Bellwork: How does the body send chemical signals? How do cells receive these signals?
Endocrine and Reproductive Systems

Section 34.1: The Endocrine system
What does your endocrine system do?

- Your nervous system works like a telephone - many messages are passed through neurons, carrying messages from cell to cell.
- The Endocrine System operates more like a radio, broadcasting chemical messages.
- Hormones are the chemical messengers.
  - Released in on part of the body, travel through the blood, and affect cells in another part of the body.
- The Endocrine system is made up of a series of glands that release hormones.
- Hormones have the potential to reach nearly every cell in the body.
What is a hormone? Why are hormones so important?

- Hormones work by binding to specific chemical receptors on cell membranes or within cells.
- A cell with a particular receptor for a hormone is called a target cell.
- No receptor = the hormone will have no effect on the cell.
- The response to hormones is slower and longer lasting than a response to the nervous system.
  - May take anywhere between minutes and days for a hormone to have its full effect on a target cell.
- Hormones often work in opposing pairs - eg. insulin and glucagon.
What are examples of glands in the body?

- The human body has numerous glands
- Exocrine glands release their secretions through tube-like structures (ducts) either out of the body, or directly into the digestive system
  - Examples - Sweat, tears, and digestive enzymes
- Endocrine glands release their secretions directly into the blood
- Other body structures (such as bones, fat tissue, heart, and small intestine) can also produce and release hormones
Major glands continued….

<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormone</th>
<th>Chemical Class</th>
<th>Representative Actions</th>
<th>Regulated By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Protein</td>
<td>Lowers blood glucose level</td>
<td>Glucose in blood</td>
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<tr>
<td></td>
<td>Glucagon</td>
<td>Protein</td>
<td>Raises blood glucose level</td>
<td>Glucose in blood</td>
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<tr>
<td>Adrenal glands</td>
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<tr>
<td>Adrenal medulla</td>
<td>Epinephrine and</td>
<td>Amine</td>
<td>Raise blood glucose level; increase metabolic activities; constrict certain blood vessels</td>
<td>Nervous system</td>
</tr>
<tr>
<td></td>
<td>norepinephrine</td>
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<tr>
<td>Adrenal cortex</td>
<td>Glucocorticoids</td>
<td>Steroid</td>
<td>Raise blood glucose level</td>
<td>ACTH</td>
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<td></td>
<td>Mineralocorticoids</td>
<td>Steroid</td>
<td>Promote reabsorption of Na⁺ and excretion of K⁺ in kidneys</td>
<td>K⁺ in blood</td>
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<tr>
<td>Gonads</td>
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<tr>
<td>Testes</td>
<td>Androgens</td>
<td>Steroid</td>
<td>Support sperm formation; promote development and maintenance of male secondary sex characteristics</td>
<td>FSH and LH</td>
</tr>
<tr>
<td>Ovaries</td>
<td>Estrogens</td>
<td>Steroid</td>
<td>Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics</td>
<td>FSH and LH</td>
</tr>
<tr>
<td></td>
<td>Progesterone</td>
<td>Steroid</td>
<td>Promotes uterine lining growth</td>
<td>FSH and LH</td>
</tr>
<tr>
<td>Pineal gland</td>
<td>Melatonin</td>
<td>Amine</td>
<td>Involved in biological rhythms</td>
<td>Light/dark cycles</td>
</tr>
</tbody>
</table>
What is a prostaglandin?

- Prostaglandins are modified fatty acids that are produced by a wide range of cells.
- They generally only affect nearby cells and tissues - often referred to as local hormones.
- They are produced by virtually all cells, not just endocrine glands.
- One example of use of prostaglandin is the ability to cause smooth muscles in the uterus, bronchioles or blood vessels to contract.
- Another group causes the sensation of pain during most headaches.
  - Aspirin inhibits the production of these prostaglandins.
How do hormones work?

- There are two types of hormones - Steroid (produced from cholesterol) and non-steroid (proteins, peptides and modified amino acids)
- As steroid hormones are lipids, they can easily cross cell membranes
- Once in a cell, a steroid hormone enters the nucleus, and can change the pattern of gene expression in a target cell
  - Effects of steroid hormones can be especially powerful and long lasting
- Hormone receptor complexes have the ability to turn on or off whole sets of genes
- Steroid hormones can produce dramatic changes in the activity of a cell
What about non steroid hormones?

- As they are not made from fats, non steroid hormones can not generally pass through the cell membrane of their target cells
- Instead, they bind to receptors on cell membranes and cause the release of secondary messengers that affect cell activities
- Secondary messengers can be Ca2+ ions, nucleotides, fatty acids, or cAMP
- Secondary messengers activate or inhibit a wide range of cell functions
Comparison of steroid and nonsteroid hormones
Key Points

- What are the two components of the endocrine system?
- What is the difference between an Endocrine and an Exocrine gland?
- How are hormones and prostaglandins similar? How are they different?
- How does a steroid hormone act on a cell?
- How does a nonsteroid hormone act on a cell?
Bellwork: Identify at least three processes, or body functions that are regulated by the endocrine system
Glands of the Endocrine system

Section 34.2
How many major glands in the Endocrine system are there?

- There are seven major glands that you need to know about:
  - The Pituitary gland
  - The hypothalamus
  - The adrenal gland
  - The pancreas
  - The thyroid gland
  - The parathyroid gland
  - The reproductive glands
What does your pituitary gland do?

- The Pituitary gland secretes hormones that directly regulate many body functions or control the actions of other endocrine glands.
- Controls growth hormone production
  - Too much - gigantism
  - Too little - dwarfism
- The pituitary gland is the size of a bean
- It is found on a slender stalk of tissue at the base of the brain
- It is divided into two parts - anterior and posterior
What does your Hypothalamus do?

- The hypothalamus controls the secretions of the pituitary gland
- It acts as the link between the central nervous system and the endocrine system
- Antidiuretic hormone (controls water reabsorption by kidney) and oxytocin (stimulates contractions during childbirth) are made in the cells of the hypothalamus, but stored in the axons that enter posterior pituitary
- The Hypothalamus also produces releasing hormones, which signal the anterior pituitary gland to release a specific hormone
Where are your adrenal glands? What do they do?

- Your adrenal glands are on your kidney
- They release hormones that help the body prepare for and deal with stress
  - Outer part - adrenal cortex (80% of gland)
    - Produces over two dozen steroid hormones (corticosteroids)
    - Examples - aldosterone regulates blood volume and pressure. Release stimulated by dehydration, excessive bleeding or Na+ deficiency
    - Cortisol - controls the rate of metabolism of carbohydrates, fats and proteins. Released during stress - e.g. intense exercise
  - Inner part - adrenal medulla - releases hormones that lead to “fight or flight” response
    - When under stress, impulses from sympathetic nervous system stimulate release of large amounts of epinephrine (adrenaline) and norepinephrine
    - Results in increased heart rate and blood pressure. Air passageways also widen
Is the pancreas an Endocrine or Exocrine gland?

- It is both!
- It releases digestive enzymes (exocrine gland)
- Other cells also release hormones into the blood (endocrine gland)
- Hormones are produced in clusters of cells that resemble islands (islets of Langerhans) - named after their discoverer
- Each islet contains Beta cells that secrete insulin, and alpha cells that release glucagon
- Together, insulin and glucagon result in stable blood glucose levels
What is diabetes mellitus?

- When the body fails to either produce or properly respond to insulin
- Often results in high blood glucose levels which can damage a number of body cells and systems
- **Type I diabetes** is an autoimmune disorder that usually develops before the age of 15
  - Beta cells are killed, meaning little to no insulin is produced
  - People with type I diabetes must follow a strict diet and receive daily doses of insulin
- **Type II** commonly develops after the age of 40. Islet cells produce normal amounts of insulin, but their cells do not properly respond to the hormone
  - In early stages can often be controlled through diet and exercise
  - Rapidly rising in US (and other western countries) due to increased obesity rates
What does your thyroid gland do?

- Your thyroid gland plays a major role in regulating the body’s metabolism.
- Metabolism is the sum of all chemical reactions that occur in your body.
- The thyroid produces thyroxine - increase the metabolic rate of cells throughout the body.
  - Cells become more active, use more energy and produce more heat.
- Iodine is needed to make thyroxine.
- In parts of the world that lack thyroxine - there are several associated health problems.
- Cretinism - neither the nervous system or skeletal system forms properly.
- Hyperthyroidism - too much thyroxine.
  - Results in nervousness, elevated body temperature and blood pressure, and weight loss.
- Hypothyroidism - too little thyroxine.
  - Lower body temp, lack of energy and weight gain are signs of this condition - sign: goiter.
What is Calcitonin, what does it do?

- Calcitonin is a hormone produced by the thyroid gland.
- It reduces blood calcium levels.
- It signals the kidney to reabsorb less calcium from filtrate, inhibits absorption of calcium from small intestine, and promotes absorption into bones.
- Parathyroid hormone is the opposing hormone - released from four parathyroid glands on the back surface of the thyroid.
- Opposing effect to calcitonin.
The reproductive glands

- Referred to as gonads - made up of Ovaries of Testes
- Two important functions - production of gametes and secretion of sex hormones
- In females - ovaries produce eggs and secrete estrogen
- In males - testes produce sperm and secrete hormone testosterone
How are endocrine glands controlled

- Like numerous other body systems, the endocrine system is regulated by feedback mechanisms that function to maintain homeostasis
- Example - controlling water balance
- Vigorous exercise = water loss due to sweat
- Dehydration is not severe because homeostasis swings into action
- As you lose water, concentration of dissolved material in the blood rises
- Hypothalamus responds
  - Tells posterior pituitary glands to release ADH
  - Sensation of thirst
Controlling metabolism

- Thyroid gland produces thyroxine
- Thyroxine - increases metabolic activity of cells
- Amount of thyroxine produced controlled by the pituitary
  - The Hypothalamus senses that thyroxine level in blood is low
  - Secretes thyrotropin releasing hormone (TRH) - stimulates anterior pituitary to release secrete thyroid stimulating hormone (TSH)
  - TSH stimulate thyroxine to be released by the thyroid gland
  - High Thyroxine levels in blood inhibit TRH and TSH secretion - stopping release of additional thyroxine
- Function also related to temperature - extra TRH produced if core body temperature begins to drop
Key Concepts

● Describe the role of each major endocrine gland
● How is the hypothalamus an important part of both the endocrine and the nervous systems?
● Compare and contrast the two types of diabetes
● How does your endocrine system help maintain homeostasis?
● After vigorous exercise, what steps does your body take to replace water lost due to sweat
The reproductive System

Section 34.3
What is Puberty?

- Puberty is a period of rapid growth and sexual maturation during which the reproductive system becomes fully functional
  - Age of onset of puberty can vary between 9 and 15 - on average begins one year earlier in females than males
- Begins in the brain with the hypothalamus signalling the pituitary gland to produce two hormones that affect the gonads -
  - Follicle stimulating hormone and Luteinizing hormone
- The actual sex of an embryo is determined during the 7th week of development
  - Male pattern of development caused by testosterone production in gonads
  - Female reproductive system develops under the influence of estrogens produced in gonads
The male reproductive system

- LH stimulates cells in testes to produce increased amounts of testosterone
- Testosterone causes the physical changes associated with puberty, and (alongside FSH) stimulate sperm production
- Upon completion of puberty, the male reproductive system is fully functional
- Testes (testis) - primary organs of male reproductive system
- Descend from abdomen into external sac called scrotum after birth
  - Important due to lower than normal body temperature (37 °C), which is important for sperm development
How do sperm develop?

- The testis contain hundreds of tiny tubules called seminiferous tubules, where sperm develop
  - Diploid cells within the tubules undergo meiosis and form haploid nuclei of mature sperm
- Sperm are then moved into the epididymis, where they mature and are stored
- Some sperm are then moved into the vas deferens
  - This extends upwards from the scrotum into the abdominal cavity
  - Merges with urethra - leading to the outside of the body through the penis
- Glands lining the reproductive tract (seminal vesicles, prostate and bulbourethral) produce nutrient rich seminal fluid
  - Seminal fluid nourishes and protects sperm
  - Combination of sperm and fluid is semen
  - 1 ml of semen contains between 50 and 130 million sperm
Sperm structure and release

- A mature sperm cell consists of a head that contains a highly dense nucleus, a midpiece packed with energy releasing mitochondria and a tail/flagellum.
- At the tip of the head is a small cap containing enzymes vital for fertilization.
- When a male is sexually aroused, the autonomic nervous system prepares the male organs to deliver sperm.
  - Not completely voluntary as it is controlled by the autonomic nervous system.
- The penis becomes erect, and the sperm are ejected from the penis by the contraction of smooth muscles lining the glands in the reproductive tract - ejaculation. Ordinarily 2 - 6 ml of semen.
The female reproductive system

- Primary reproductive system are the ovaries - function to produce egg cells (ova) and nourish a developing embryo
- FSH stimulates cells within the ovaries to start producing egg cells and increased amounts of estrogens
- At puberty each ovary contains as many as 400,000 primary follicles
  - Helps eggs mature for release
- A female’s ovary actually only releases about 400 eggs cells
- Beside ovary, female reproductive system also includes fallopian tubes, uterus, cervix and vagina
The menstrual cycle

- One ovary produces and releases a mature ovum about every 28 days - forms part of the menstrual cycle
- The menstrual cycle is a regular sequence of events involving the ovaries, lining of the uterus, and the endocrine system
  - It is regulated by hormones made in the hypothalamus, pituitary and ovaries, and is controlled by internal feedback mechanisms
- During each cycle an egg develops within a follicle and is released from an ovary. The uterus is also prepared to receive a fertilized egg. If not fertilized, it is discharged, along with the lining of the uterus
- If an egg is fertilized, embryonic development begins, and the menstrual cycle ceases
The phases of the menstrual cycle

- **The follicular phase**
- Day 1 - low blood estrogen level
- Hypothalamus stimulates secretion of FSH and LH from pituitary.
  - Travel to ovary, cause follicle to mature
- Over following days, cells surrounding the eggs enlarge, begin to produce increased amounts of estrogens. Estrogen levels in blood can rise dramatically
  - Can cause the hypothalamus to produce less releasing hormone and pituitary to release less LH and FSH
- Estrogens cause lining of uterus to thicken in preparation for receiving fertilized eggs
  - Takes about 12 days
Ovulation

● As the follicle grows more and more estrogens are released
● When concentrations of estrogens reach a certain level the hypothalamus reacts by triggering a burst of LH and FSH from anterior pituitary
● Sudden increase in LH causes follicle to rupture
● Result is ovulation - the release of an egg into one of the fallopian tubes
● When released the egg is stalled in metaphase of meiosis II and remains there unless fertilized
● In the fallopian tube, microscopic cilia push the cell through the tube towards the uterus
Luteal phase

- This phase begins immediately after ovulation
- As the egg moves through the Fallopian tube, the cells of the ruptured follicle change
  - Follicle turns yellow and is known as the corpus luteum
  - Continues to release estrogen, but also progesterone
- Progesterone stimulates the growth and development of the blood supply and surrounding tissue in the already thickened uterine lining. The rise in these hormones inhibits the production of FSH and LH.
  - Additional follicles do not develop during this cycle
- Unless fertilization occurs and an embryo starts to develop, the fall of LH levels leads to degeneration of the corpus luteum
  - Estrogen levels fall, hypothalamus signals the release of FSH and LH from the anterior pituitary, and the follicular phase begins again
Menstruation

- At the start of the new follicular phase, low estrogen levels also cause the lining of the uterus to detach from the uterine wall.
- This tissue, along with the blood and unfertilized egg, are discharged through the vagina - menstruation.
- Menstruation lasts about three to seven days on average. A new cycle begins with the first day of menstruation.
- The menstrual cycle continues, on average until a female is in her late forties to early fifties.
- At this time, the production of estrogens declines and ovulation and menstruation stop. This process is called menopause.
Pregnancy

- The menstrual cycle stops if a woman becomes pregnant.
- Chance of egg fertilization is greatest during the first two days of the luteal phase.
- Within a few days of implantation, the uterus and growing embryo release hormones that keep the corpus luteum functioning for several weeks.
- This allows the lining of the uterus to nourish and protect the developing embryo, and prevents the menstrual cycle from starting again.
Sexually transmitted diseases

- A sexually transmitted disease (STD) is any disease that is spread through sexual contact
- Serious health problem in the United States (and to be honest around the world)
- Chlamydia is the most common bacterial STD, but also the most common bacterial diseases in the USA
  - Damages the reproductive tract and can lead to infertility
- Other bacterium include gonorrhea and syphilis
- Viruses can also cause STD’s - examples include hepatitis B, genital herpes genital warts and AIDS. Some can be fatal
  - Some can even lead to more serious side effects - genital warts caused by HPV, can lead to cervical cancer
- Any sexual contact carries with it the chance of infection
Fertilization and development

Section 34.4
Fertilization

- During sexual intercourse semen is released just below the cervix, the opening that connects the vagina to the uterus just below the cervix (opening that connects the vagina to the uterus)
- Sperm swim through the uterus to the fallopian tubes
- The egg is surrounded by a protective layer that contains binding sites to which sperm can attach
- Sperm head releases enzymes that break down protective layer of the egg
- Haploid nucleus of sperm enters the egg, and the two chromosomes are bought together - producing a single diploid nucleus (a zygote). A developing human is called an embryo at this point
Why can only one sperm enter an egg

- As soon as fertilization occurs, the egg will release a series of granules from just beneath it’s surface.
- The material in the granules coats the surface of the egg, forming a barrier that prevents other sperm from attaching to it.

What happens if multiple eggs are released at one time?

- Fraternal twins are caused by two separate eggs being released.
- Identical twins are produced by the splitting of a single zygote.
When does implantation occur?

- About six or seven days after fertilization
- The embryo grows, and essentially forms into a hollow ball of cells - a blastocyst, which implants itself into the wall of the uterus - implantation!
- At this point individual cells in the blastocyst begin to specialize - differentiation
- Inner cell mass develops within inner cell cavity
- Body of embryo develops from these cells
- Other cells of blastocyst develop into tissues that support and protect the embryo
What happens next?

- The embryo begins a series of dramatic changes that will produce the key structures and tissue layers of the body
- Gastrulation produces the three cell layers of the embryo
- Neurulation leads to formation of the nervous system
- A block of mesodermal tissue forms a notochord
- Ectoderm near notochord thickens, forms neural plate
- Neural tube forms from neural plate
- If neural tube does not close completely, it can lead to spina bifida
What does the placenta do?

- As the embryo develops, specialized membranes form to protect and nourish the embryo.
- The embryo is surrounded by the amnion - a fluid-filled sac with amniotic fluid that cushions and protects the developing embryo.
  - Chorion forms outside the amnion, making direct contact with the tissues of the uterus.
- During the third week of development, small fingerlike projections called chorionic villi form on the outer surface of the chorion, and extend into the uterine lining.
  - Chorionic villi and uterine lining form the placenta, a connection between the mother and embryo that facilitates respiration, excretion, and nutrition.
  - Blood of mother and embryo flow past each other, but do not mix.
  - Umbilical cord, which contains two arteries and one vein, connects the embryo to the placenta.
- After 8 weeks, the embryo becomes a fetus. After 3 months, most major organs and tissues have formed (it is 8 cm long and weighs about 28 grams).
What are other important stages of development

- During months 4 - 6, the tissues of the fetus become more specialized and complex, and begin to function.
  - The heart can be heard through a stethoscope
  - Bone replaces cartilage
  - Soft hair grows over skin of fetus

- During Months 7 - 9, the organ systems mature, and the fetus grows in size and mass
  - Organs, such as lungs prepare themselves for life in the outside world
  - Fetus can regulate body temperature

- Ordinarily takes 9 months for fetus to fully develop.
  - Babies born before 8 months are called premature babies, and may have breathing difficulties due to incomplete lung development
In images

Human Embryo - Carnegie Stages

Dr Mark Hill, School of Medical Science, UNSW AUSTRALIA
https://embryology.med.unsw.edu.au

Stage 1 Zygote
(1 day, not to scale)

1 (1 day)
2 (3 days)
3 (4 days)

7 (15-17 days)
8 (17-19 days)

15 (35-38 days)
16 (37-42 days)
17 (42-44 days)
18 (44-48 days)

9 (19-21 days)
10 (21-23 days)
11 (23-26 days)
12 (26-30 days)
13 (28-32 days)
14 (31-35 days)

19 (48-51 days)
20 (51-55 days)
21 (53-54 days)
22 (54-58 days)

23

Fetal Calendar - embryos with permission of Prof. Kateri Smidt and Prof. Prangdech Yavasita.
Childbirth

- After about 9 months the fetus is ready for birth - caused by a series of factors
  - One factor is release of hormone oxytocin - affects group of involuntary muscles in uterine wall, beginning a series of rhythmic contractions (labor)
  - Contractions become more frequent as labor progresses
- Cervix opening expands until it is large enough for the head of a baby to pass through
  - Amniotic sac will break - fluid rushes out of vagina
  - Baby ordinarily presents head first
- Once born, the baby will cough or cry to clear lungs of fluids
  - Umbilical cord clamped and cut
- Finally placenta is born
- Within a few hours after birth pituitary hormone prolactin stimulates the production of milk in the breast tissues of mothers.
  - Nutrients in milk provide everything the baby needs for the first few months of life
Infant and maternal health

- Although the placenta acts as a barrier to many harmful or disease forming agents, some can pass through the barrier and affect the embryo
  - AIDS can affect the fetus
  - Virus that causes rubella can also cause birth defects
- Alcohol can permanently damage nervous system
- Drugs such as cocaine or heroin can cause the baby to become addicted to the drugs before they are even born
- Smoking during pregnancy doubles the risk of low weight at birth - can lead to other health problems
- From 1970 to 2000, infant mortality rate in the United States decreased by 65% - can be linked to increased access to prenatal care and advances in medical technology
Key concepts

● Describe the process of fertilization
● What is the role of the placenta?
● What is Gastrulation? What is Neurulation?
● What is oxytocin? What is it’s role in childbirth?
● Why should pregnant women take extra care over what they ingest during pregnancy?