Pregnancy and Lactation

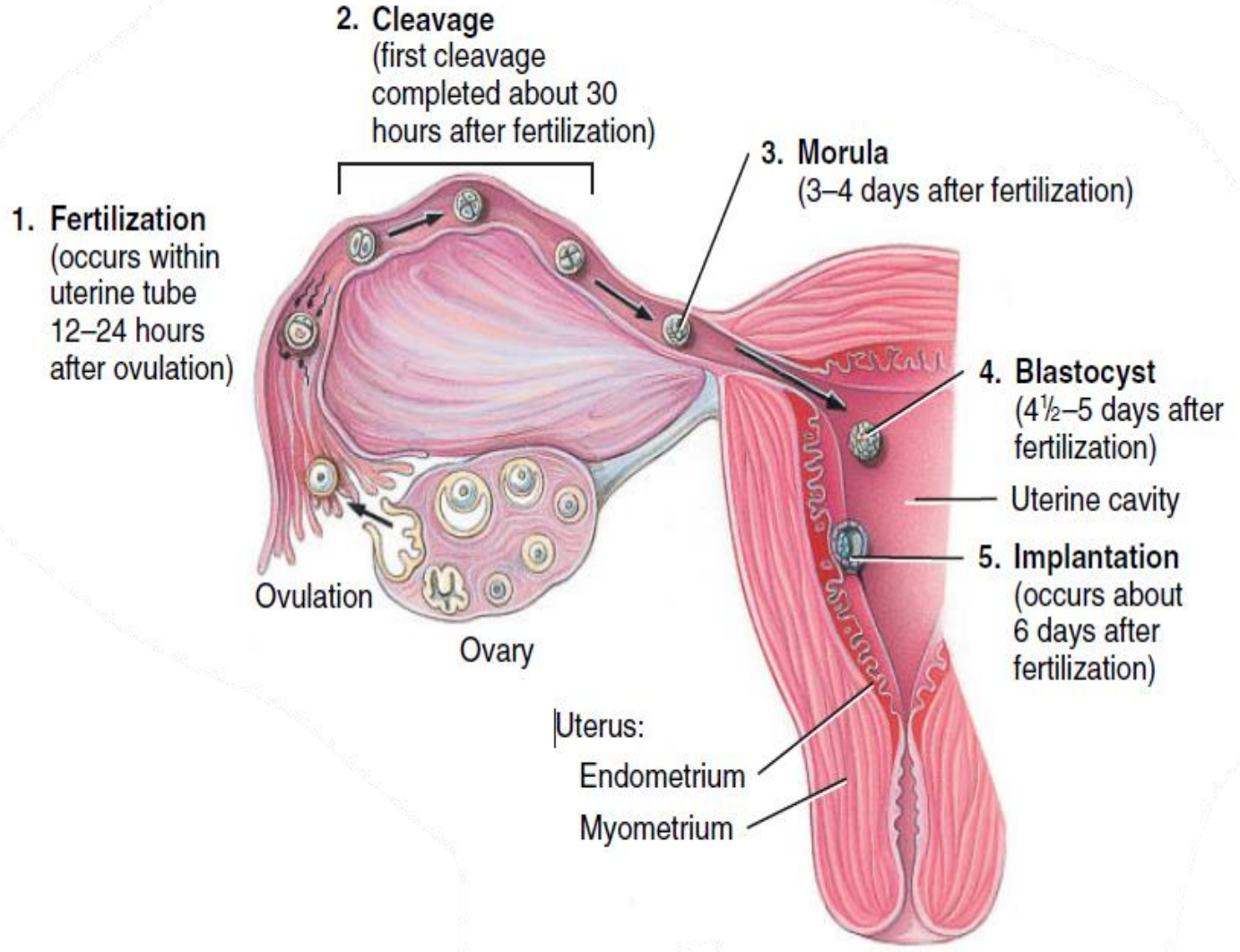
Chapter 83

Maturation and Fertilization of the Ovum

- Entry of the Ovum into the Fallopian Tube

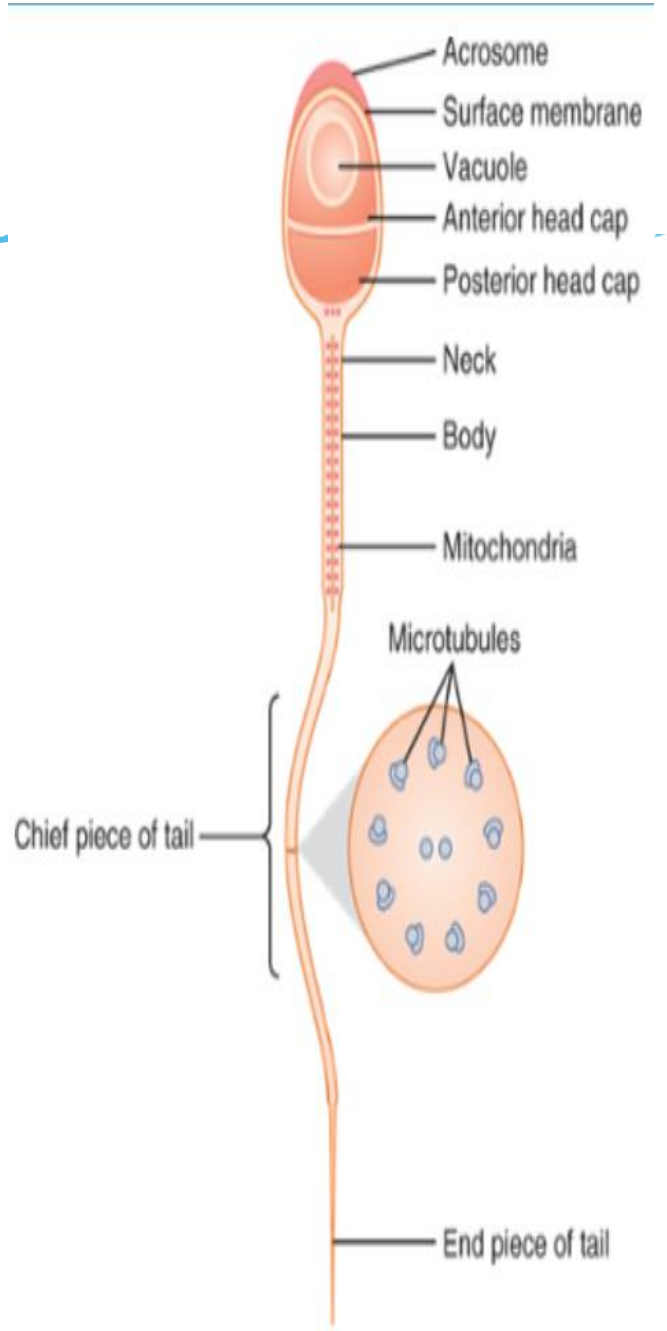
- Cilia are activated by estrogen.
- 98% success

- Fertilization of the Ovum
  - At ampullae of the fallopian tubes.
  - Transport of the sperm is aided by:
    1.**Contractions** of the uterus and fallopian tubes stimulated by **prostaglandins** in the male seminal fluid.
  - 2. **Oxytocin** release during female orgasm.
  - **The secondary oocyte is ovulated into the abdominal cavity. Then, almost immediately, it enters the fimbriated end of one of the fallopian tubes.
  - **slow fluid current flowing toward the ostium



"Capacitation" of Spermatozoa Is Required for Fertilization of the Ovum (Ch.81)

- Although spermatozoa are said to be "**mature**" when they leave the **epididymis**, their activity is held in check by **multiple inhibitory factors** secreted by the genital duct epithelia. (unable to fertilize)
- Coming in contact with the **fluids of the female genital tract**, multiple **changes** occur that activate the sperm for the final processes of fertilization.
- These collective changes are called **capacitation** of the spermatozoa (1-10 h)



“Capacitation” of Spermatozoa Is Required for Fertilization of the Ovum (Ch.81)

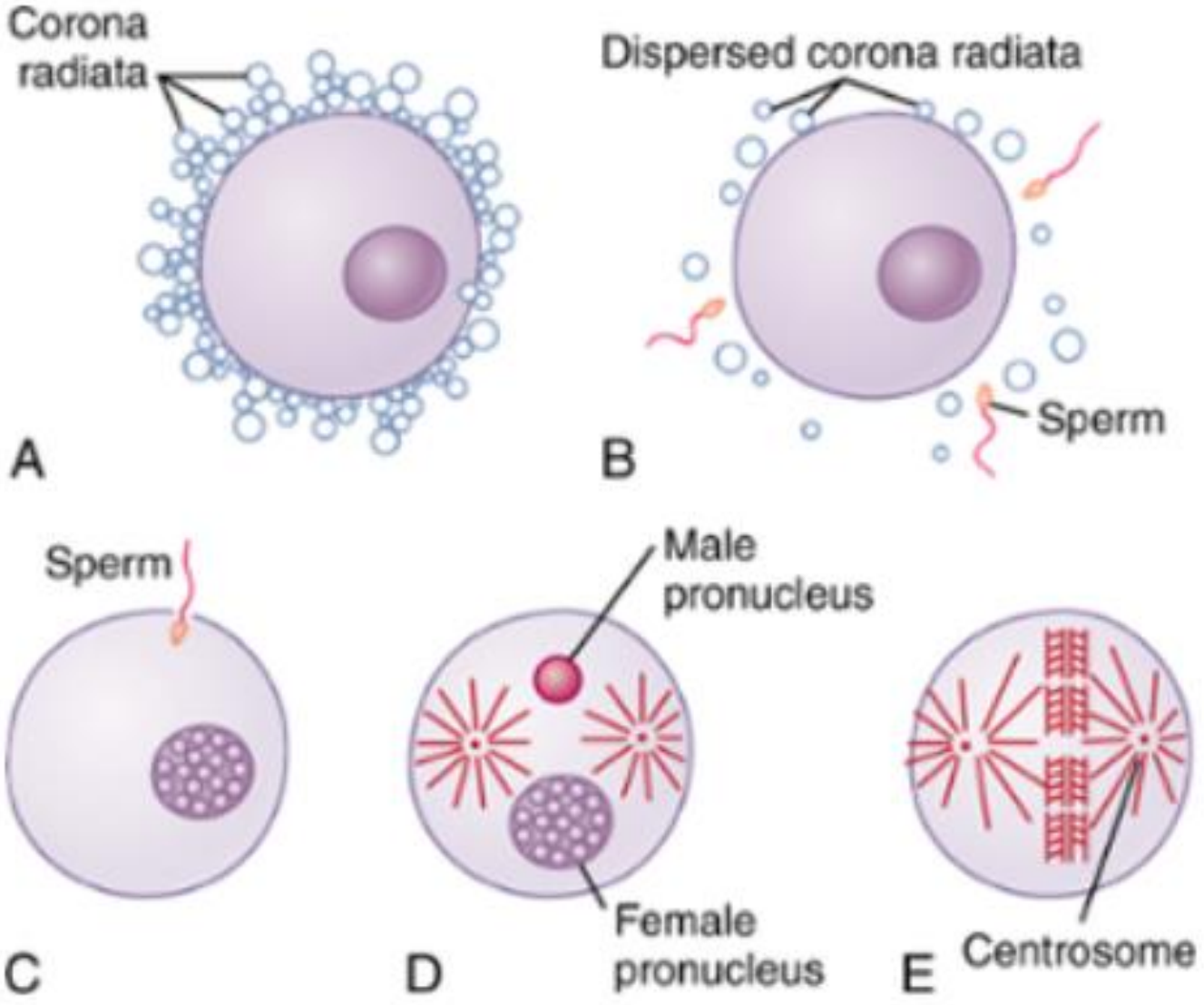
- 1. Female fluids **wash** away the various **inhibitory factors**.
- 2. Sperms **lose** much of their other **excess cholesterol** → the membrane at the head of the sperm (the acrosome) becomes much weaker.
- 3. The membrane of the sperm also becomes much **more permeable to calcium ions**, so calcium now enters the sperm in abundance and changes the activity of the **flagellum.**
- 4. Calcium ions make it possible for the **acrosome to release its enzymes** rapidly and easily.

- 2. While the spermatozoa remain in the fluid of the male genital ducts, they are continually exposed to many floating vesicles from the seminiferous tubules containing large amounts of cholesterol. This cholesterol is continually added to the cellular membrane covering the sperm acrosome, toughening this membrane and preventing release of its enzymes. After ejaculation, the sperm deposited in the vagina swim away from the cholesterol vesicles upward into the uterine cavity, and they gradually lose much of their other excess cholesterol during the next few hours. In so doing, the membrane at the head of the sperm (the acrosome) becomes much weaker.
- 3+4. The membrane of the sperm also becomes much more permeable to calcium ions, so calcium now enters the sperm in abundance and changes the activity of the flagellum, giving it a powerful whiplash motion in contrast to its previously weak undulating motion. In addition, the calcium ions cause changes in the cellular membrane that cover the leading edge of the acrosome, making it possible for the acrosome to release its enzymes rapidly and easily as the sperm penetrates the granulosa cell mass surrounding the ovum, and even more so as it attempts to penetrate the zona pellucida of the ovum.

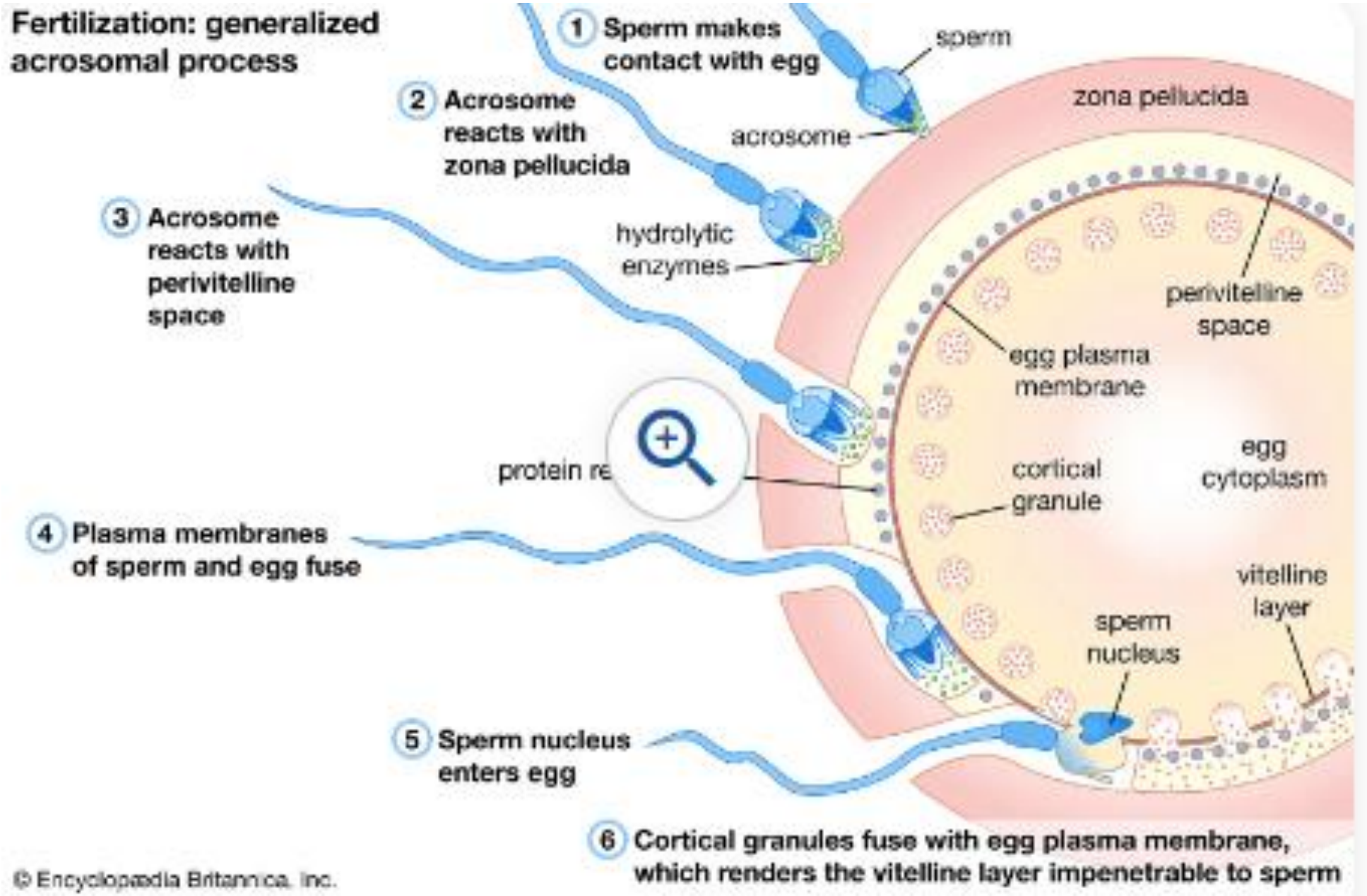
Fertilization of the Ovum

- Sperm penetrates corona radiata and zona pellucida.
- Oocyte divides to form mature ovum (female pronucleus 23 unpaired chr)
- Head of sperm swells (male pronucleus 23 unpaired chr)
- Release of cortical granules preventing further sperm penetration
- Fertilized ovum (zygote) contains 23 paired chr

**What Determines the Sex of the Fetus That Is Created?



Why only one sperm? within afew minutes after the first sperm penetrates the zona pellucida of the ovum, calcium ions diffuse inward through the oocyte membrane and cause multiple cortical granules to be released by exocytosis from the oocyte into the perivitelline space. These granules contain substances that permeate all portions of the zona pellucida and prevent binding of additional sperm, and they even cause any sperm that have already begun to bind to fall off.



Acrosome Enzymes, the "Acrosome Reaction," and Penetration of the Ovum

- Stored in the **acrosome** of the sperm are large quantities of **hyaluronidase** and **proteolytic enzymes**.

- Hyaluronidase depolymerizes the hyaluronic acid polymers in the **intercellular cement that holds the ovarian granulosa cells together**.

- The proteolytic enzymes **digest proteins in the structural elements** of tissue cells that still adhere to the ovum.

Acrosome Enzymes, the "Acrosome Reaction," and Penetration of the Ovum

- The **anterior membrane** of the sperm binds specifically with **receptor** proteins in the zona pellucida.
- Next, the entire acrosome rapidly dissolves, and **all** the **acrosomal** enzymes are released.
- Within minutes, these enzymes open a **penetrating pathway** for passage of the sperm head through the zona pellucida to the inside of the ovum.
- Within another 30 minutes, the **cell membranes of the sperm head and of the oocyte fuse with each other to form a single cell.**
- At the same time, the **genetic material** of the sperm and the oocyte **combine** to form a completely new cell genome, containing equal numbers of chromosomes and genes from mother and father.

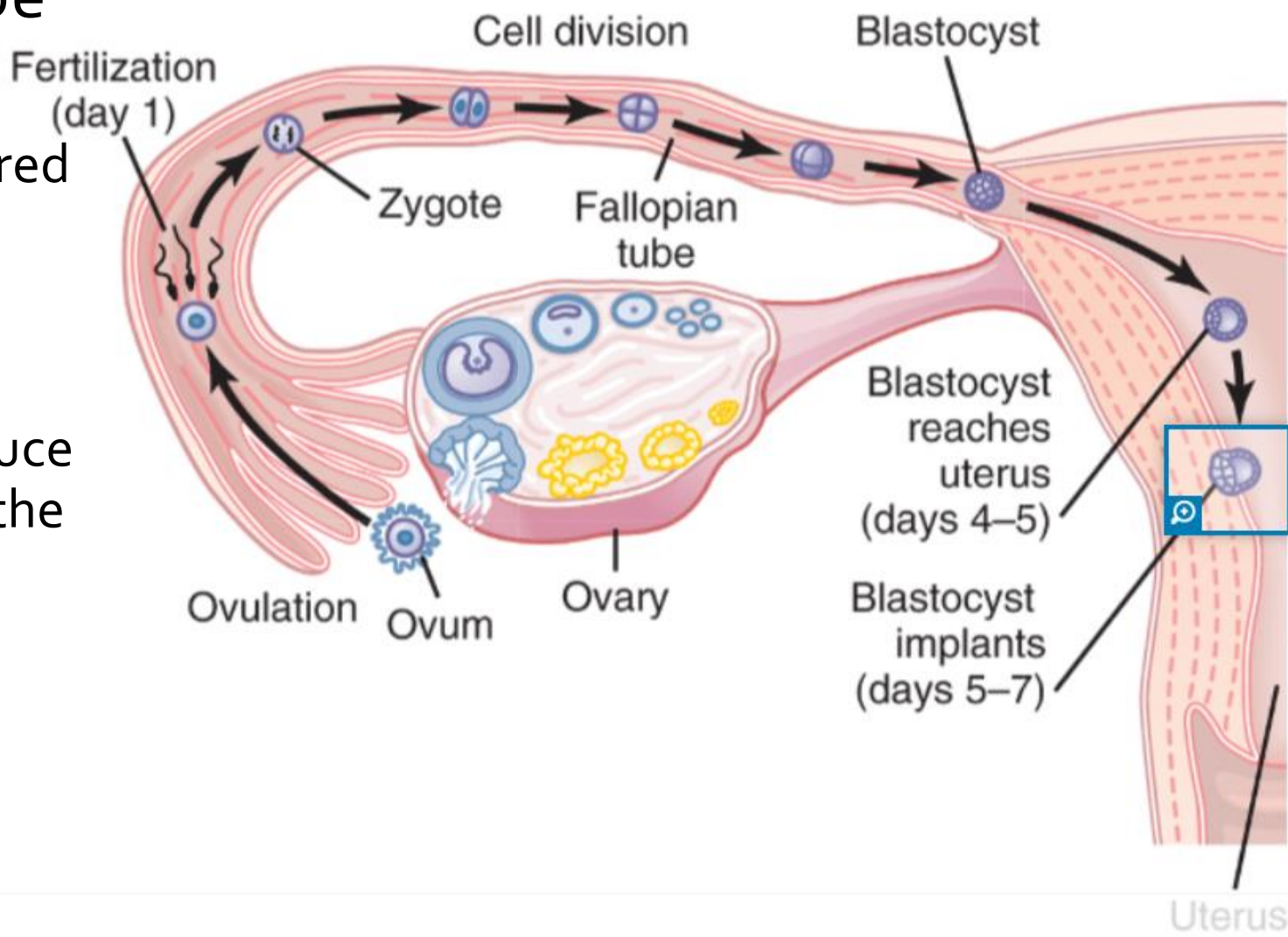
Why Does Only One Sperm Enter the Oocyte?

- Within a **few minutes** after the first sperm penetrates the zona pellucida of the ovum, **calcium ions diffuse inward** through the oocyte membrane and cause **multiple cortical granules** to be released by **exocytosis** from the oocyte into the perivitelline space.

- These granules contain substances that **permeate all portions of the zona pellucida** and prevent binding of additional sperm, and they even cause any sperm that have already begun to bind to fall off.

- # Transport of the Fertilized Ovum in the Fallopian Tube

- After fertilization has occurred, an additional 3 to 5 days is normally required for transport of the fertilized ovum through the remainder of the fallopian tube into the cavity of the uterus.
- The fallopian tube secretory cells produce large quantities of secretions used for the nutrition of the developing blastocyst.
- Several stages of cell division occurs, blastocyst, 100 cells.
- **Progesterone** causes relaxation of isthmus.



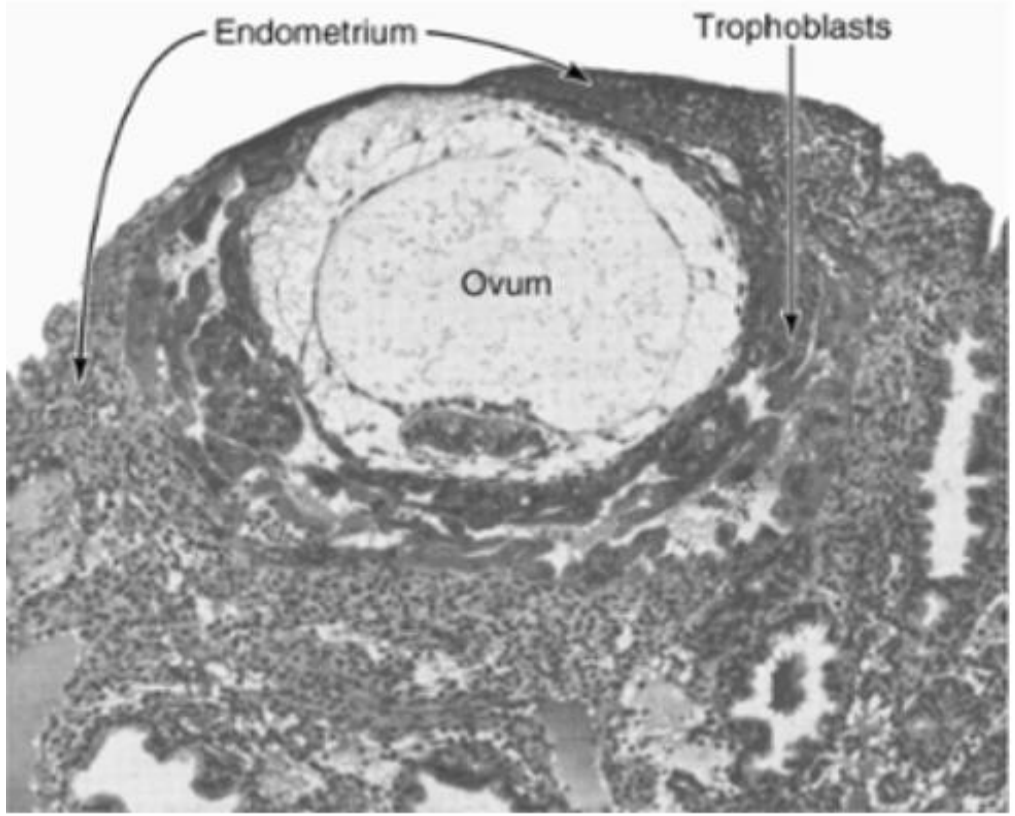
- **This transport is effected mainly by a feeble **fluid current** in the tube resulting from epithelial secretion plus action of the **ciliated epithelium** that lines the tube; the cilia always beat toward the uterus. **Weak contractions** of the fallopian tube may also aid passage of the ovum
- **the *isthmus* of the fallopian tube (the last 2 centimeters before the tube enters the uterus) remains spastically contracted for about the first 3 days after ovulation.

- # Implantation of the Blastocyst in the Uterus

- After reaching the uterus, the developing blastocyst usually remains in the uterine cavity an additional 1 to 3 days before it implants in the endometrium. (**5-7 after ovulation).**

- Before implantation, the blastocyst obtains its nutrition from the uterine endometrial secretions, called **"uterine milk."**

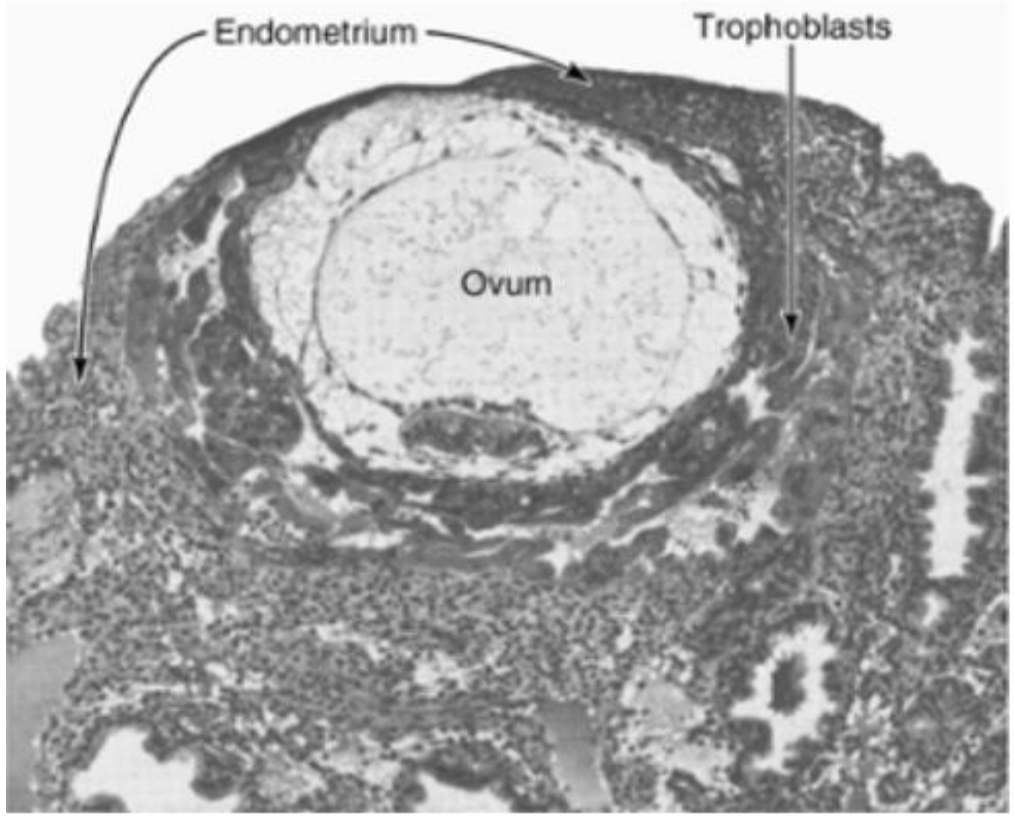
- **Implantation results from the action of trophoblast** cells that develop over the surface of the blastocyst.



- Implantation of the Blastocyst in the Uterus

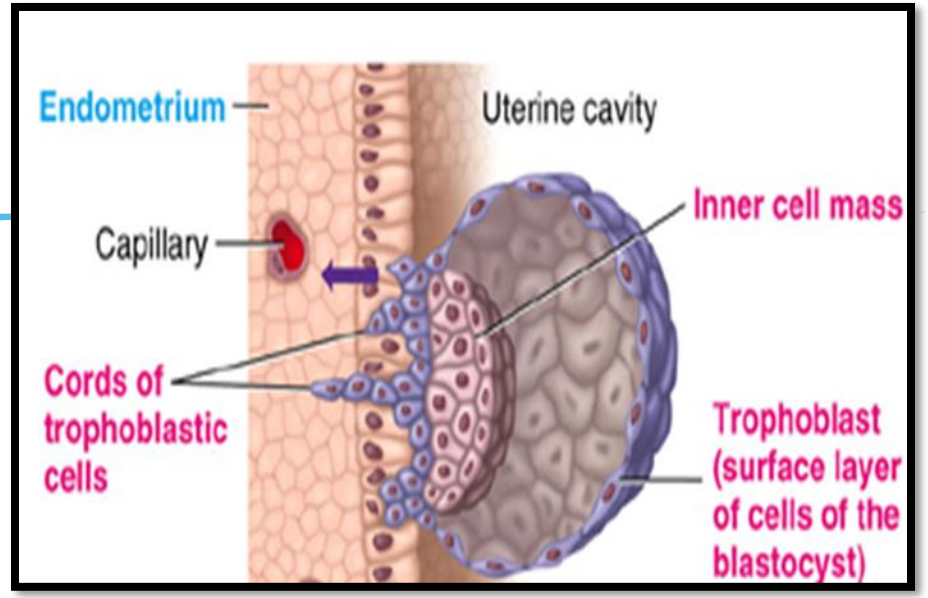
- Trophoblast secrete proteolytic enzymes that digest and liquefy the adjacent cells of the uterine endometrium.

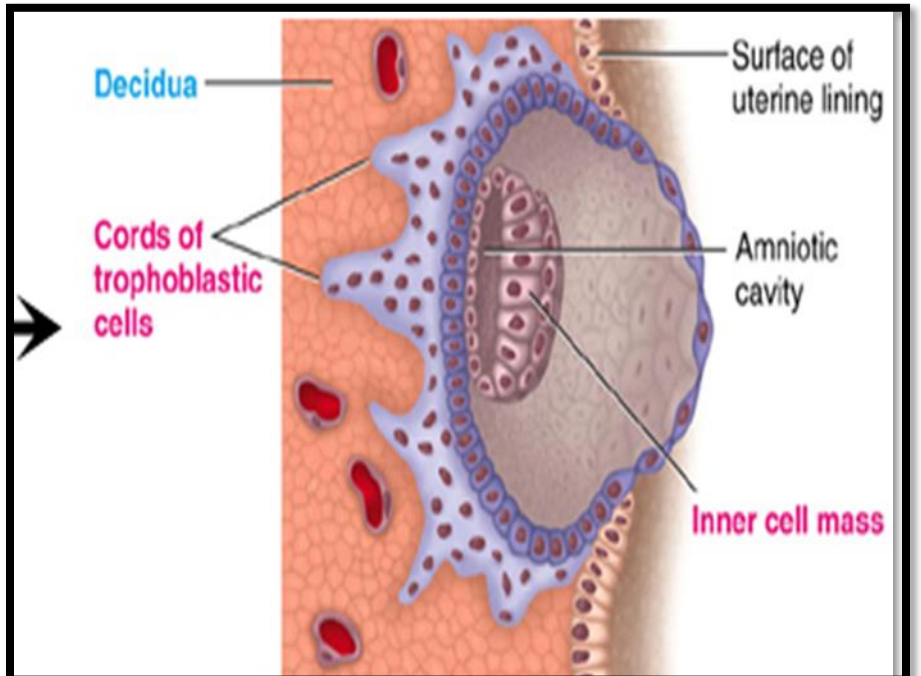
- Some of the fluid and nutrients released are actively transported by the same trophoblast cells into the blastocyst, adding more sustenance for growth.



Implantation

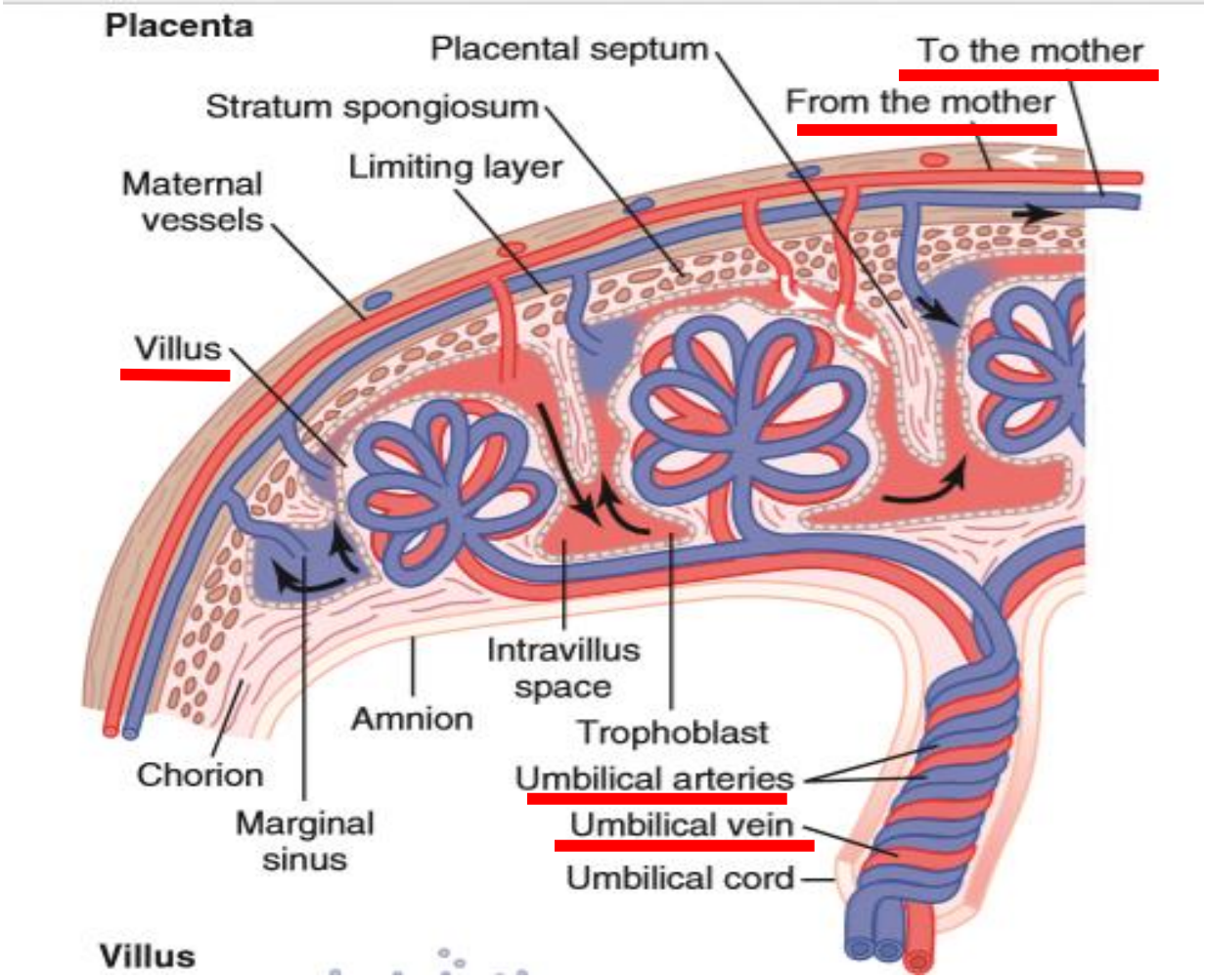
- The trophoblast cells and other adjacent cells (from the blastocyst and the uterine endometrium) proliferate rapidly, forming the placenta and the various membranes of pregnancy.
- Blood capillaries grow in the trophoblastic cords.
- 21 days after fertilization, blood starts to be pumped by fetal heart into the capillaries.
- Maternal blood sinuses develop around the trophoblastic cords.
- More and more trophoblast projections develop (placental villi).





PLACENTA

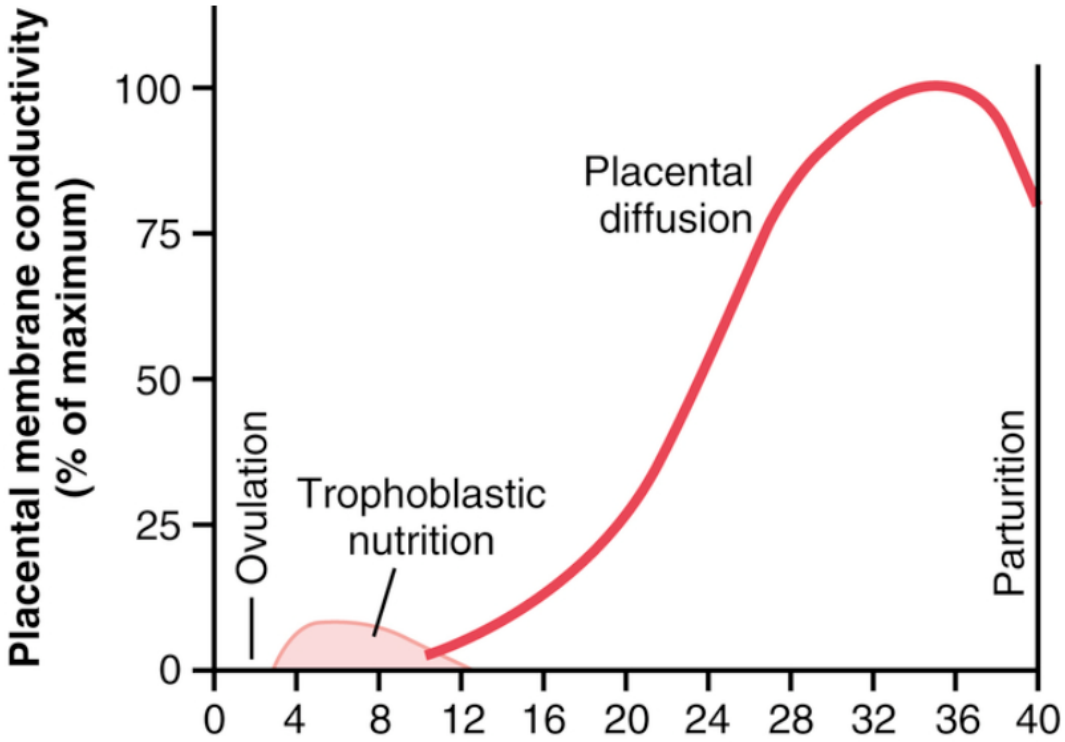
- Fetus's blood flows through two umbilical arteries, then into the capillaries of the villi.
- Finally back through a single umbilical vein into the fetus.
- At the same time, the mother's blood flows from her uterine arteries into large maternal sinuses that surround the villi and then back into the uterine veins of the mother.



- **Thus, the villi, carrying fetal blood, are surrounded by sinuses that contain maternal blood.
- **he final structure of the placenta, Note that the blood of the fetus flows through two umbilical arteries, then into the capillaries of the villi, and finally back through a single umbilical vein into the fetus. At the same time, the mother's blood flows from her uterine arteries into large maternal sinuses that surround the villi and then back into the uterine veins of the mother.

Early Nutrition of the Embryo

- During the first week after implantation, decidua is the **only mean** by which the embryo can obtain nutrients.
- The embryo continues to obtain at least some of its nutrition in this way for up to 8 weeks.
- The placenta also begins to provide nutrition after about the 16th day beyond fertilization (a little more than 1 week after implantation).



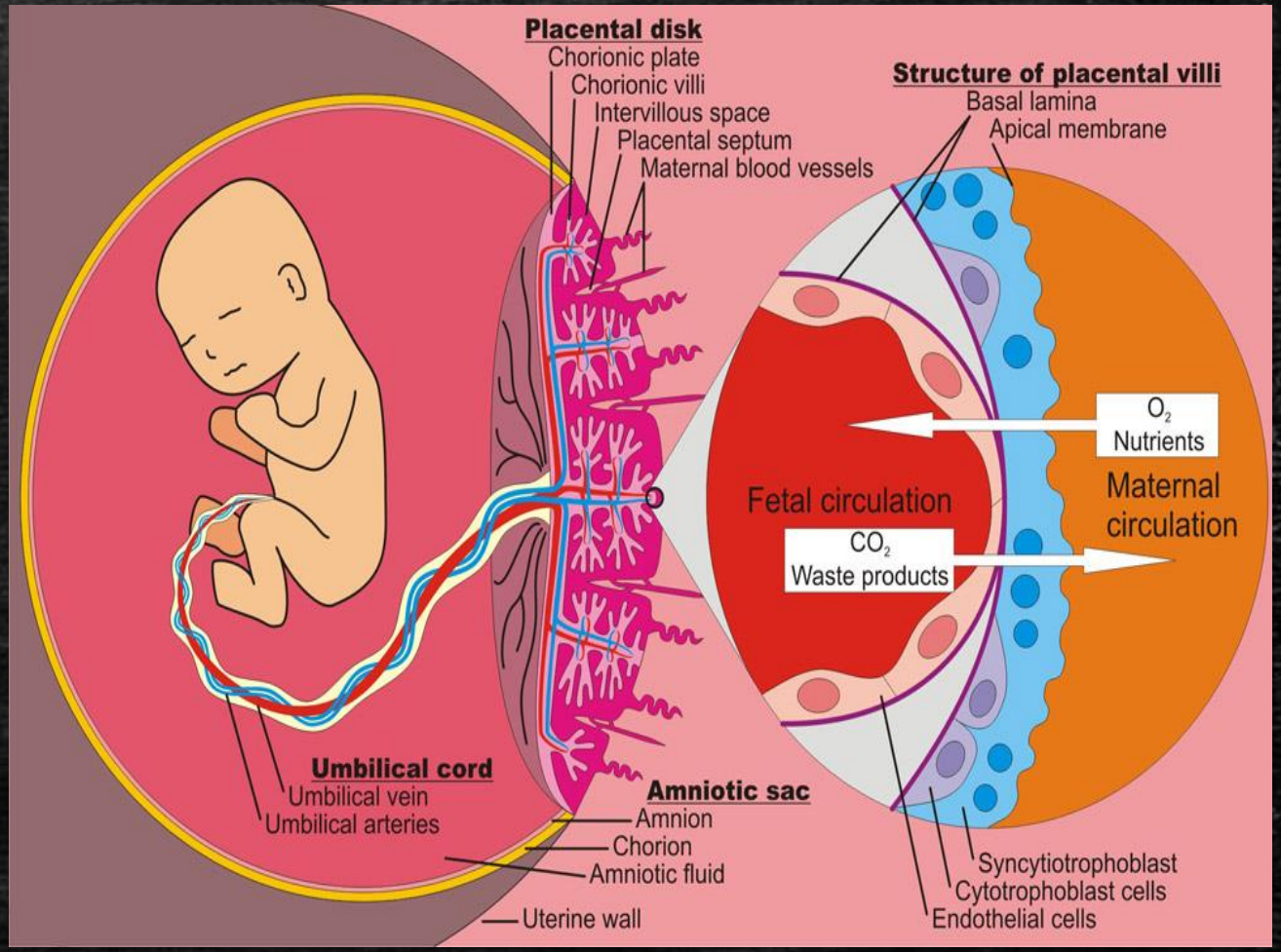
**As the trophoblast cells invade the decidua (endometrial cells), digesting and imbibing it, the stored nutrients in the decidua are used by the embryo for growth and development.
In the early months of pregnancy, the placental membrane is still thick because it is not fully developed. Therefore, its permeability is low. Further, the surface area is small because the placenta has not grown significantly. Therefore, the total diffusion conductance is minuscule at first. In later pregnancy, the **permeability increases because of thinning of the membrane diffusion layers and because the **surface area** expands many times over, thus giving the tremendous **increase in placental diffusion.**

Functions of the placenta

Functions of the placenta

- Respiration (simple diffusion)
- Nutrition (facilitated diffusion of glucose)
- Excretion
- Endocrine
- Protection

- ****simple diffusion**, driven by an oxygen pressure gradient from the mother's blood to the fetus's blood



Diffusion of Oxygen Through the Placental Membrane

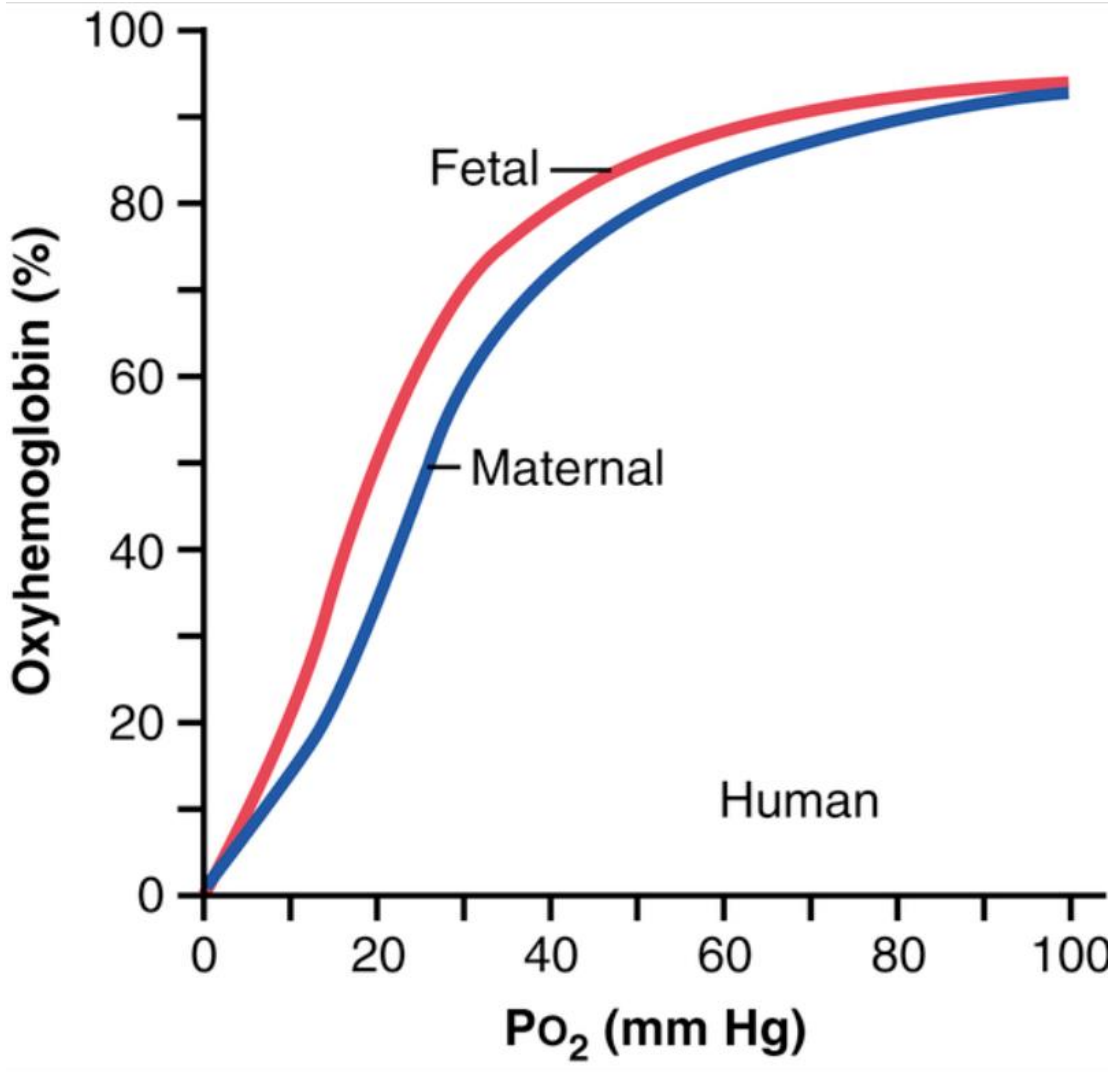
- Near the end of pregnancy, the mean partial pressure of oxygen (PO 2) of the mother's blood in the placental sinuses is about 50 mm Hg, and the mean PO 2 in the fetal blood after it becomes oxygenated in the placenta is about 30 mm Hg.

- Therefore, the mean pressure gradient for diffusion of oxygen through the placental membrane is about 20 mm Hg.

Is that enough Oxygen?

Diffusion of Oxygen Through the Placental Membrane

- The curve for fetal hemoglobin is shifted to the left of that for maternal hemoglobin. This means that at the low PO 2 levels in fetal blood, the fetal hemoglobin can carry 20% to 50% more oxygen than can maternal hemoglobin.
- Hemoglobin concentration of fetal blood is about 50% greater than that of the mother.



- 1: the hemoglobin of the fetus is mainly *fetal hemoglobin,* a type of hemoglobin synthesized in the fetus before birth
- At lower PO2 this hemoglobin is able to carry more o2 than maternal hemoglobin
- 3: Bohr effect: hemoglobin can carry more oxygen at a low Pco2 than it can at a high Pco2. when fetal blood clears co2 into maternal blood it will become alkaline and increases affinity to oxygen.

Hormonal Factors in Pregnancy

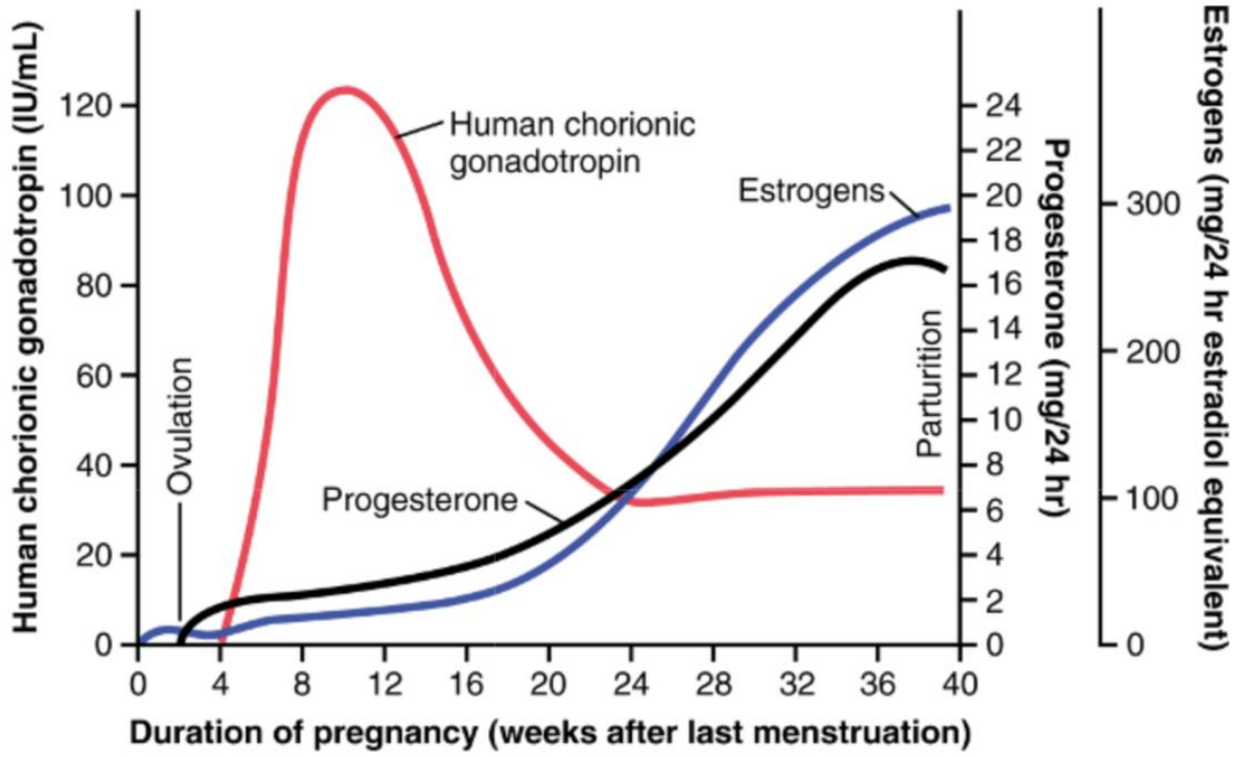
Pregnancy hormones

- In pregnancy, the placenta forms especially large quantities of

➢human chorionic gonadotropin,

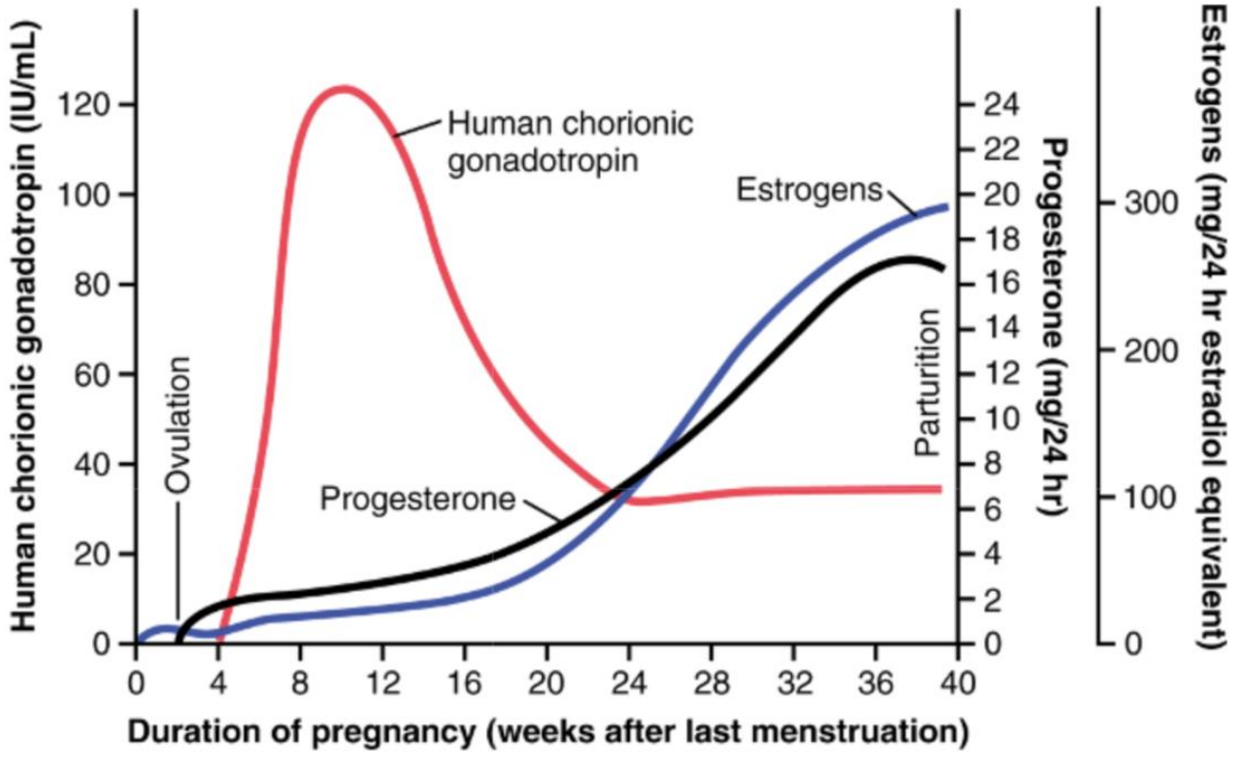
➢estrogens,

➢progesterone.



Human Chorionic Gonadotropin (HCG)

- Synthesized by trophoblast cells and secreted into the fluids of the mother.
- Can be measured in the blood 8 to 9 days after ovulation.
- Reach a maximum at about 10 to 12 weeks of pregnancy and decreases back to a lower value by 16 to 20 weeks.
- It continues at this level for the remainder of the pregnancy.



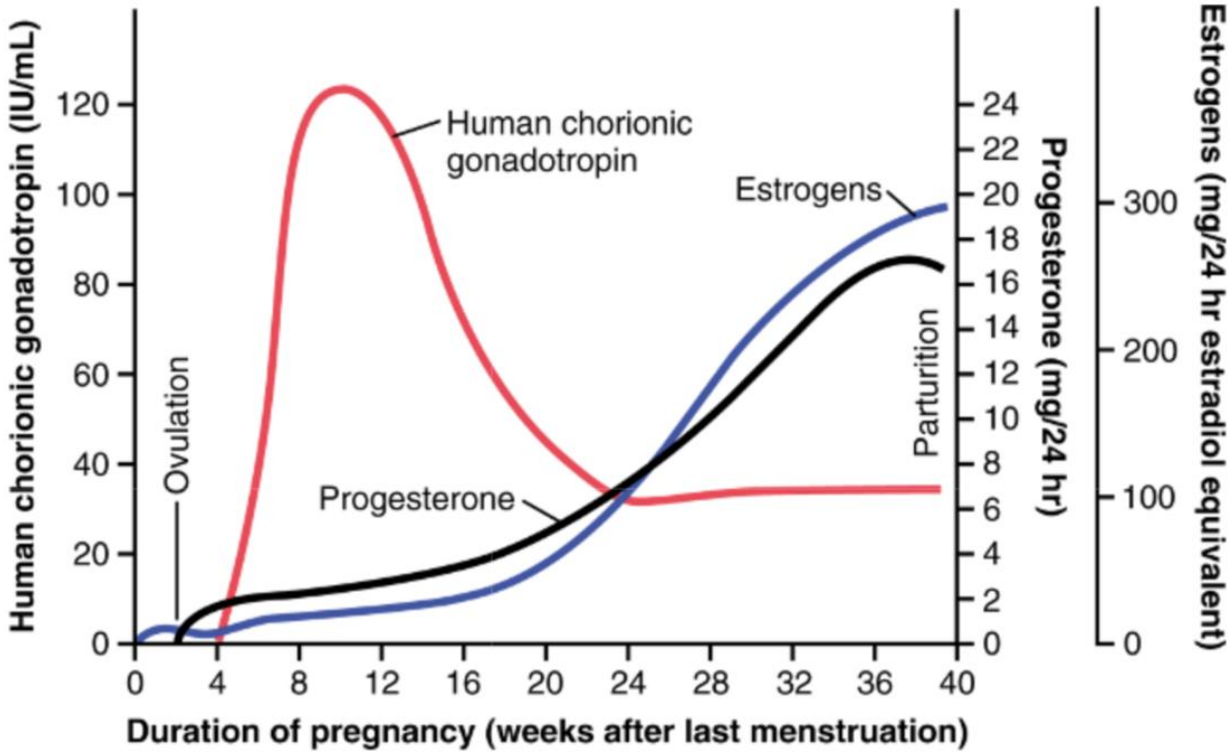
Human Chorionic Gonadotropin (HCG)

- Much similar molecular structure and function as luteinizing hormone.
- Prevents involution of the corpus luteum at the end of the monthly female sexual cycle.
- Stimulates testes of the male fetus to produce testosterone until the time of birth. (grow male sex organs)
- Under the influence of human chorionic gonadotropin,the corpus luteum in the mother's ovary grows to about twice its initial size by a month or so after pregnancy begins. Its continued secretion of estrogens and progesterone maintains the decidual nature of the uterine endometrium, which is necessary for the early development of the fetus.

Estrogen

- Secreted by syncytial trophoblast cells of placenta
- Towards the end of pregnancy it reaches 30×
- Derived from weak androgen (DHEA) released from maternal & fetal adrenals cortex

- Functions in the mother
- Enlargement of uterus, breast (and ductal) & external genitalia
- Relaxation of pelvic ligaments in preparation for labor(sacroiliac joints, symphysis pubis)



Progesterone

- Progesterone is essential for a successful pregnancy;
- Moderate quantities by the corpus luteum at the beginning of pregnancy
- later in large quantities by the placenta(10X), by syncytial trophoblast cells from cholesterol.
- Effects of progesterone in pregnancy:
- 1. Progesterone causes decidual cells development (nutrition of the early embryo)
- 2. Progesterone decreases the contractility of the pregnant uterus
- 3. Progesterone increases secretions of the mother's fallopian tubes and uterus.
- 4. Prepare the mother's breasts for lactation