rise to structures of the nervous system and the epidermis.

C. Organogenesis: Differentiation of the Germ Layers (pp. 1087–1089; Figs. 28. 9–28.12)

1. Organogenesis is the formation of organs and organ systems; by the end of the embryonic period at 8 weeks, all organ systems are recognizable.
   a. The embryo starts off as a flat plate, but as it grows, folds laterally into a tube, and folds toward the center from both ends, finally fusing where the yolk sac and umbilical vessels protrude.
2. Specialization of the endoderm forms the GI tract; outpocketings of endoderm form the mucosa of the respiratory tract and several glands.
3. Specialization of the ectoderm results in the development of the brain and anterior end of the spinal cord
   a. Neural crest cells migrate and give rise to the cranial, spinal, and sympathetic ganglia, adrenal medulla, pigment cells of the skin, and some connective tissues.
4. Specialization of mesoderm occurs as mesodermal aggregates appear on either side of the notochord.
   a. Mesodermal specialization forms the notochord and gives rise to the dermis, parietal serosa, bones, muscles, kidneys, gonads, cardiovascular structures, and connective tissues.

D. Development of the Fetal Circulation (p. 1090; Fig. 28.13)

1. By $3\frac{1}{2}$ weeks, the embryo has a blood vessel system and a pumping heart.
2. Unique prenatal vascular modifications include umbilical arteries and veins that carry blood to and from the placenta, a ductus venosus that serves to bypass the
   liver, and the foramen ovale and ductus arteriosus, used to divert most blood flowing through the heart away from the pulmonary circulation into the systemic circulation.

D. Events of Fetal Development (pp. 1090–1092; Fig. 28.14; Table 28.1)

1. By the end of the embryonic period, bones begin to ossify, muscles are formed, and most organ systems are forming in place, and blood supply to and from the placenta is well developed. (p. 1081; Fig. 28.15)
2. During the fetal period, there is rapid growth of the structures established in the embryo, and the greatest amount of growth occurs during the first eight weeks of life. (pp. 1081–1082)

28.5 During pregnancy, the mother undergoes anatomical, physiological, and metabolic changes (pp. 1094–1095; Fig. 28.15)

A. Anatomical Changes (pp. 1094–1095; Fig. 28.15)
   1. The female reproductive organs and breasts become increasingly vascular and engorged with blood.
   2. The uterus enlarges dramatically, causing a shift in the woman's center of gravity and an accentuated lumbar curvature (lordosis).
   3. Placental production of the hormone relaxin causes pelvic ligaments and the pubic symphysis to soften and relax.
   4. There is a normal weight gain of around 28 pounds, due to the growth of the fetus, maternal reproductive organs, and breasts, and increased blood volume.

B. Metabolic Changes (p. 1095)
   1. As the placenta enlarges, it produces human placental lactogen (hPL), which works with estrogen and progesterone to promote maturation of the breasts for lactation.
   2. Human placental lactogen also promotes the growth of the fetus and exerts a glucose-sparing effect on maternal metabolism.
   3. Plasma levels of parathyroid hormone and activated vitamin D rise, ensuring a positive maternal calcium balance throughout pregnancy.

C. Physiological Changes (p. 1095)
   1. Many women suffer morning sickness during the first few months of pregnancy, until their systems adapt to elevated levels of hCG, estrogens, and progesterone.
   2. Heartburn often results from the displacement of the esophagus, and constipation may result due to the decreased motility of the digestive tract.
   3. The kidneys produce more urine, because maternal metabolic rate is higher, and there is additional fetal metabolic waste that must be eliminated.
   4. Vital capacity and respiratory rate increases, but there is a decrease in residual volume, and many women suffer from difficult breathing, or dyspnea.
   5. Blood volume increases to accommodate the needs of the fetus and may increase up to 40% by the 32nd week of pregnancy.
   6. Mean blood pressure decreases during the second trimester, but then returns to normal levels during the third trimester; cardiac output increases by 35–40%.

28.6 The three stages of labor are the dilation, expulsion, and placental stages (pp. 1096–1097; Figs. 28.16–28.17)

A. Parturition is the process of giving birth and usually occurs within 15 days of the calculated due date, which is 280 days from the last menstrual period. (p. 1096)

B. Initiation of Labor (p. 1096; Fig. 28.16)
   1. Estrogen levels peak, possibly due to rising levels of fetal adrenal cortical hormones (cortisol), stimulating myometrial cells of the uterus to form abundant oxytocin receptors and antagonizing the quieting effect of progesterone on uterine muscle.

2. Fetal cells produce oxytocin, which promotes the release of prostaglandins from the placenta and further stimulates uterine contraction.
3. Increasing cervical distention activates the mother's hypothalamus, which signals the release of oxytocin, setting up a positive feedback loop in which further distention of the cervix promotes the release of more oxytocin, which causes greater contractile force.
4. Expulsive contractions are aided by a change that occurs in an adhesive protein, fetal fibronectin, converting it to a lubricant.

C. Stages of Labor (pp. 1096–1097; Fig. 28.17)
1. The dilation stage of labor extends from onset of labor to the time when the cervix is fully dilated by the baby's head, at about 10 cm in diameter.
    a. At first, only the superior uterine muscle is active, but as labor progresses, contractions become more vigorous and rapid, and more of the uterus becomes involved.
    b. As the infant's head is forced against the cervix, the cervix softens, thins, and dilates; ultimately, the amnion ruptures, releasing amniotic fluid.
    c. The dilation stage is the longest part of labor; during this phase, the infant's head becomes engaged as it passes into the true pelvis, and as descent continues, the baby's head rotates so that its greatest dimension is along the anteroposterior line, allowing easier navigation of the pelvic outlet.
2. The expulsion stage extends from full dilation until the time the infant is delivered.
    a. Crowning occurs when the baby's head distends the vulva; when the baby is in the vertex, or head-first, presentation, the skull acts as a wedge to dilate the cervix.
    b. Once the head has been delivered, the rest of the baby follows much more easily; after birth, the umbilical cord is clamped and cut.
3. During the placental stage, uterine contractions compress uterine blood vessels, limiting bleeding, and cause detachment of the placenta from the uterine wall, followed by delivery of the placenta and membranes (afterbirth).

28.7 An infant's extrauterine adjustments include taking the first breath and closure of vascular shunts (p. 1098)

A. At 1–5 minutes after birth, the baby's physical signs are assessed based on heart rate, color, muscle tone, and reflexes; a score from 0–2 is assigned to each factor, and the total is called the Apgar score. (p. 1098)

B. Taking the First Breath and Transition (p. 1098)
1. Once the placenta is no longer removing carbon dioxide from the blood, it builds up in the infant's blood, resulting in acidosis that signals the respiratory control centers.
    a. The first breath is very difficult, due to the fact that airways are small, and the lungs are collapsed.
2. The transitional period is the 6–8 hours after birth characterized by intermittent waking periods in which the infant's vital signs fluctuate but after a time, the baby stabilizes and wakes mostly in response to hunger.

C. Occlusion of Special Fetal Blood Vessels and Vascular Shunts (p. 1098)

1. After birth, the umbilical arteries and veins constrict and become fibrosed, becoming the medial umbilical ligaments, superior vesical arteries of the bladder, and the round ligament of the liver, or ligamentum teres.
2. The ductus venosus closes and is eventually converted to the ligamentum venosum.
3. The pulmonary circulation becomes functional, and pressure in the right side of the heart decreases, while pressure in the left side increases, causing pulmonary shunts to close.
   a. A flap of tissue covers the foramen ovale and fuses with the wall, becoming the fossa ovalis; the ductus arteriosus constricts, becoming the ligamentum arteriosus.

28.8 Lactation is milk secretion by the mammary glands in response to prolactin (pp. 1098–1099; Fig. 28.18)

A. Lactation is the production of milk by the hormone-prepared mammary glands. (pp. 1098–1099; Fig. 28.18)
1. Rising levels of placental estrogens, progesterone, and human placental lactogen stimulate the hypothalamus to produce prolactin-releasing factors (PRFs), which promote secretion of prolactin by the anterior pituitary.
2. Colostrum, a high-protein, low-fat product, is initially secreted by the mammary glands, but after two to three days, true milk is produced.
   a. Colostrum, like milk, is rich in IgA antibodies, but has less lactose, and more protein, vitamin A, and minerals.
3. Nipple stimulation during nursing sends neural signals to the hypothalamus, resulting in production of PRH and a burst of prolactin that stimulates milk production for the next feeding.
4. Oxytocin causes the let-down reflex, resulting in the release of milk from the alveoli of the mammary glands in both breasts.
5. Advantages of breast milk are: better absorption and more efficient metabolism of fats, iron, and protein; antibodies and other beneficial chemicals that protect the infant; it aids in the bacterial colonization of the infant's gut; and has a natural laxative effect that helps to prevent physiological jaundice.
6. When nursing is discontinued, the lack of stimulation causes milk production to cease, but as long as prolactin levels are high, the normal hypothalamic controls of the ovarian cycle are inhibited, although most women begin to ovulate while still nursing.

28.9 Assisted reproductive technology may aid an infertile couple's ability to have offspring (p. 1101)

A. Hormones can be used to increase sperm or egg production and surgery can be used to open blocked uterine tubes. (p. 1101)

B. Assisted reproductive technology involves surgically removing oocytes from a woman's ovaries, fertilizing the eggs, and returning them to the woman's body. (p. 1101)
1. In vitro fertilization (IVF) combines oocytes and sperm in culture dishes for several days, to allow fertilization to occur. The two-cell or blastocyst stage embryo is transferred to the woman's uterus.

2. Zygote intrafallopian transfer (ZIFT) immediately places fertilized oocytes into the woman's uterine tubes, with the hope that normal blastocyst formation and implantation occurs.
3. Gamete intrafallopian transfer (GIFT) directly transfers sperm and oocytes to a woman's uterine tube, hoping that normal fertilization, blastocyst formation, and implantation occurs.

C. Cloning involves the placing of a somatic cell nucleus into an oocyte; this process has been used most successfully in the creation of stem cells, rather than for reproductive purposes. (p. 1101)