Lecture 24
Embryonic & Fetal Development

Acrosomal Reaction and Sperm Penetration

- An ovulated oocyte is encapsulated by:
  - The corona radiata and zona pellucida
  - Extracellular matrix
- Sperm binds to the zona pellucida and undergoes the acrosomal reaction
  - Enzymes are released near the oocyte
  - Hundreds of acrosomes release their enzymes to digest the zona pellucida
- Once a sperm makes contact with the oocyte’s membrane:
  - A protein on its surface finds and binds to receptors on the oocyte membrane
  - Another protein causes it to insert into the membrane

Blocks to Polyspermy

- Only one sperm is allowed to penetrate the oocyte
- Two mechanisms ensure monospermy
  - **Fast block to polyspermy**
    - On contact of 1st sperm, Na⁺ diffuses into the oocyte from extracellular space
    - Membrane depolarization prevents additional sperm from fusing with the oocyte membrane
  - **Slow block to polyspermy**
    - On sperm entry, Ca²⁺ released by oocyte endoplasmic reticulum as part of preparation for cell division
    - Cortical reaction granules in plasma membrane rupture contents into extracellular space
    - These zonal inhibiting proteins (ZIPs) destroy sperm receptors
    - Sperm already bound to receptors are forced to detach
Events Immediately Following Sperm Penetration

- Upon entry of sperm, the secondary oocyte:
  - Completes meiosis II
  - Casts out the second polar body
- The ovum nucleus swells, and the two nuclei approach each other
- When fully swollen, the two nuclei are called pronuclei
- Fertilization – when the pronuclei come together

Process of Development

- The vertebrate embryo develops in three stages
  - **Cleavage**
    - A hollow ball of cell forms
  - **Gastrulation**
    - Cells move to the interior, forming the primary tissues
  - **Neurulation**
    - The organs of the body form

Cleavage: From Zygote to Blastocyst

- The first cleavage produces two daughter cells called blastomeres
- **Morula** – the 16 or more cell stage (72 hours old)
- By the fourth or fifth day the preembryo consists of 100 or so cells (blastocyst)
- **Blastocyst** – a fluid-filled hollow sphere composed of:
  - A single layer of trophoblasts
  - A fluid-filled cavity, the blastocoel
  - An inner cell mass
- Trophoblasts take part in placenta formation
- The inner cell mass becomes the embryonic disc (the embryo)
Extraembryonic Membranes

- The embryo reaches the uterus on day 6
- It penetrates the endometrial lining & initiates membrane formation
- Amnion
  - Encloses embryo
- Chorion
  - Forms from the trophoblast
  - Interacts with uterine tissue to form the placenta
- Yolk sac
- Allantois
- Amnion

Gastrulation: Onset of Developmental Change

- Certain groups of cells move inwards from the inner cell mass at about 10-11 days after fertilization
- This process of gastrulation results in the three primary germ layers
  - Endoderm
  - Ectoderm
  - Mesoderm

Fates of the Primary Germ Layers

<table>
<thead>
<tr>
<th>Germ Layer</th>
<th>Fate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ectoderm</td>
<td>Epidermis, central nervous system, sense organs, neural crest</td>
</tr>
<tr>
<td>Mesoderm</td>
<td>Skeleton, muscles, blood vessels, heart, gonads</td>
</tr>
<tr>
<td>Endoderm</td>
<td>Lining of digestive and respiratory tracts; liver, pancreas</td>
</tr>
</tbody>
</table>
Neurulation: Determination of Body Architecture

- In the third week, the three primary germ layers begin development into body tissues and organs
  - First, the neural tube develops from the ectoderm
  - The notochord develops from the mesoderm
  - The gut develops from the endoderm
- On either side of the notochord blocks of tissue (somites) form
  - These give rise to muscles, vertebrae and connective tissues developing notochord
- By the end of the third week, the embryo is about 2 mm (<0.1 inches) long

Fetal Development: 4th Week

Fourth week
- Formation of body organs, or organogenesis
- Critical time in development
- Alcohol use may cause fetal alcohol syndrome
- Embryo reaches about 5 mm

Fetal Development: 2nd Month

Second month
- Great changes in morphology occur
  - Limbs assume adult shape
  - Major internal organs are evident
- Embryo reaches about 25 mm
Third month
Development is essentially complete except for lungs and brain

Developing human is now called a fetus
It carries out primitive reflexes like sucking

Second trimester
A time of growth
Bone formation occurs
Hair and body are covered with fine hair called lanugo
By the end of the 6th month, the fetus is 30 cm (1 foot) long

Third trimester
Pace of growth accelerates
Weight of fetus more than doubles as nutrients are still provided by mother’s blood via the placenta

Most major nerve tracts are formed in the brain
**Postnatal Development**

Babies typically double birth weight within a few months.

Different body parts grow at different rates

- Allometric growth

Nerve cells produced at an average rate of >250,000 per minute

- At 6 months, neuron production ceases permanently

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**Circulation in Fetus and Newborn**

- By the end of the 3rd week:
  - The embryo has a system of paired vessels.
  - The vessels forming the heart have fused.

- Unique vascular modifications seen in prenatal development include umbilical arteries and veins, and three vascular shunts (occluded at birth):
  - Ductus venosus – venous shunt that bypasses the liver.
  - Foramen ovale – opening in the interatrial septum to bypass pulmonary circulation.
  - Ductus arteriosus – transfers blood from the right ventricle to the aorta.

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**Effects of Pregnancy: Anatomical Changes**

- **Chadwick’s sign** – the vagina develops a purplish hue.
- **Breasts** enlarge and their areolae darken.
- **The uterus expands**, occupying most of the abdominal cavity.
- **Lordosis** is common due to the change of the body’s center of gravity.
- **Relaxin** causes pelvic ligaments and the pubic symphysis to relax.
- **Typical weight gain** is about 29 pounds.
Effects of Pregnancy: Metabolic Changes

- The placenta secretes human placental lactogen (hPL), also called human chorionic somatomammotropin (hCS), which:
  - Stimulates the maturation of the breasts
  - Promotes growth of the fetus
  - Exerts a maternal glucose-sparing effect
- Human chorionic thyrotropin (hCT) increases maternal metabolism
- Parathyroid hormone levels are high, ensuring a positive calcium balance

Effects of Pregnancy: Physiological Changes

- GI tract – morning sickness occurs due to elevated levels of estrogen and progesterone
- Urinary system – urine production increases to handle the additional fetal wastes
- Respiratory system – edematous and nasal congestion may occur
  - Dyspnea (difficult breathing) may develop late in pregnancy
- Cardiovascular system – blood volume increases 25-40%
  - Venous pressure from lower limbs is impaired, resulting in varicose veins

Parturition: Initiation of Labor

- Estrogen reaches a peak during the last weeks of pregnancy causing myometrial weakness and irritability
- Weak Braxton Hicks contractions may take place
- As birth nears, oxytocin and prostaglandins cause uterine contractions
- Emotional and physical stress:
  - Activates the hypothalamus
  - Sets up a positive feedback mechanism, releasing more oxytocin
**Stages of Labor: Dilation Stage**

- From the onset of labor until the cervix is fully dilated (10 cm)
- *Initial contractions* are 15–30 minutes apart and 10–30 seconds in duration
- The cervix effaces and dilates
- The amnion ruptures, releasing amniotic fluid (breaking of the water)
- *Engagement* occurs as the infant’s head enters the true pelvis

**Stages of Labor: Expulsion Stage**

- From full dilation to delivery of the infant
- *Strong contractions* occur every 2–3 minutes and last about 1 minute
- The urge to push increases in labor without local anesthesia
- *Crowning* occurs when the largest dimension of the head is distending the vulva

**Stages of Labor: Expulsion Stage**

- The delivery of the placenta is accomplished within 30 minutes of birth
- *Afterbirth* – the placenta and its attached fetal membranes
- All placenta fragments must be removed to prevent postpartum bleeding
At 1-5 minutes after birth, the infant’s physical status is assessed based on five signs: heart rate, respiration, color, muscle tone, and reflexes. Each observation is given a score of 0 to 2. **Apgar score** is the total score of the above assessments. 8-10 indicates a healthy baby, while lower scores reveal problems.