# v. Excretory and Endocrine Systems

v. Excretory and Endocrine Systems - Excretory products and their elimination from the body, acid-base regulation, Endocrine glands and Hormonal functions

# Excretory System: Excretory Products, Elimination, and Acid-Base Regulation

# **Overview of Excretory Products**

#### 1. Nitrogenous Wastes

- **Urea**: Primary waste product of protein metabolism in most mammals. Synthesized in the liver via the urea cycle; relatively less toxic, water-soluble.
- Uric Acid: Produced from purine catabolism. In humans, moderately soluble; higher levels can precipitate (gout).
- Ammonia: Highly toxic, excreted directly by many aquatic organisms; in humans, converted primarily to urea.

#### 2. Other Metabolic Byproducts

- o Creatinine: Byproduct of muscle creatine phosphate breakdown, a measure of kidney filtration efficiency.
- **Bilirubin**: Heme breakdown product, processed by the liver and excreted into bile.

### **Anatomy of the Human Excretory System**

# 1. Kidneys

- Location: Retroperitoneal organs in the abdomen, each containing ~1-1.5 million nephrons (functional units).
- **Gross Structure**: Cortex (outer region), medulla (inner region with renal pyramids), pelvis (collecting area leading to ureter).

# 2. Nephron

- o Glomerulus: A tuft of capillaries in Bowman's capsule. Filtration driven by hydrostatic pressure.
- **Tubules**: Proximal convoluted tubule (PCT), loop of Henle (descending and ascending limbs), distal convoluted tubule (DCT), and collecting duct.
- Selective Processes:
  - **Filtration**: Blood → Renal tubule (filtrate).
  - Reabsorption: Valuable solutes (glucose, amino acids, ions, water) returned to the bloodstream.
  - Secretion: Additional waste/toxins actively transported from peritubular capillaries into the tubule.
  - **Excretion**: Remaining fluid (urine) flows to renal pelvis → ureter → bladder → urethra.

#### 3. Associated Structures

- **Ureters**: Convey urine from kidneys to the urinary bladder.
- **Urinary Bladder**: Temporarily stores urine; lined with transitional epithelium.
- **Urethra**: Conducts urine out of the body (longer in males, shorter in females).

#### Regulation of Kidney Function

#### 1. Glomerular Filtration Rate (GFR)

- Influenced by renal blood flow, hydrostatic/osmotic pressures, and structural integrity of glomerular capillaries
- **Autoregulation** (myogenic and tubuloglomerular feedback in the juxtaglomerular apparatus) stabilizes GFR over a wide range of blood pressures.

### 2. Hormonal Control

#### • Renin-Angiotensin-Aldosterone System (RAAS):

- Decreased blood volume/pressure → Renin release (juxtaglomerular cells) → Angiotensin II formation
  → Aldosterone release (adrenal cortex).
- Effects: Increased Na<sup>+</sup> and water reabsorption, vasoconstriction → raises blood pressure.
- o Antidiuretic Hormone (ADH, vasopressin): Released from posterior pituitary when plasma osmolality is

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- high or blood volume is low. Promotes water reabsorption in the collecting ducts by increasing aquaporin channels  $\rightarrow$  concentrated urine.
- Atrial Natriuretic Peptide (ANP): Released by atria in response to stretch (high blood volume), reduces Na+ reabsorption, lowers blood pressure and volume.

#### 3. Neural Regulation

 Sympathetic Nervous System: Can constrict afferent arteriole (reducing GFR) under stress or shock, redirecting blood flow to vital organs.

# **Acid-Base Regulation**

#### 1. Importance of pH Homeostasis

 Normal arterial blood pH ~7.35-7.45. Deviations disrupt enzyme function, protein structure, and cellular metabolism.

#### 2. Buffer Systems

- Bicarbonate Buffer: CO<sub>2</sub> + H<sub>2</sub>O ≠ H<sub>2</sub>CO<sub>3</sub> ≠ H<sup>+</sup> + HCO<sub>3</sub><sup>-</sup>.
- o Phosphate and protein buffers also contribute but bicarbonate is primary in blood plasma.

#### 3. Respiratory Mechanisms

- ∘ Adjusting ventilation changes blood CO₂ (respiratory acid).
- Hyperventilation → Decreases CO<sub>2</sub> (alkalosis), Hypoventilation → Increases CO<sub>2</sub> (acidosis).

#### 4. Renal Mechanisms

- Bicarbonate Reabsorption and H<sup>+</sup> Excretion: Proximal tubule cells reabsorb most filtered HCO₃<sup>−</sup>, secrete H<sup>+</sup>.
- Distal Nephron and Collecting Duct: Fine-tuning of acid-base via intercalated cells secreting H<sup>+</sup> or HCO₃⁻.
- Formation of titratable acids (e.g., phosphate) and ammonium (NH<sub>4</sub>+) aids in H+ excretion.

#### 5. Disorders

- Metabolic Acidosis: Excess acid or loss of bicarbonate (e.g., diabetic ketoacidosis).
- Metabolic Alkalosis: Excess base or loss of acid (e.g., vomiting).
- Compensatory responses involve both respiration and kidney adjustments.

# **Endocrine System: Endocrine Glands and Hormonal Functions**

# **General Principles of Endocrine Signaling**

#### 1. Hormones

- Chemical messengers secreted by endocrine glands into the bloodstream, acting on distant target cells via specific receptors.
- Categories: **Peptide/Protein Hormones**, **Steroid Hormones**, **Amino Acid Derivatives** (e.g., catecholamines, thyroid hormones).

# 2. Feedback Regulation

- **Negative Feedback**: Most common; elevated hormone levels or end-product signals inhibit further hormone release (e.g., hypothalamic-pituitary axes).
- o Positive Feedback: Rare; hormone action amplifies production (e.g., oxytocin during childbirth).

# 3. Receptor Mechanisms

- Cell Surface Receptors: Peptide/protein hormones and catecholamines (e.g., GPCRs, tyrosine kinase receptors). Trigger second messenger cascades (cAMP, IP₃/DAG).
- **Intracellular Receptors**: Steroid, thyroid hormones diffuse into cells, bind cytoplasmic or nuclear receptors, directly modulate gene transcription.

## **Major Endocrine Glands and Hormones**

#### 1. Hypothalamus and Pituitary Gland

- **Hypothalamus**: Secretes releasing/inhibiting hormones (TRH, CRH, GnRH, GHRH, somatostatin, etc.) that act on the anterior pituitary. Produces oxytocin and ADH (stored in posterior pituitary).
- Anterior Pituitary:
  - TSH (Thyroid-Stimulating Hormone) → Thyroid gland.

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- ACTH (Adrenocorticotropic Hormone) → Adrenal cortex.
- LH, FSH (Luteinizing Hormone, Follicle-Stimulating Hormone) → Gonads.
- GH (Growth Hormone) → Growth, metabolism.
- PRL (Prolactin) → Lactation.
- **Posterior Pituitary**: Stores and releases ADH (water reabsorption in kidneys) and Oxytocin (uterine contractions, milk ejection).

#### 2. Thyroid Gland

- Produces **Thyroxine** (**T**<sub>4</sub>) and **Triiodothyronine** (**T**<sub>3</sub>) under TSH control. Influence basal metabolic rate, growth, and development.
- o Calcitonin: Lowers blood calcium levels by inhibiting osteoclasts, increasing calcium deposition in bones.

#### 3. Parathyroid Glands

• **PTH (Parathyroid Hormone)**: Raises blood calcium by stimulating osteoclast activity, enhancing renal reabsorption of calcium, and activating vitamin D (increasing intestinal calcium absorption).

#### 4. Adrenal Glands

- Adrenal Cortex:
  - Glucocorticoids (Cortisol): Stress response, gluconeogenesis, anti-inflammatory effects.
  - Mineralocorticoids (Aldosterone): Na+ retention, K+ excretion, blood pressure regulation.
  - **Androgens**: Minor source of sex steroids.
- Adrenal Medulla: Secretes Epinephrine and Norepinephrine (catecholamines), augmenting sympathetic "fight or flight" responses.

#### 5. Pancreas (Endocrine Portion)

- Islets of Langerhans:
  - β-cells produce Insulin → lowers blood glucose by facilitating cellular uptake, glycogenesis, lipogenesis.
  - $\alpha$ -cells produce Glucagon  $\rightarrow$  raises blood glucose (glycogenolysis, gluconeogenesis).
  - **δ-cells** produce **Somatostatin** → inhibits insulin and glucagon release, modulates digestion.

#### 6. Gonads (Testes and Ovaries)

- **Testes**: Produce **Testosterone** under LH stimulation; essential for spermatogenesis, male secondary sexual characteristics.
- **Ovaries**: Produce **Estrogen** and **Progesterone**; regulate menstrual cycle, female secondary sexual characteristics, pregnancy maintenance.

#### 7. Pineal Gland

• Secretes **Melatonin**, regulating circadian rhythms and sleep-wake cycles. Influenced by light exposure.

# **Hormonal Functions and Integration**

#### 1. Metabolic Regulation

- Insulin and Glucagon coordinate glucose homeostasis.
- o Cortisol modulates metabolism under stress, affecting protein and lipid catabolism.

# 2. Calcium-Phosphate Homeostasis

 PTH, Calcitonin, Vitamin D interplay to maintain serum calcium levels, impacting bone density and neuromuscular excitability.

#### 3. Reproductive Function

• **FSH, LH, Estrogen, Testosterone, Progesterone** orchestrate gametogenesis, sexual development, and reproductive cycles.

## 4. Growth and Development

 GH, Thyroid Hormones, Insulin, IGFs (Insulin-like Growth Factors) coordinate tissue growth, cellular differentiation.

#### 5. Stress Response

 Acute (adrenal medulla catecholamines) vs. chronic (cortisol) stress adaptations, impacting cardiovascular and metabolic states.

# **Concluding Remarks**

The excretory system, centered on the kidneys, fulfills critical roles in removing metabolic wastes and regulating acid-base balance, fluid volume, and electrolyte composition. Intricate hormonal signals (e.g., RAAS, ADH, ANP)

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integrate with **neural** inputs to modulate renal function in response to physiological demands.

Meanwhile, the **endocrine system**—via **ductless glands** releasing hormones into the bloodstream—maintains **systemic homeostasis**, orchestrating metabolism, growth, reproduction, and stress responses. Negative feedback loops, receptor specificity, and tightly regulated release mechanisms ensure a delicate balance across these networks. Dysregulation can lead to pathologies, ranging from **kidney failure** and **acid-base imbalances** to **diabetes mellitus**, **thyroid disorders**, and **adrenal insufficiencies**.

Understanding these **hormonal and renal regulatory axes** underpins therapeutic strategies for a myriad of conditions, highlighting the interconnectedness of excretory and endocrine systems in sustaining optimal human health.

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