GENERAL PHYSIOLOGY WITH FAMILY PLANNING

GEN PHYSIO | **2ND SEMESTER | 2025-2026 | DMD-2A**

TOPIC 12: HEARING

Lecturer: Dr. Ma. Noemi E. Jiao, MD, DPPS
Based on: Guyton & Hall Textbook of Medical Physiology, 14th Edition

I. ANATOMY OF THE EAR

The ear is divided into 3 major divisions:

1. **External / Outer Ear**
2. **Middle Ear**
3. **Inner / Internal Ear (Labyrinth)**

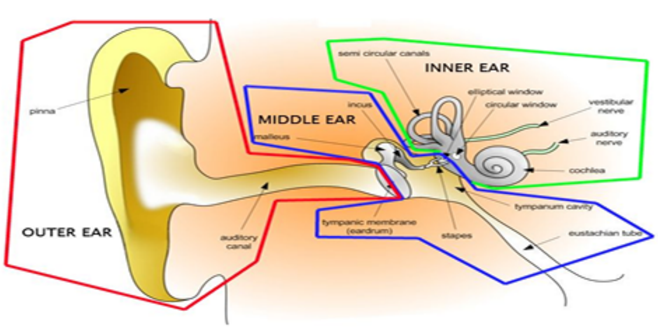
A. Outer / External Ear

1. Pinna (Auricle)

- **Shell-shaped** structure surrounding the auditory canal
  - **Collects** and **directs** sound waves into the auditory canal
  - This function is largely **lost** in humans (vestigial); we can no longer move our pinna in order to catch the sound coming from the outside
  - Serves to collect and direct the sounds coming from the environment

2. External Auditory Canal

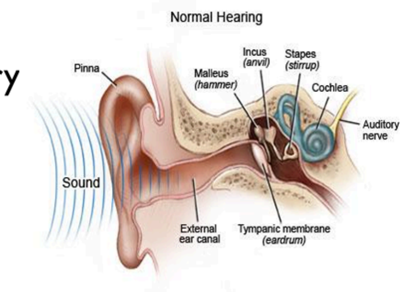
- Short, narrow chamber carved in the temporal bone
- Lined with skin containing ceruminous glands
  - **Ceruminous glands:** found on the skin lining the walls of the external auditory canal
  - **Ceruminous glands** secrete earwax or cerumen
  - *Cerumen (earwax)* protects and lubricates the canal



3. Tympanic Membrane (Eardrum)

- Found at the end of the **external auditory canal**
- Separates the outer ear from the middle ear
- Acts as a resonator that reproduces the vibrations of the sound source
  - Multiplies the force of vibration by 17X

sound waves
↓
external auditory canal
↓
eardrum
↓
vibrate



🗣***What happens to the sound waves from the environment?***

When someone shouts, the sound waves enter the pinna and pass through the external auditory canal. The waves hit the eardrum, causing the eardrum to vibrate.

B. Middle Ear

Tympanic Cavity

- Small, air-filled cavity within the temporal bone
- Boundaries:
  - **Laterally**: eardrum/external auditory canal/. The eardrum constitutes the lateral boundary of middle ear
  - **Medially**: oval window and round window (both membrane-covered)

3 Auditory Ossicles

Ossicle	Common Name	Key Anatomical Features
Malleus	Hammer	a. ***Handle*** (manubrium) attached to tympanic membrane b. ***Head*** attached to wall of middle ear c. ***Short process*** attached to incus
Incus	Anvil	Articulates with the head of the stapes
Stapes	Stirrup	Resembles a stirrup; Foot plate attached to the annular ligament of the oval window. Very close to oral window, as stapes move through and through, it produces waves behind the oval window

🗣***What happens when vibration occurs in the tympanic membrane?***

- The vibration is transmitted to the malleus, then to the incus, and then to the stapes.

Sound Transmission Through Ossicles

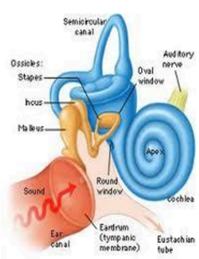
- Sound from the environment enters the ear.
- It reaches the **tympanic membrane (eardrum)** and causes it to vibrate.

- The vibration moves the **malleus, incus, and stapes**.
- The **stapes** is connected to the **oval window**.
- Vibrations create **pressure at the oval window**.
- This pressure is transmitted into the **cochlea**.

Tympanic membrane acts as a resonator that reproduces the vibrations of the sound source

Motions in the Tympanic Membrane
↓
Rocking of the malleus
↓
Vibrations are transmitted to the incus

Incus transmits vibrations to the head of the stapes
↓
Swinging of stapes to and fro at the oval window
↓
Causes sound pressure against the perilymph filled scala vestibuli



The 3 ossicles found are proximate to each other. When the stapes vibrate, it starts to swing and hit At the back oval window you have the fluid filled scala vestibuli. Where there is pressure on your oval window it causes waves inside the cochlea.

Force Amplification

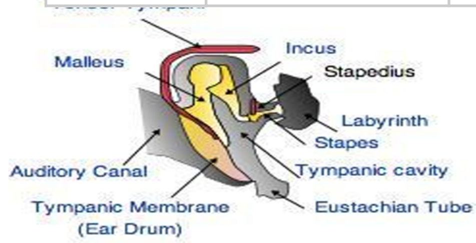
Structure	Force Multiplication
Lever action of incus + malleus	1.3×
Tympanic membrane (area ratio)	17×
TOTAL sound pressure at oval window	22×

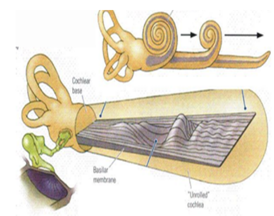
‣ **CLINICAL NOTE: Ossicular System**

- Only 60% of sound energy in the tympanic membrane is transmitted to the cochlear fluid
- Absence of the ossicular system + tympanic membrane → **decrease** in hearing sensitivity by **15–20 dB**
- A **medium voice** will be heard as a *whisper*/barely perceptible

2 Small Skeletal Muscles of the Middle Ear

Muscle	Action	Effect
Tensor tympani	Contraction pulls manubrium of malleus medially or away from tympanic membrane	Decreases/less vibration from tympanic membrane
Stapedius	Contraction pulls the foot plate of stapes out of the oval window.	As the malleus, incus and stapes are swinging to and fro because of its distance from the oval window, it reduces sound transmission to inner ear





Tympanic / Attenuation Reflex

- Involves simultaneous **contraction** of *tensor tympani* and *stapedius muscles. (Attenuate is decrease)*
- Decreases sound transmission by **30–40 dB**

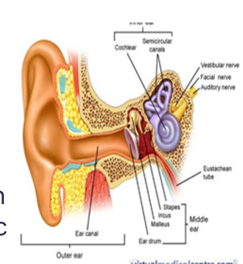
Functions:

- **Protects the cochlea from damaging vibrations caused by excessively loud sounds.** When constantly listening to very loud music, your cochlea eventually gets damaged, resulting in hearing loss.
- **Masks low-frequency sounds in loud environments** – removes background noise. When in a club, initially the sound is so loud that you cannot talk to each other; as time passes, you get adapted to your environment. There is attenuation of the background noise. At this time, the reflex is activated.
- ***Decreases*** a **person's sensitivity** to **his own voice -** when you shout very loudly into your friend's ear, you cannot hear or feel your shout as very loud because the moment you plan or shout, your attenuation reflex is activated. Unlike the person you are shouting to, their reflex is not activated.

🗣️Your attenuation reflex gets activated when the sound is present for some time. When a short, loud sound occurs, it cannot activate your attenuation reflex; when the sound is acute, like the sound of a gunshot, that sound does not activate your attenuation reflex.

Auditory Tube (Eustachian Tube)

- Links the middle ear cavity with the throat (nasopharynx)
- Normally flat and closed
- Opens during swallowing and yawning to Equalizes pressure in the middle ear with atmospheric pressure



🗣️As planes start to descend, our ears start to pop or feel painful. We either chew gum or swallow saliva. When we swallow saliva or chew, this opens the auditory tube, normalizing the pressure between the ear and the atmosphere. The act of swallowing and chewing will actually relieve the pressure and the popping feeling.

▸ **CLINICAL: Ear Infections**

Otitis Externa – **inflammation** of the **EXTERNAL ear**

Otitis Media (buog) – fairly common result of sore throat, especially in children

- Children's auditory tubes run more *horizontally* → easier for bacteria to ascend
- Eardrum bulges and often becomes inflamed
- Pus coming out of the ear due to a ruptured eardrum

Treatment: (1) Antibiotics (2) Decongestants (3) Myringotomy

Prevention: Never prop a bottle or feed infants when they are lying flat

C Inner Ear (Labyrinth)

- Made up of TWO parts – one within the other

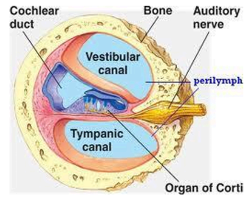
Structure	Composition	Contents
Bony Labyrinth (Outside)	Series of channels in the temporal bone	Fluid known as Perilymph; Encloses the membranous labyrinth
Membranous Labyrinth (inside)	Duplicates the shape of the bony labyrinth	Fluid = Endolymph

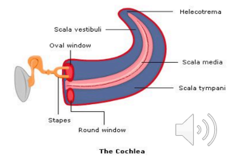
Ballpen plastic = bony labyrinth , tube with ink = membranous labyrinth, ink = endolymph

The inner ear contains your cochlea, which is circular in form. The inner ear looks like the body of a snail. The spiral shape of the cochlea is stretched out.

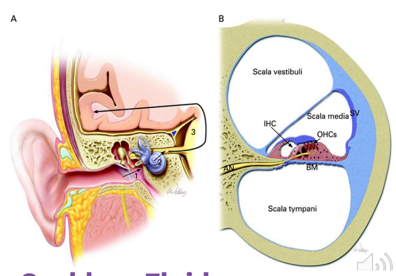
The Cochlea

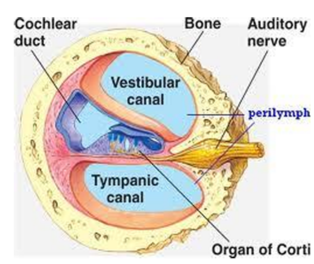
- A coiled tube in the labyrinth
- Divided into 3 chambers by **Reissner's membrane** and the **Basilar membrane**
- Reissner's membrane is found superiorly, while the basilar membrane is found inferiorly. Because of these membranes, you now have the membranous labyrinth.
- In the cross-section, you can see the three canals. At the distal end of the cochlea, you have the helicotrema, which is the communication between the scala vestibuli and the scala tympani; these contain perilymph. The scala vestibuli ends at the oval window, while the scala tympani ends at the round window.
- If the stapes moves to and fro, it hits the oval window and creates waves on the other side, which is inside the cochlea. This movement of waves causes the fluid in the three chambers to move.





Chamber	Location	Fluid	Boundaries / Notes
Scala Vestibuli	Upper chamber (Superiorly)	Perilymph	Communicates with scala tympani through Helicotrema; ends at oval window at base of cochlea
Scala Media (Cochlear Duct)	Middle chamber	Endolymph	Continuous with membranous labyrinth; bounded by Reissner's membrane (top) and basilar membrane (below); contains Organ of Corti (receptor of hearing)
Scala Tympani	Lower chamber (Inferiorly)	Perilymph	Ends at the round window





Cochlear Fluids

Fluid	Location	Origin	Ionic Composition	Function
Endolymph	Fills the Scala media	Produced by stria vascularis which is found of the wall of scala media Resembles ICF	High K+, Low Na+	Bathes the **TOP** of hair cells (found in organ of corti)
Perilymph	Scala vestibuli + Scala tympani	Formed from plasma; resembles ECF	High Na+, Low K+	Bathes the **BASE** of hair cells

Basilar Membrane

•A fibrous membrane separating the scala media and scala tympani

- Contains ***20,000–30,000*** *basilar fibers*
  - **Basal ends** are **fixed** on the bony structures of the cochlea
  - **Distal ends** are **embedded** in the loose basilar membrane
- Basilar fibers can *vibrate* (key to frequency discrimination):
  - **STIFF SHORT** (found near the oval window) fibers near the oval window → vibrate best at **HIGH frequency.**
  - **LONG fibers** near the tip (apex) of the cochlea → vibrate best at **LOW frequency. B**

‣ PLACE PRINCIPLE (Guyton)

- The position of maximum basilar membrane vibration determines the perceived pitch
- **High-pitch (high-frequency) sound** → maximum vibration near **BASE** of cochlea
- **Low-pitch (low-frequency) sound** → maximum vibration near **APEX** of cochlea
- Spatial organization of nerve fibers from cochlea to cerebral cortex mirrors this tonotopic map

Organ of Corti

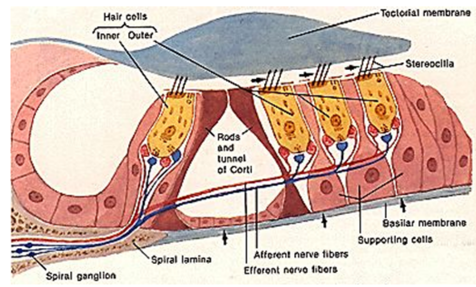
- Located on the basilar membrane
- The receptor organ for hearing
- Contains hair cells – the auditory receptors

Hair Cell Type	Features	Role
Outer Hair Cells	3 rows; stereocilia embedded in tectorial membrane	Control the sensitivity of inner hair cells; amplify basilar membrane motion. Tell the brain when the sound is loud
Inner Hair Cells	1 row; 95% of cochlear nerve endings terminate here	Primary detectors of sound; more important in sound detection. They are activated when there are sound coming from the environment

Hair Cell Structure

- They generate nerve impulses in response to sound vibration
- With stereocilia which project from the hair cells and are embedded in the surface gel coating of the tectorial membrane
- Bases synapse with cochlear nerve endings
- Upper ends are fixed on the reticular lamina, which are supported by rods of Corti
- Generate nerve impulses in response to sound vibration

🗣When the basilar membrane moves, the hair cells move with it. As the hair cells move, the stereocilia bend to and fro. This bending of the stereocilia stimulates the hair cells, leading to the generation of nerve impulses.



II. TRANSMISSION OF SOUND WAVES IN THE COCHLEA – 'THE TRAVELLING WAVE'

- Movement of the foot plate produces a series of travelling waves in the perilymph of the scala vestibuli
- As the wave moves up the cochlea, its height increases to a maximum then drops rapidly
- Distance from the stapes to the point of maximum height varies with frequency of vibrations
- **High-frequency** sounds peak near the base (close to the oval window).
- **Low-frequency** sounds peak farther along toward the apex (near the **helicotrema)**

Sequence of Events from Sound to Nerve Impulse

Step	Event
1	Sound waves enter external auditory canal
2	Eardrum vibrates
3	Vibration of the oval window
4	Movement of the basilar fibers
5	Rocking of the Rods of Corti
6	Hair shears back and forth against the tectorial membrane
7	Hair cells are excited
8	Send impulses to cochlear nerve endings
9	Spiral ganglion of Corti
10	Send axons to the cochlear nerve

🗣Now let us summarize what happens to the sound coming from the environment. The sound enters the ear in the form of waves and passes through the external auditory canal. It hits the tympanic membrane, causing it to vibrate. The vibration of the tympanic membrane causes movement of the malleus, and because the malleus is connected to the incus, the incus also moves back and forth. Since the incus is connected to the stapes, the stapes moves to and fro as well.

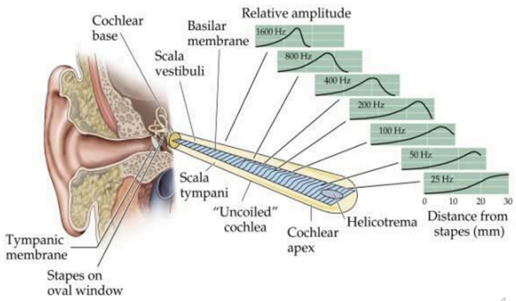
This movement reaches the oval window. The vibration of the oval window creates waves inside the cochlea, causing movement of the basilar membrane. Remember the organ of Corti, which sits on the basilar membrane. When the basilar membrane moves, the organ of Corti also moves, causing the hair cells to move from left to right and right to left.

When this happens, the stereocilia of the hair cells shear back and forth against the tectorial membrane. This stimulates the hair cells, causing them to become excited and generate nerve impulses. These impulses are then transmitted to the cochlear nerve endings, to the spiral ganglion of Corti, and eventually to the axons of the cochlear nerve

III. DETERMINATION OF SOUND QUALITIES

A. Pitch (Frequency)

- **Pitch** is correlated with **frequency**
- Unit: **Hertz (Hz)**
- Determined by the PLACE PRINCIPLE:
    - ***Lower frequency*** sound → activation of basilar membrane near the **APEX** (man voice hair cells near helicotrema or apex are activated)
    - ***High frequency*** sound → activation near the **BASE** (hair cells near the cochlea get excited)
    - Spatial organization of nerve fibers from cochlea to cerebral cortex

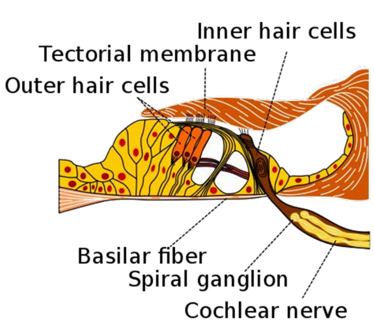


🗣️Doc Jiao's Yapping:

- Specific neurons are activated by specific sound frequencies
- If we call the area near the apex "Area A" and the area near the base "Area B," nerve fibers from each region project to corresponding areas in the brain.
- Thus, impulses from a specific part of the basilar membrane go to the same mapped area in the brain. Signals from Area B indicate high-frequency sound (base), while signals from Area A indicate low-frequency sound (apex).
- Stimulation of the base of the cochlea produces high-pitched sound (around 1600 Hz) because short, stiff fibers there respond to high frequencies.
- Stimulation of the apex near the helicotrema produces low-pitched sound (around 25 Hz) because long, flexible fibers there respond to low frequencies.

B. Loudness

- **Loudness** is correlated with **amplitude**
- Unit: **Decibel (dB)**
- Determined by 3 mechanisms:
    1. Excitation of the nerve endings by the hair cells at more rapid rates
    2. Transmission of impulses through many nerve fibers
    3. Significant stimulation of the outer hair cells through high-intensity vibration of the basilar membrane
    4. The outer hair cells are only stimulated when the sound from the environment is loud, when the sound is soft, then the outer hair cells are not stimulated.



C. Sound Direction

1. **Depends upon the DIFFERENCE IN ARRIVAL TIME of sound in the 2 ears**
    - Most important factor at frequency **<3,000 Hz**
2. **Sound is LOUDER on the side closest to the source**
    - Most important factor at frequency **>3,000 Hz**
3. **Sounds** coming from **directly in front** of the individual differ in quality from those coming from behind because the external ears are turned *slightly forward*

🗣️Sound from the **left** is detected slightly earlier and louder in the left ear, creating interaural time and level differences. The brain compares these inputs, with stronger contralateral processing in the **right auditory cortex,** allowing sound localization.

The brain localizes sound using interaural time differences (ITD) and interaural level differences (ILD) for left-right positioning. These cues are less effective for sounds coming directly in front or behind, since they reach both ears at the same time and intensity.

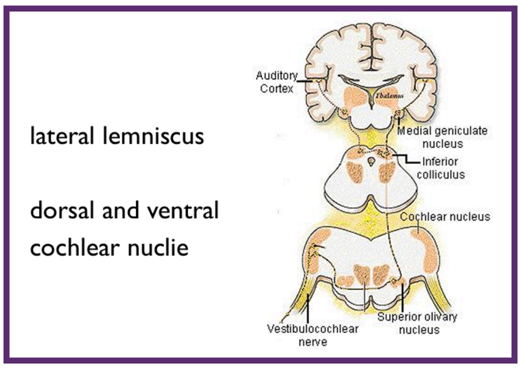
To distinguish front from back, the brain uses spectral filtering—subtle frequency changes caused by the shape of the outer ear and ear canal. This helps identify the sound's direction.

Because of this, front-back localization is generally more difficult than left-right localization in hearing experiments.

IV. CENTRAL AUDITORY MECHANISMS (AUDITORY PATHWAY)

Pathway (in order):

Station	Location	Notes
Cochlear Nerve (CN VIII)	Inner ear	Arises from spiral ganglion of Corti
Dorsal & Ventral Cochlear Nuclei	Medulla	First synapse in CNS
Fibers Decussate	Brainstem	Cross to the opposite side (left ear will now reach to right brain)
Contralateral Superior Olivary Nucleus	Pons	Important for sound direction (contra - other side)
Fibers pass through the Lateral Lemniscus	Brainstem tract	Ascending auditory pathway
Inferior Colliculus	Midbrain	Reflex responses to sound
Medial Geniculate Nucleus	Thalamus	Relay station
Auditory Cortex	Superior gyrus of temporal lobe (Brodmann's area 41)	Primary and secondary cortex



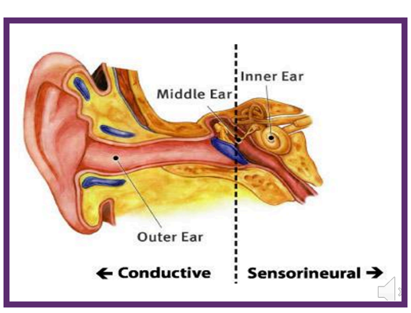
Auditory Cortex

- Located in the superior gyrus of the temporal lobe – Brodmann's area 41
- 2 separate areas:
    1. **Primary auditory cortex** – directly excited by projections of the medial geniculate body
    2. **Secondary auditory cortex** (*association cortex*) – excited by impulses from the primary auditory cortex, from the thalamic association areas, and areas adjacent to the medial geniculate body

V. HEARING ABNORMALITIES

Deafness – hearing loss of any degree

Feature	Conduction Deafness	Sensorineural Deafness
Definition	Interference with conduction of sound vibrations to fluids of the inner ear	Degeneration or damage to receptor cells in Organ of Corti, cochlear nerve, or neurons to auditory cortex
Causes	Otosclerosis, ruptured eardrum, otitis media – mechanical factors	Extended listening to excessively loud sounds; problem of nervous system structures
Bone Conduction	May still hear via bone conduction even if air conduction is lost	Both air and bone conduction affected
Hearing Aid	Helpful (skull bones conduct sound vibrations)	Less helpful
Location	Outer or Middle Ear	Inner Ear, cochlear nerve, or auditory cortex

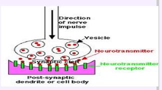
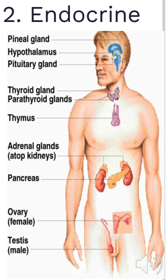
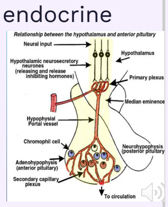


TOPIC 13: INTRODUCTION TO ENDOCRINOLOGY

Lecturer: Dr. Ma. Noemi E. Jiao, MD, DPPS

Based on: Guyton & Hall Textbook of Medical Physiology, 14th Edition

I. TYPES OF COMMUNICATION SYSTEMS THAT COORDINATE BODY ACTIVITIES

Type	Mechanism	Key Feature
1. Neural 	Release of chemicals or neurotransmitters at synaptic junctions - Nervous system	Immediate; fast; localized effect Ex; Neuromuscular junction
2. Endocrine 	Glands release hormones into the blood to influence cells at another location in the body	Slow-acting; widespread; chemical messengers (hormones)
3. Neuro-endocrine 	Neurons secrete neurohormones that reach the circulating blood and influence cells at another location of the body	Example: hypothalamic-pituitary axis\ - Hypothalamus secretes inhibitory hormones that cause pituitary glands to release hormones to the bloodstream through the hypophyseal portal system
4. Paracrine	Cells secrete substances that diffuse into the extracellular fluid and affect NEIGHBORING cells	Local; does not enter bloodstream
5. Autocrine (self)	Cells secrete substances that affect the function of the SAME cell by binding to its surface	Self-regulatory

Endocrine System vs. Nervous System

Feature	Endocrine System	Nervous System
Speed	Slow acting	Built for speed; causes immediate action
Messenger	Chemical messengers (hormones)	Nerve impulse
Role	Coordinates and directs activities of body cells; the second great controlling system of the body	Coordinates and directs activities of body cells. Main communicating system
Onset	Minutes to months	Milliseconds
Duration	Hours to days	Brief

II. HORMONES

Control Major Processes:

- **Reproduction** – sex hormones (hormonal imbalance)
- **Growth and development** – growth hormones, too much hormone person ends up gigantism or little growth hormone ends up dwarfism
- **Mobilizing body defenses against stress** – cortisol, under stress this hormone will increase
- **Maintain electrolyte, water and nutrient balance of the blood** – aldosterone (adrenal gland)
- **Regulate cellular metabolism** – thyroid hormones, like T3 and T4 are very important in regulating cellular metabolism. Too much will end up in Graves' diseases, little amount will end up with hypothyroidism or in children is cretinism.
- **Regulate energy balance** – insulin (condition = Diabetes mellitus) Insulin regulates energy balance by enabling cells to use glucose as a source of energy. When there is insulin deficiency or when cells are not sensitive to insulin, it leads to Diabetes mellitus.

Three General Classes of Hormones

Class	Examples	Source Glands
1. Proteins & Polypeptides	**Constitutes the most numbers of hormones:** **Anterior pituitary:** Prolactin, GH, ACTH, TSH, FSH, LH **Posterior pituitary:** ADH, Oxytocin Pancreas: Insulin, Glucagon Parathyroid: PTH	Anterior & posterior pituitary, pancreas, parathyroid
2. Steroid Hormones	**Synthesized from cholesterol** **Adrenal cortex:** Cortisol, Aldosterone **Ovaries/Placenta:** Estrogen, **Progesterone** **Testes:** Testosterone	Adrenal cortex, gonads, ovaries, testes placenta
3. Derivatives of Tyrosine (Amine Hormones)	**Thyroid gland:** T3, T4 **Adrenal medulla**: Epinephrine, Norepinephrine	Thyroid gland, adrenal medulla

A. Proteins and Polypeptide Hormones

- **Most abundant** hormones of the body
- **Peptides** – hormones with **< 100** amino acids
    - Example: TRH – 3 amino acids
- **Proteins** – hormones with **> 100** amino acids
    - Example: Growth hormone, Prolactin

Synthesis and Secretion:

- Synthesized in the rough endoplasmic reticulum (ER)
- Usually synthesized as large proteins that are biologically inactive

Step	Process	Location
1	Preprohormones synthesized	Rough ER
2	Cleaved/converted to Prohormones	ER
3	Packaged into secretory vesicles containing biologically active hormones and inactive fragments	Golgi apparatus
4	Vesicles stored in cytoplasm, bound to cell membrane until needed	Cytoplasm
5	Exocytosis – granular contents extruded to outside of cell	Cell membrane

🗣️**Exocytosis** - process by which the granular contents of the secretory vesicles are extruded to the outside of the cell

Stimulus for Exocytosis:

- Increase in cytosolic Ca++ concentration secondary to depolarization of the plasma membrane.

🗣️When the plasma membrane depolarizes, calcium from outside the cell enters, increasing cytoplasmic calcium concentration and leading to an increase in cAMP.

- Increase in cAMP → activation of protein kinases → secretion of the *hormone*

B. Steroid Hormones

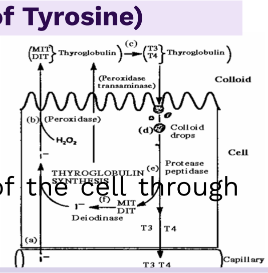
- Synthesized from *cholesterol*
- Very *little* steroid hormones are stored in ***steroid-producing endocrine cells***
- **Large** amounts of *cholesterol esters* from *plasma* are stored in *steroid-producing cells*
- Once synthesized, they diffuse across the cell membrane
- Stored are cholesterol esters that are the raw materials.

‣ **EXAMPLES: Steroid Hormones (Guyton)**

- **Adrenal cortex**: Cortisol (glucocorticoid), Aldosterone (mineralocorticoid)
- **Ovaries & Placenta**: Estrogen, Progesterone
- **Testes**: Testosterone
- All are lipid-soluble → diffuse freely across cell membranes → bind to intracellular receptors

C. Amine Hormones (Derivatives of Tyrosine)

- Derived from *tyrosine*
- Formed by the action of enzymes in the cytoplasm of the glandular cell
- Transported to the outside of the cell through **ACTIVE TRANSPORT**



Circulation → Thyroid hormone + thyroxine-binding globulin → Target tissue → Epinephrine/NE – released from the adrenal medulla by EXOCYTOSIS

🗣️Steroid hormones move out of the cell and reach the bloodstream by diffusion. The way amine hormones reach the bloodstream is not completely understood, but some studies suggest they may be transported out of the cell through active transport.

Once in circulation, thyroid hormones bind to thyroxine-binding globulin. This means they travel in the blood not as free hormones, but attached to this transporter, which carries them to the target tissues.

When they reach the target tissues, the thyroid hormone is released from thyroxine-binding globulin, and this is when it becomes active.

On the other hand, epinephrine and norepinephrine, although they are amine hormones derived from tyrosine, are released from the adrenal medulla through exocytosis. In this way, they behave like protein hormones in terms of their release mechanism.

Hormone	Source	Secretion Mechanism
Thyroid hormones (T3, T4)	Thyroid gland	Circulation → binds thyroxine-binding globulin → target tissue
Epinephrine / Norepinephrine	Adrenal medulla	Released by EXOCYTOSIS

III. ONSET AND DURATION OF ACTION OF HORMONES

Hormone	Onset of Action
Epinephrine / Norepinephrine	Act within minutes - Epinephrine causes For fight or flight
Thyroxine / Growth Hormone	May require months for full effect

‣ **CONCENTRATION OF HORMONES IN BLOOD (Guyton)**

- Measured in PICOGRAM/mL of blood
- 1 picogram = 1 millionth of 1 millionth of a gram
- Despite extremely low concentrations, hormones exert powerful physiologic effects

IV. CONTROL OF HORMONE SECRETION

3 Categories of Stimuli that Activate Endocrine Organs

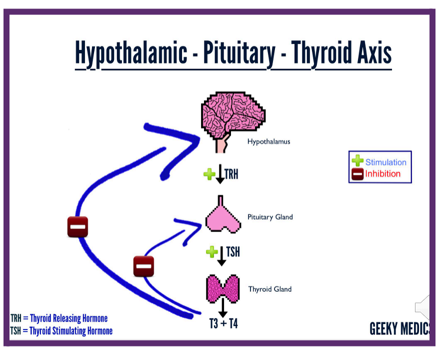
Stimulus Type	Mechanism	Example
1. Hormonal Stimulus	Gland is prodded into action by other hormones	Hypothalamus → Ant. Pituitary → Target gland Thyroid stimulus stimulates thyroid gland then stimulates thyroid hormone

2. Humoral Stimulus	Changes in blood levels of certain ions stimulate hormone release	Low Ca++ → PTH secretion from parathyroid Exocytosis
3. Neural Stimulus	Nerve fibers stimulate the endocrine gland to release hormones	Sympathetic NS → Adrenal medulla → Epinephrine/NE

Sympath NS → Adrenal medulla → Epineph/NE

Feedback Control of Hormone Secretion

1. **Negative Feedback Mechanism** – *most common;* hormone inhibits its own secretion
   Example: High T3/T4 → inhibits TRH (hypothalamus) and TSH (anterior pituitary)
2. **Positive Feedback Mechanism** – hormone stimulates further secretion
   Example: Estrogen surge → LH surge → ovulation
3. **Cyclical Variations** – hormone levels vary predictably over time
   Example: Menstrual cycle hormones, cortisol diurnal variation



‣ HYPOTHALAMIC-PITUITARY-THYROID AXIS (Guyton – Negative Feedback)

Hypothalamus → TRH (+) → Anterior Pituitary → TSH (+) → Thyroid Gland → T3 + T4

T3 + T4 (–) → inhibit both Hypothalamus and Anterior Pituitary

This negative feedback keeps thyroid hormone levels within a narrow physiologic range

CYCLIC VARIATION

- In this mechanism, there is a certain time of the day wherein the hormone that is needed to function is released.

Example: Your cortisol is produced to protect the body against stress. If you are a student who would take an exam in the morning on Thursday. The adrenal gland which produced cortisol will start to produce the hormone at dawn.

V. TRANSPORT OF HORMONES IN THE BLOOD

Hormone Type	Transport Mechanism	Notes
Water-Soluble Hormones (peptide, catecholamine)	Site of synthesis → Dissolved in plasma → target tissue	Free in circulation; short half-life
Steroid & Thyroid Hormones	Site of synthesis → bound to plasma proteins (CHONS) → blood → dissociate from plasma proteins → target tissue	< 10% of steroid/thyroid hormones dissolved in plasma; plasma proteins serve as reservoir; longer half-life
	When a hormone is not bound to any protein then that hormone is known to be active. When it is bound to a protein or a transporter then that hormone becomes inactive. It has to disassociate itself from the transporter first before it becomes active	

Clearance of Hormones from the Blood

1. Metabolic destruction by tissues
2. Binding with tissues
3. Excretion by the liver into the bile
4. Excretion by the kidneys into the urine

🗣️Hormone has to be cleared from the blood and excreted outside the body because when the hormone stay in the blood and the levels of this hormone is higher than normal then this will cause adisease process in the person

VI. HORMONE RECEPTORS

General Characteristics

- Large proteins (CHONs)
- About **2,000–100,000** receptors per cell
- Highly specific – each receptor binds only to its particular hormone or closely related substances

Locations of Different Types of Hormone Receptors

Location	Hormone Class	Example
In or on the surface of the cell membrane	Protein hormones, catechola mines	Insulin receptor, epinephrine receptor
In the cell cytoplasm	Steroid hormones	Cortisol receptor, aldosterone receptor
Cell nucleus	Thyroid hormones	T3 receptor on nuclear chromatin

Regulation of the Number of Hormone Receptors

Regulation Type	Definition	Effect on Response	Example
Down Regulation	Binding of a hormone to the target cell receptor causes **DECREASE** in the number of active receptors	Cell becomes **LESS sensitive** to the hormone	Caused by: (a) decreased receptor production, (b) inactivation of receptor molecules; e.g., chronic high insulin → insulin resistance
Up Regulation	Binding of a hormone to a target cell receptor causes **INCREASE** in the number of active receptors	Cell becomes **MORE sensitive** to the hormone	Some hormones stimulate production of receptors for other hormones

VII. INTRACELLULAR SIGNALING AFTER HORMONE-RECEPTOR ACTIVATION

Mechanism 1: Changes in Membrane Permeability

- H + R → HR complex → Opening/Closing of ionic channels
    - Hormone-receptor complex directly affects membrane ion channels
    - Results in rapid changes in cell membrane potential or ion fluxes

Mechanism 2: Activation of Intracellular Enzyme (G-Protein/Adenylyl Cyclase System)

- INSULIN binding to R causes activation of the intracellular portion of the R converting it into an activated kinase → phosphorylation
- Hormone binds receptor on cell surface
- HR complex activates G-protein
- G-protein activates adenylyl cyclase
- cAMP activates protein kinases → phosphorylation of intracellular proteins → cell response

Adenylyl cyclase converts ATP → cAMP (second messenger) → intracellular changes

‣ SECOND MESSENGERS (Guyton)

- cAMP (cyclic adenosine monophosphate) – most common
- Calmodulin – calcium-binding protein; activated by Ca++ influx
- Products of membrane phospholipid breakdown (IP3, DAG)

Key concept: The hormone is the FIRST MESSENGER; cAMP/calmodulin etc. are SECOND MESSENGERS

Mechanism 3: Activation of Genes by Binding with Intracellular Receptors

Steroid Hormones:

- Binds to receptors in the cell **CYTOPLASM**
- Hormone-receptor complex enters the nucleus
- Transcription of DNA → formation of mRNA → synthesis of new proteins

Thyroid Hormones (Derived from Tyrosine):

- Thyroid H + R → DNA activated → Transcription of genes → Formation of mRNA
- Binds to receptors inside the target cell nucleus

Hormone Class	Receptor Location	Mechanism of Action	Onset
Protein/ Peptide (e.g., insulin, ACTH)	Cell membrane surface	G-protein / cAMP second messenger / ion channels	Rapid (seconds to minutes)
Catecholamines (e.g., epinephrine)	Cell membrane surface	G-protein / cAMP	Rapid (seconds)
Steroid (e.g., cortisol, estrogen)	Cell cytoplasm	Transcription of DNA → mRNA → new protein synthesis	Slow (hours to days)
Thyroid hormones (T3, T4)	Cell nucleus	Direct nuclear receptor activation → gene transcription → mRNA → protein	Very slow (days to weeks)

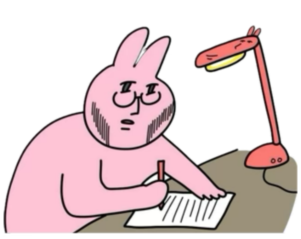
TOPIC 12 & 13 – SUMMARY COMPARISON TABLES

Key Numbers to Remember – Hearing

Parameter	Value
Tympanic membrane force amplification	17×
Incus-malleus lever force amplification	1.3×
Total sound pressure increase at oval window	22×
% Sound energy transmitted from tympanic membrane to cochlea	60%
Hearing decrease if ossicular system absent	15–20 dB
Sound transmission decrease with attenuation reflex	30–40 dB
Number of basilar fibers in basilar membrane	20,000–30,000
Frequency threshold for timing cue (direction)	< 3,000 Hz
Frequency threshold for loudness cue (direction)	> 3,000 Hz
% Cochlear nerve endings on inner hair cells	95%

Key Numbers to Remember – Endocrinology

Parameter	Value
Number of receptors per cell	2,000 – 100,000
Hormone blood concentration	Picogram/mL
Steroid/thyroid H dissolved freely in plasma	< 10%
Peptide hormones with < 100 amino acids	Peptides (e.g., TRH = 3 AA)
Protein hormones with > 100 amino acids	Proteins (e.g., GH, Prolactin)



study well! -joie&matt