UNIT 2: Introduction to hormones & neurotransmitters

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Topics

• Major systems of human body
• Glands
• Hormones vs neurotransmitters
• Classification of hormones
  • Solubility
  • Where they function
  • Chemical structure
• Briefing on synthesis of hormones/neurotransmitters
• Physiological role of hormones/neurotransmitters
Major system of human body

Nervous system – Central Nervous system

- Controls all the actions of our body
- Our nervous system is divided into two components:
  - central nervous system - brain and spinal cord
  - peripheral nervous system - which encompasses nerves outside the brain and spinal cord.
- These two components cooperate at all times to ensure our lively functions: we are nothing without our nervous system
- Brain has 3 major parts
  - Cerebrum – sensing, thinking & imagination
  - Cerebellum – motion, balance & learning new things
  - Medulla – involuntary actions in the body (digestion, heart beat and breathing etc.)


Video 1
Nervous system – peripheral nervous system

- Peripheral nervous system - which encompasses nerves outside the brain and spinal cord.
- Two functions
  - Sensory nerves – carry messages from body (senses) to the brain
  - Motor nerves - carry messages from brain to the body
- Nerves are made of neurons
- Neuron has three major parts
  - Cell body – contains nucleus, maintain the neuron’s structure and provide energy to drive activities
  - Dendrites – receive stimulation and pass to cell body
  - Axon – conducts electrical impulses away from nerve cell body

# Neurotransmitters functions

<table>
<thead>
<tr>
<th>Neurotransmitters</th>
<th>Major known function/diseases</th>
</tr>
</thead>
</table>
| **Dopamine**      | • Critical for memory and motor skills.  
                   • Deficiency in dopamine production is associated with Parkinson’s disease, a degenerative condition causing “shaking palsy” |
| **Norepinephrine (also a hormone)** | • Neuromodulator optimizes brain function.  
  • As part of bodies fight or flight hormone.  
  • Norepinephrine quickly provides an accurate assessment of danger or stressful situations. |
| **Epinephrine (also a hormone)** | • Activates muscle adenylate cyclase, thereby stimulates glycogen breakdown.  
  • Promotes lipolysis in adipose tissue.  
  • Promotes Glycogenolysis and Gluconeogenesis in Liver. |
| **Histamine**     | • Involved in allergic responses as well as in the control of acid secretion by the stomach |
| **Serotonin**     | • It is popularly through to be a contributor to feelings of well-being and happiness.  
  • Important factor in mood, depression, anxiety, sleep quality, emotions and regulation of appetite and body temperature.  
  [However, biological functional role of serotonin is not clear.]
| **Acetylcholine** | • Its basic functions involve the control of skeletal muscles via activation of the motor neurons as well as stimulating the muscles of the body |
| **Gamma-aminobutyric acid or GABA** | • The role of GABA is to inhibit or reduce the activity of the neurons or nerve cells.  
  • People with too little GABA tend to suffer from anxiety disorders.  
  • If GABA is lacking in certain parts of the brain, epilepsy results. |
| **Glutamate**     | • Glutamate is the principal excitatory neurotransmitter in the brain. |
| **Nitric oxide**  | • Plays a role in affecting smooth muscles, relaxing them to allow blood vessels to dilate and increase blood flow to certain areas of the body. |
Glands and their secreted hormones

- A gland is just any structure that makes and secretes a hormone.

http://www.austincc.edu/apreview/PhysText/Endocrine.html
The endocrine glands of the brain are crucial in regulating mood, growth and development, metabolism, sexual functions & reproductive processes in the human body.
Hypothalamus

Neurohormones

Releasing hormones

- Gonadotrophin RH (GnRH)
  - Stimulation

Anterior Pituitary

- Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH)
  - Hormone secretion

Inhibiting hormones

- Somatostatin
  - Inhibition

Antidiuretic Hormone (ADH)/Vasopressin

- Antidiuretic hormone conserves body water by reducing the loss of water in urine.
- This hormone signals the collecting ducts of the kidneys to reabsorb more water and constrict blood vessels, which leads to higher blood pressure and thus counters the blood pressure drop caused by dehydration.

Oxytocin

- Stimulates the smooth muscle of the uterus to contract, inducing labor.
- Stimulates the myoepithelial cells of the breasts to contract which releases milk from breasts when nursing.
- Stimulates maternal behavior.
- In males it stimulates muscle contractions in the prostate gland to release semen during sexual activity

- Neurohormones – regulate the synthesis and secretion of Pituitary hormones
- These hypothalamic hormones pass through the exons and are released from their nerve endings into the Pituitary and into the portal circulatory system
- This hypothalamus and pituitary system is direct proof of coordination between the hormonal and nervous system
- Maintains homeostasis inside the body and regulates most of its physiological activities.
Pituitary gland

- Pituitary gland is the smallest endocrine gland yet it is called the master of endocrine glands because it produces the hormones that control the thyroid gland, adrenal cortex and gonads.
Pituitary gland

Video 4 & http://www.austincc.edu/apreview/NursingPics/NursingAnimationsWebPage.html#hypothal
## Pituitary gland hormones and their functions

<table>
<thead>
<tr>
<th>Pituitary gland parts</th>
<th>Hormones</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior pituitary gland</strong></td>
<td>Growth hormone (GH) or Somatotropin</td>
<td>Regulates growth, metabolism and body composition</td>
</tr>
<tr>
<td></td>
<td>Prolactin (PL)</td>
<td>Stimulates milk production</td>
</tr>
<tr>
<td></td>
<td>Luteinizing hormone (LH) and Follicle Stimulating Hormone (FSH) (gonadotrophins)</td>
<td>Act on the ovaries or testes to stimulate sex hormone production, and egg and sperm maturity</td>
</tr>
<tr>
<td></td>
<td>Adrenocorticotropic Hormone (ACTH) or Corticotropin</td>
<td>Stimulates the adrenal glands to secrete steroid hormones, principally cortisol</td>
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<tr>
<td></td>
<td>Thyroid Stimulating Hormone (TSH) or Thryotropin</td>
<td>Travels to the thyroid gland (target cells) where it stimulates the release of thyroid hormones in response to low temperatures, stress, and pregnancy</td>
</tr>
<tr>
<td><strong>Intermediate pituitary gland</strong></td>
<td>Melanocyte-stimulating hormone (MSH)</td>
<td>Acts on cells in the skin to stimulate the production of melanin</td>
</tr>
<tr>
<td><strong>Posterior pituitary</strong></td>
<td>Anti-diuretic hormone (ADH) (also called vasopressin)</td>
<td>Controls water balance and blood pressure</td>
</tr>
<tr>
<td></td>
<td>Oxytocin</td>
<td>Stimulates uterine contractions during labour and milk secretion during breastfeeding</td>
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</tbody>
</table>
Thyroid and parathyroid glands

http://www.austincc.edu/apreview/NursingPics/NursingAnimationsWebPage.html#parathyroid
## Thyroid and parathyroid glands

<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormones</th>
<th>Functions/diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid</td>
<td>Triiodothyronine (T3)</td>
<td>• Help regulate tissue growth and development</td>
</tr>
<tr>
<td></td>
<td>Thyroxine (T4)</td>
<td>• Support the formation of red blood cells</td>
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<tr>
<td></td>
<td></td>
<td>• Control the metabolism of proteins carbohydrates and fats</td>
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<td></td>
<td></td>
<td>• Maintain the water and electrolyte balance and regulate the basal metabolic rate</td>
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<tr>
<td></td>
<td><strong>Hyperthyroidism</strong></td>
<td>• High metabolic rate</td>
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<tr>
<td></td>
<td></td>
<td>• Weight loss</td>
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<tr>
<td></td>
<td></td>
<td>• Hyperactivity</td>
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<tr>
<td></td>
<td></td>
<td>• Heat intolerance</td>
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<td></td>
<td></td>
<td>• Goiter</td>
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<tr>
<td></td>
<td><strong>Hypothyroidism</strong></td>
<td>• Low metabolic rate</td>
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<tr>
<td></td>
<td></td>
<td>• Weight gain</td>
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<tr>
<td></td>
<td></td>
<td>• Sluggishness</td>
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<tr>
<td></td>
<td></td>
<td>• Sensitivity to cold</td>
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<tr>
<td>Parathyroid</td>
<td>Parathyroid hormone (PTH)</td>
<td>• Regulator of calcium and phosphorus concentration in extracellular fluid. PTH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>has the opposite effect of calcitonin.</td>
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<tr>
<td></td>
<td></td>
<td>• PTH stimulates osteoclasts which increases blood calcium levels.</td>
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<td></td>
<td></td>
<td>• PTH causes reabsorption of Ca^{2+} from kidneys so it is not excreted in the urine</td>
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<tr>
<td></td>
<td></td>
<td>• PTH stimulates synthesis of calcitriol (hormone made in the kidney which the</td>
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<tr>
<td></td>
<td></td>
<td>active form of Vitamin D which increases Ca+2 absorption from small intestine)</td>
</tr>
</tbody>
</table>

[Video 5](http://www.austincc.edu/apreview/NursingPics/NursingAnimationsWebPage.html#parathyroid)
**Adrenal glands**

- The yellowish triangular shaped glands are also called supra-renal glands because they are situated on the top of the anterior part of the kidneys.
- The adrenal glands are also known as 3F glands. The 3F’s stands for fright, fight or flight.
- These glands also called 4S glands where the four S stands for sugar metabolism, salt metabolism, sex hormones and source of energy.

http://www.austincc.edu/apreview/PhysText/Endocrine.html

Video 6 (from 0:58 to 6:29)
## Adrenal glands: Adrenal cortex hormones & their functions

<table>
<thead>
<tr>
<th>Mineralocorticoids</th>
<th>The primary function of mineralocorticoids is to regulate the balance of water and electrolytes in our body.</th>
</tr>
</thead>
</table>
| Aldosterone        | • Acts on the renal tubules on the kidneys and stimulates the reabsorption of sodium and water and the removal of potassium and phosphate ions.  
• Also helps to maintain the body fluid volume, electrolytes, osmotic pressure and blood pressure |

| Glucocorticoids    | • Involved in carbohydrate metabolism  
• Chief function is to stimulate Gluconeogenesis, Lipolysis and Proteolysis.  
• Also inhibit the utilization of amino acids and cellular uptake. |
|--------------------|-----------------------------------------------------------------------------------------------------------|
| Cortisol           | • Provides anti-inflammatory reactions, helps to maintain the cardiovascular system and the functions of the kidneys  
• Cortisol stimulate red blood cell production and suppresses the immune response |

**Testosterone (male hormone)**  
• Stimulate the development of secondary sexual characters such as axial hair, pubic hair, facial hair and deepening of the voice.
Adrenal glands: Adrenal medulla hormones & their functions

Video 6 (from 0:58 to 6:29)

Catecholamine's

- Increase the strength of heart contractions, heart beat and rate of respiration
- Also increase alertness, sweating and papillary dilation
- Stimulates the breakdown of glycogen, proteins and lipids
- In short, catecholamine's are rapidly secreted in response to stress and emergency situations and or thus also called emergency hormones or hormones of flight or fight.

http://www.austincc.edu/apreview/PhysText/Endocrine.html
Adrenal glands: overview

Short-term stress response
1. Glycogen broken down to glucose; increased blood glucose
2. Increased blood pressure
3. Increased breathing rate
4. Increased metabolic rate
5. Change in blood-flow patterns, leading to increased alertness and decreased digestive and kidney activity

Long-term stress response

Mineralocorticoids
1. Retention of sodium ions and water by kidneys
2. Increased blood volume and blood pressure

Glucocorticoids
1. Proteins and fats broken down and converted to glucose, leading to increased blood glucose
2. Immune system may be suppressed
Pancreas

Heterocrine Glands

Pancreas

Duodenum

Alpha Cell
Glucagon

F Cell
Pancreatic Polypeptide

Delta Cell
Somatostatin

Beta Cell
Insulin

Islets of Langerhans

Video 7 (from 0:28 to 1:30) & Video 8

http://www.austincc.edu/apreview/PhysText/Endocrine.html
## Pancreas

<table>
<thead>
<tr>
<th><strong>Insulin</strong></th>
<th><strong>Glucagon</strong></th>
<th><strong>Somatostatin</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reduces the blood glucose concentration</td>
<td>• Increases blood glucose concentration</td>
<td>• Somatostatin, also known as growth hormone-inhibiting hormone (GHIH) or by several other names, is a peptide hormone that regulates the endocrine system and affects neurotransmission and cell proliferation via interaction with G protein-coupled somatostatin receptors and inhibition of the release of numerous secondary hormones. Somatostatin inhibits insulin and glucagon secretion</td>
</tr>
<tr>
<td>• In liver it promotes glycogen synthesis and stops glucose production</td>
<td>• In liver it promotes glycogen breakdown to release as glucose (Glycogenolysis) and also synthesis of glucose (Gluconeogenesis)</td>
<td></td>
</tr>
<tr>
<td>• Promotes glucose uptake by muscle cells to use it for energy and store glucose as glycogen (glycogen synthesis)</td>
<td>• Hormone releases when glucose concentration is low in blood</td>
<td></td>
</tr>
<tr>
<td>• Promotes glucose uptake by adipose tissue to store it as fat (lipogenesis)</td>
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</tr>
<tr>
<td>• Overall, it stimulates cell growth and differentiation by increasing the synthesis of glycogen, proteins and triacylglycerol</td>
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</tbody>
</table>

**Function of Glucagon and Insulin**

[Diagram showing the function of glucagon and insulin]

[Links to videos: Video 7 (from 0:28 to 1:30) & Video 8]
Classification

Solubility
- Fat soluble hormones
- Water soluble hormones

Where they function
- Endocrine hormones
- Autocrine hormones
- Paracrine hormones

Chemical structure
- Proteins/polypeptides hormones
- Steroid hormones
- Amino acid derivative hormones

Videos 9 & 10
Hormones classification

Hormones classification based on chemical structure

- **Proteins/polypeptides hormones**
  - Amino acids (≥3)
  - Rough endoplasmic reticulum
  - Water soluble as they are charged
  - Can not cross the membrane
  - Receptors in/on cell surface
  - Receptor mediated signaling

- **Steroids hormones**
  - Lipids (cholesterol)
  - Cross the cell membrane
  - Receptors inside the cell (cytoplasm or nucleus)
  - Affect transcription or translation

- **Amino acid derivatives**
  - One amino acid
  - Derivatives
  - Dual signaling mode

- **Insulin**
- **Glucagon**

- **Progestagens**
  - Progesterone

- **Glucocorticoids**
  - Cortisol

- **Mineralocorticoids**
  - Aldosterone

- **Estrogens**
  - Estrone

- **Androgens**
  - Testosterone

- **Tyrosine derivatives**
  - Dopamine
  - Norepinephrine
  - Epinephrine

- **Histidine derivatives**
  - Histamine

- **Tryptophan derivatives**
  - Serotonin

- **Thyroid hormones**
  - Thyroxine

- **Catecholamine hormones**

Videos 9 & 10
Insulin & Glucagon

http://www.namrata.co/insulin-biosynthesis-secretion-and-action/
https://www.diapedia.org/metabolism-insulin-and-other-hormones/51040851520/glucagon
Steroid hormones

- Cholesterol
  - Pregnenolone
    - 17-Hydroxypregnenolone
      - Testosterone (androgen)
      - Estradiol (estrogen)
    - Progesterone (progestin)
      - Cortisol (glucocorticoid)
      - Aldosterone (mineralocorticoid)
Amino acid derivatives: Thyroid hormones

https://basicmedicalkey.com/thyroid-drugs-2/

Triiodothyronine (T3) – 20%

Tetraiodothyronine (T4) – 80%
Amino acid derivatives: Catecholamine

Tyrosine

Tyrosine hydroxylase → DOPA

DOPA decarboxylase → Dopamine

DOPA β-hydroxylase → Norepinephrine

Phenylethanolamine N-methyltransferase → Epinephrine
Amino acid derivatives: Histamine & Serotonin

Histamine is derived from the decarboxylation of the amino acid histidine, a reaction catalyzed by the enzyme L-histidine decarboxylase.

Histidine $\xrightarrow{\text{Histidine decarboxylase}}$ Histamine

Histidine

http://www.wormatlas.org/neurotransmitterstable.htm

Tryptophan $\xrightarrow{\text{Tryptophan Hydroxylase}}$ 5-Hydroxytryptophan $\xrightarrow{\text{Aromatic L-Amino Acid Decarboxylase}}$ Serotonin

http://www.wormatlas.org/neurotransmitterstable.htm
Hormones vs neurotransmitters

- A hormone is any member of a class of signaling molecules produced by glands in multicellular organisms that are transported by the circulatory system to target distant organs to regulate physiology and behavior.
- Neurotransmitters, also known as chemical messengers, are endogenous chemicals that enable neurotransmission.

Nervous System

- Neurons release neurotransmitters
- A neurotransmitter acts on specific cell right next to it.
- Neurotransmitters have their effects within milliseconds.
- The effects of neurotransmitters are short-lived.
- Performs short term crisis management

Endocrine System

- Endocrine cells release hormones
- Hormones travel to another nearby cell or act on cell in another part of the body.
- Hormones take minutes or days to have their effects.
- The effects of hormones can last hours, days, or years.
- Regulates long term ongoing metabolic function

http://www.wormatlas.org/neurotransmitterstable.htm
Hormones & the Endocrine system (updated): https://www.youtube.com/watch?v=7STDtdryYTI
Sources


• Video 1: The Nervous System Functions and Facts - Animation video: https://www.youtube.com/watch?v=NALZwb--YO4

• Video 2: Neurotransmitters - What Are Neurotransmitters And What Do They Do In The Body?: https://www.youtube.com/watch?v=Mz3Plvyu3ew

• Video 3: CBSE Class 11 Biology, Chemical Coordination and integration – 1, Human Endocrine System: https://www.youtube.com/watch?v=OECzHqH_mGA
• Video 4: CBSE Class 11 Biology, Chemical Coordination and integration – 2, Hypothalamus, Pituitary Gland & Pineal gland: https://www.youtube.com/watch?v=qMCWQ2LnLsg
• Video 5: CBSE Class 11 Biology, Chemical Coordination and integration – 3, Thyroid and Parathyroid Glands: https://www.youtube.com/watch?v=3BWUpSxwrOI
• Video 6: CBSE Class 11 Biology, Chemical Coordination and integration – 4, Hormone Secreting Glands & Tissues: https://www.youtube.com/watch?v=aQc_e4R1L2s (from 0:58 to 6:29)
• Video 7: CBSE Class 11 Biology, Chemical Coordination and integration – 5, Heterocrine Glands Pancreas: https://www.youtube.com/watch?v=PF_VKS4D4qM (from 0:28 to 1:30)
• Video 8: Endocrine pancreas | Gastrointestinal system physiology | NCLEX-RN | Khan Academy: https://www.youtube.com/watch?v=xNf--q0YMq8

• Video 9: Types of hormones/overview of cell signaling: https://www.youtube.com/watch?v=FQFBynIgj8U
• Video 10: Types of hormones | Endocrine system physiology | NCLEX-RN | Khan Academy: https://www.youtube.com/watch?v=KSclrkk_Ako

• Endocrine gland hormone review | Endocrine system physiology | NCLEX-RN | Khan Academy: https://www.youtube.com/watch?v=ER49EweKwW8

• Hormones and the endocrine systems: https://www.youtube.com/watch?v=WMVEGAVdEoc
• Good videos: http://www.austincc.edu/apreview/NursingPics/NursingAnimationsWebPage.html

• Textual information: http://www.austincc.edu/apreview/PhysText/Endocrine.html