UNIT – 3 🫁 RESPIRATORY SYSTEM & 🔄 URINARY SYSTEM

POINTS TO BE COVERED IN THIS TOPIC

- ➤ RESPIRATORY SYSTEM ANATOMY 🫁
- ➤ MECHANISM OF RESPIRATION 💨
- ➤ LUNG VOLUMES AND CAPACITIES 📊
- ➤ GAS TRANSPORT 🔄
- ➤ ARTIFICIAL RESPIRATION 🆘
- ➤ URINARY SYSTEM ANATOMY 🔋
- ➤ KIDNEY FUNCTIONS ⚡
- ➤ URINE FORMATION 💧
- ➤ ACID-BASE BALANCE ⚖️

🫁 RESPIRATORY SYSTEM

📍 ANATOMY OF RESPIRATORY SYSTEM

The respiratory system is a complex network of organs and structures responsible for gas exchange between the body and the environment. It facilitates the intake of oxygen and the removal of carbon dioxide, which is essential for cellular metabolism and survival.

UPPER RESPIRATORY TRACT

- **Nose and Nasal Cavity** - Primary entry point for air, warms, humidifies, and filters incoming air
- **Pharynx** - Common pathway for respiratory and digestive systems
- **Larynx** - Voice box containing vocal cords and epiglottis

LOWER RESPIRATORY TRACT

- **Trachea** - Main airway extending from larynx to bronchi
- **Bronchi** - Primary bronchi divide into secondary and tertiary bronchi
- **Bronchioles** - Terminal and respiratory bronchioles leading to alveolar ducts
- **Alveoli** - Microscopic air sacs where gas exchange occurs

🔬 ANATOMY OF LUNGS

The lungs are paired, cone-shaped organs located in the thoracic cavity, separated by the mediastinum. Each lung is enclosed by the pleural membrane, creating a pleural cavity filled with pleural fluid.

STRUCTURAL ORGANIZATION

Right Lung:

- Three lobes: Superior, Middle, and Inferior
- Two fissures: Horizontal and Oblique
- Ten bronchopulmonary segments

Left Lung:

- Two lobes: Superior and Inferior

- One fissure: Oblique
- Eight bronchopulmonary segments
- Cardiac notch to accommodate the heart

MICROSCOPIC ANATOMY

Alveolar Structure:

- Alveolar walls composed of Type I and Type II pneumocytes
- Type I cells facilitate gas exchange
- Type II cells produce surfactant
- Alveolar macrophages provide immune defense
- Rich capillary network surrounds each alveolus

Respiratory Membrane:

- Thickness: 0.5 micrometers
- Composed of alveolar epithelium, basement membrane, and capillary endothelium
- Total surface area: 70 square meters in adults

MECHANISM OF RESPIRATION

Respiration involves two main phases: inspiration (inhalation) and expiration (exhalation). These processes are driven by pressure gradients created through changes in thoracic cavity volume.

INSPIRATION (INHALATION)

Active Process:

- Diaphragm contracts and moves downward
- External intercostal muscles contract, elevating ribs
- Thoracic cavity volume increases
- Intrapleural pressure decreases
- Intrapulmonary pressure falls below atmospheric pressure
- Air flows into lungs down pressure gradient

Accessory Muscles (During Forced Inspiration):

- Scalene muscles
- Sternocleidomastoid muscles
- Pectoralis minor
- Serratus anterior

EXPIRATION (EXHALATION)

Quiet Expiration (Passive Process):

- Diaphragm relaxes and moves upward
- External intercostal muscles relax
- Elastic recoil of lungs and chest wall
- Thoracic cavity volume decreases
- Intrapulmonary pressure exceeds atmospheric pressure
- Air flows out of lungs

Forced Expiration (Active Process):

- Internal intercostal muscles contract

- Abdominal muscles contract
- Rapid decrease in thoracic volume
- Increased expiratory airflow

🧠 REGULATION OF RESPIRATION

Respiratory control involves both neural and chemical mechanisms to maintain appropriate ventilation levels and blood gas concentrations.

NEURAL CONTROL

Respiratory Control Centers:

Control Center	Location	Function
Medullary Rhythmicity Center	Medulla Oblongata	Primary rhythm generation
Pneumotaxic Center	Pons	Modifies respiratory rhythm
Apneustic Center	Pons	Prolongs inspiration

Medullary Centers:

- **Inspiratory Center** - Controls diaphragm and external intercostals
- **Expiratory Center** - Controls internal intercostals and abdominal muscles
- **Pre-Bötzinger Complex** - Pacemaker for respiratory rhythm

Pontine Centers:

- **Pneumotaxic Center** - Fine-tunes respiratory pattern
- **Apneustic Center** - Promotes prolonged inspiration

CHEMICAL CONTROL

Central Chemoreceptors:

- Located in medulla oblongata
- Respond to changes in cerebrospinal fluid pH
- Indirectly monitor blood CO_2 levels
- Primary drive for quiet breathing

Peripheral Chemoreceptors:

- Located in carotid and aortic bodies
- Respond to decreased blood O_2, increased CO_2, and decreased pH
- Become primary drive when O_2 levels fall below 60 mmHg

📊 LUNG VOLUMES AND CAPACITIES

Spirometry measures various lung volumes and capacities to assess respiratory function and diagnose pulmonary disorders.

LUNG VOLUMES

Volume	Abbreviation	Normal Value	Description
Tidal Volume	TV/VT	500 mL	Air inhaled/exhaled during quiet breathing
Inspiratory Reserve Volume	IRV	3100 mL	Maximum air inhaled after normal inspiration
Expiratory Reserve Volume	ERV	1200 mL	Maximum air exhaled after normal expiration
Residual Volume	RV	1200 mL	Air remaining in lungs after maximum expiration

LUNG CAPACITIES

Capacity	Formula	Normal Value	Clinical Significance
Inspiratory Capacity (IC)	TV + IRV	3600 mL	Maximum inhalation capacity
Functional Residual Capacity (FRC)	ERV + RV	2400 mL	Air in lungs at resting expiratory level
Vital Capacity (VC)	TV + IRV + ERV	4800 mL	Maximum air that can be moved
Total Lung Capacity (TLC)	TV + IRV + ERV + RV	6000 mL	Total air capacity of lungs

Clinical Applications:

- **Restrictive Disorders** - Decreased vital capacity and total lung capacity
- **Obstructive Disorders** - Increased residual volume and functional residual capacity
- **Mixed Disorders** - Combination of restrictive and obstructive patterns

🔄 TRANSPORT OF RESPIRATORY GASES

Gas transport involves the movement of oxygen from alveoli to tissues and carbon dioxide from tissues to alveoli through the cardiovascular system.

OXYGEN TRANSPORT

Dissolved Oxygen:

- Only 3% of oxygen transported in dissolved form
- Concentration: 0.3 mL O_2/100 mL blood
- Follows Henry's Law of gas solubility

Oxyhemoglobin:

- 97% of oxygen bound to hemoglobin
- Each hemoglobin molecule binds 4 oxygen molecules
- Oxygen-hemoglobin dissociation curve shows cooperative binding
- Factors affecting oxygen binding:
  - pH (Bohr effect)
  - Temperature
  - 2,3-DPG levels

- Carbon monoxide

Hemoglobin Structure:

- Quaternary protein with 4 subunits
- Each subunit contains heme group with iron
- Adult hemoglobin (HbA): $\alpha_2\beta_2$ chains
- Oxygen binding capacity: 1.34 mL O_2/g Hb

CARBON DIOXIDE TRANSPORT

Three Mechanisms of CO_2 Transport:

1. **Dissolved CO_2 (10%)** • Directly dissolved in plasma • More soluble than oxygen (20x)
2. **Carbaminohemoglobin (23%)** • CO_2 bound to amino groups of hemoglobin • Deoxyhemoglobin has higher CO_2 affinity (Haldane effect)
3. **Bicarbonate Ion (67%)** • $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ • Catalyzed by carbonic anhydrase in RBCs • Chloride shift maintains electrochemical balance

SOS ARTIFICIAL RESPIRATION AND RESUSCITATION METHODS

Artificial respiration techniques are life-saving interventions used when natural breathing is inadequate or absent.

INDICATIONS FOR ARTIFICIAL RESPIRATION

- Respiratory arrest

- Severe respiratory depression
- Drowning
- Drug overdose
- Cardiac arrest
- Severe trauma
- Anesthesia complications

METHODS OF ARTIFICIAL RESPIRATION

Manual Methods:

1. **Mouth-to-Mouth Resuscitation** • Tilt head back, lift chin • Pinch nose, seal mouth • Give 2 initial breaths • Continue at 10-12 breaths/minute
2. **Bag-Mask Ventilation** • Maintain proper mask seal • Squeeze bag rhythmically • Monitor chest rise and fall • Provide supplemental oxygen

Mechanical Methods:

1. **Mechanical Ventilators** • Volume-controlled ventilation • Pressure-controlled ventilation • Positive end-expiratory pressure (PEEP) • Synchronized intermittent mandatory ventilation (SIMV)
2. **Iron Lung (Historical)** • Negative pressure ventilation • Encases entire body except head • Creates pressure changes around chest

CARDIOPULMONARY RESUSCITATION (CPR)

Adult CPR Protocol:

- Check responsiveness and breathing
- Call for emergency help
- Chest compressions: 30 compressions
- Rescue breaths: 2 breaths
- Compression depth: 2-2.4 inches
- Compression rate: 100-120/minute
- Continue cycles of 30:2

🔋 URINARY SYSTEM

📍 ANATOMY OF URINARY TRACT

The urinary system consists of organs responsible for filtering blood, producing urine, and eliminating waste products from the body. It plays a crucial role in maintaining fluid and electrolyte balance.

COMPONENTS OF URINARY SYSTEM

Primary Organs:

- **Kidneys (2)** - Filter blood and produce urine
- **Ureters (2)** - Transport urine from kidneys to bladder
- **Urinary Bladder (1)** - Stores urine temporarily
- **Urethra (1)** - Eliminates urine from body

LOCATION AND GROSS ANATOMY

Kidneys:

- Location: Retroperitoneal, T12-L3 vertebral levels
- Right kidney slightly lower than left
- Protected by ribs 11 and 12
- Surrounded by perirenal fat and renal fascia
- Dimensions: 10-12 cm long, 5-7 cm wide, 2.5-3 cm thick
- Weight: 120-170 grams each

Ureters:

- Length: 25-30 cm
- Three constriction points:
  - Ureteropelvic junction
  - Pelvic brim crossing
  - Ureterovesical junction

Urinary Bladder:

- Capacity: 600-1000 mL
- Three layers: mucosa, muscularis (detrusor), adventitia
- Trigone: triangular area between ureteral and urethral openings

🔬 ANATOMY OF KIDNEY AND NEPHRONS

The kidney's intricate structure enables its complex filtration and regulatory functions through millions of microscopic units called nephrons.

KIDNEY STRUCTURE

External Anatomy:

- **Renal Cortex** - Outer granular layer containing glomeruli
- **Renal Medulla** - Inner striated layer with pyramids
- **Renal Pyramids** - Triangular structures pointing toward pelvis
- **Renal Pelvis** - Funnel-shaped structure collecting urine
- **Renal Calyces** - Cup-shaped structures (major and minor)
- **Renal Hilum** - Indented area where vessels and ureter enter

Vascular Supply:

- **Renal Artery** → Segmental → Interlobar → Arcuate → Interlobular arteries
- **Afferent Arterioles** → Glomerular capillaries → **Efferent Arterioles**
- **Peritubular Capillaries** and **Vasa Recta** → Venous return

NEPHRON STRUCTURE

The nephron is the functional unit of the kidney, with approximately 1.2 million nephrons per kidney.

Types of Nephrons:

Type	Location	Percentage	Function
Cortical Nephrons	Cortex	85%	Basic filtration and reabsorption
Juxtamedullary Nephrons	Cortex-Medulla border	15%	Concentration of urine

Components of Nephron:

1. **Renal Corpuscle** • **Bowman's Capsule** - Double-walled cup surrounding glomerulus • **Glomerulus** - Cluster of capillaries for filtration • **Filtration Barrier** - Endothelium, basement membrane, podocytes
2. **Renal Tubule System** • **Proximal Convoluted Tubule** - Primary site of reabsorption • **Loop of Henle** - Descending and ascending limbs • **Distal Convoluted Tubule** - Fine-tuning of electrolyte balance • **Collecting Duct** - Final urine concentration

Juxtaglomerular Apparatus:

- **Juxtaglomerular Cells** - Secrete renin
- **Macula Densa** - Monitors sodium concentration
- **Extraglomerular Mesangial Cells** - Support function

FUNCTIONS OF KIDNEY AND URINARY TRACT

The kidneys perform multiple vital functions beyond simple waste elimination, serving as sophisticated regulators of body homeostasis.

PRIMARY FUNCTIONS

1. Excretory Function

- Removal of metabolic waste products (urea, creatinine, uric acid)
- Elimination of foreign substances and toxins
- Maintenance of nitrogen balance

2. Regulatory Function

- Fluid balance regulation

- Electrolyte balance (Na^+, K^+, Ca^{2+}, PO_4^{3-})
- Acid-base balance maintenance
- Blood pressure regulation

3. Endocrine Function

- **Erythropoietin** production - Stimulates red blood cell production
- **Renin** secretion - Regulates blood pressure and sodium balance
- **Calcitriol** synthesis - Active form of Vitamin D

4. Metabolic Function

- Gluconeogenesis during fasting states
- Protein catabolism
- Lipid metabolism

URINARY TRACT FUNCTIONS

Ureters:

- Peristaltic transport of urine
- Prevention of backflow through ureterovesical valves

Bladder:

- Urine storage and concentration
- Accommodation to increasing volumes
- Maintenance of continence

Urethra:

- Urine elimination pathway
- Sphincter control mechanisms

💧 PHYSIOLOGY OF URINE FORMATION

Urine formation is a complex process involving three main mechanisms: filtration, reabsorption, and secretion.

GLOMERULAR FILTRATION

Filtration Process:

- Blood pressure forces fluid through glomerular capillaries
- Filtration barrier allows passage of water and small solutes
- Large molecules (proteins, blood cells) are retained

Glomerular Filtration Rate (GFR):

- Normal GFR: 120-125 mL/min (180 L/day)
- Factors affecting GFR:
  - Blood pressure
  - Plasma protein concentration
  - Filtration membrane permeability

Filtration Fraction:

- Percentage of plasma filtered: ~20%
- Calculation: GFR/Renal Plasma Flow

TUBULAR REABSORPTION

Proximal Convoluted Tubule (65% of filtrate):

- **Sodium reabsorption** - Active transport via Na^+-K^+ ATPase
- **Glucose reabsorption** - Secondary active transport (SGLT)
- **Amino acid reabsorption** - Multiple transport systems
- **Water reabsorption** - Follows sodium osmotically
- **Bicarbonate reabsorption** - Maintains acid-base balance

Loop of Henle:

- **Descending Limb** - Water reabsorption, creates concentrated urine
- **Ascending Limb** - Sodium and chloride reabsorption
- **Countercurrent Multiplication** - Concentrates medullary interstitium

Distal Convoluted Tubule and Collecting Duct:

- **Fine-tuning** of electrolyte balance
- **ADH action** - Water reabsorption in collecting duct
- **Aldosterone action** - Sodium reabsorption, potassium secretion

TUBULAR SECRETION

Substances Secreted:

- **Hydrogen ions** - Acid-base balance regulation
- **Potassium ions** - Electrolyte balance
- **Creatinine** - Waste product elimination
- **Para-aminohippuric acid (PAH)** - Organic anion transport
- **Drugs and toxins** - Active elimination

🧠 MICTURITION REFLEX

Micturition (urination) is a complex reflex involving both voluntary and involuntary components.

ANATOMY OF MICTURITION

Bladder Components:

- **Detrusor Muscle** - Smooth muscle of bladder wall
- **Internal Urethral Sphincter** - Involuntary smooth muscle
- **External Urethral Sphincter** - Voluntary skeletal muscle

Neural Innervation:

- **Parasympathetic** - Pelvic nerves (S2-S4) - Bladder contraction
- **Sympathetic** - Hypogastric nerves (T12-L2) - Bladder relaxation
- **Somatic** - Pudendal nerves (S2-S4) - External sphincter control

MICTURITION PROCESS

Filling Phase:

- Bladder accommodates increasing volume
- Stretch receptors remain inactive initially
- Internal sphincter remains closed
- External sphincter under voluntary control

Storage Phase:

- Sympathetic activity inhibits detrusor

- Parasympathetic activity suppressed
- Voluntary control of external sphincter

Voiding Phase:

- Stretch receptors activate at ~300-400 mL
- Parasympathetic stimulation causes detrusor contraction
- Sympathetic activity decreases
- Voluntary relaxation of external sphincter
- Coordinated bladder emptying

⚖️ ROLE OF KIDNEYS IN ACID-BASE BALANCE

The kidneys play a crucial role in maintaining blood pH within the narrow range of 7.35-7.45 through multiple mechanisms.

ACID-BASE REGULATION MECHANISMS

1. Bicarbonate Reabsorption:

- **Proximal Tubule** - Reabsorbs 80-85% of filtered HCO_3^-
- **Mechanism** - H^+ secretion, carbonic anhydrase activity
- **Net Effect** - Conservation of body's bicarbonate stores

2. Acidification of Urine:

- **Distal Nephron** - Can lower urine pH to 4.5
- **H^+ Secretion** - Active transport via H^+-ATPase
- **Titrable Acid** - $HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$

3. Ammonia Production:

- **Glutamine Metabolism** - $NH_3 + H^+ \rightarrow NH_4^+$
- **NH_4^+ Excretion** - Traps H^+ for elimination
- **Adaptive Response** - Increases during acidosis

COMPENSATION MECHANISMS

Metabolic Acidosis:

- Increased H^+ secretion
- Enhanced NH_4^+ production
- Maximum urine acidification
- Bicarbonate regeneration

Metabolic Alkalosis:

- Decreased H^+ secretion
- Reduced NH_4^+ production
- Bicarbonate excretion
- Urine alkalinization

🔄 ROLE OF RAS (RENIN-ANGIOTENSIN SYSTEM) IN KIDNEY

The Renin-Angiotensin System is a critical hormonal system regulating blood pressure, fluid balance, and kidney function.

RAS COMPONENTS AND PATHWAY

Step-by-Step Process:

1. **Renin Release** • **Juxtaglomerular Cells** detect decreased blood pressure • **Macula Densa** senses decreased sodium delivery • **Sympathetic Stimulation** triggers renin release
2. **Angiotensin I Formation** • Renin cleaves **Angiotensinogen** (liver protein) • Produces **Angiotensin I** (inactive decapeptide)
3. **Angiotensin II Formation** • **ACE (Angiotensin Converting Enzyme)** in lungs • Converts Angiotensin I to **Angiotensin II** • Active octapeptide with multiple effects

PHYSIOLOGICAL EFFECTS OF ANGIOTENSIN II

Cardiovascular Effects:

- **Vasoconstriction** - Increases peripheral resistance
- **Cardiac Stimulation** - Increases heart rate and contractility
- **Blood Pressure Elevation** - Direct and indirect mechanisms

Renal Effects:

- **Aldosterone Release** - Adrenal cortex stimulation
- **ADH Release** - Posterior pituitary stimulation
- **Sodium Retention** - Direct tubular effects
- **GFR Regulation** - Efferent arteriole constriction

Central Effects:

- **Thirst Stimulation** - Hypothalamic activation
- **Salt Appetite** - Behavioral modification
- **Sympathetic Activation** - CNS stimulation

REGULATION OF RAS

Stimuli for Renin Release:

- Decreased blood pressure
- Reduced sodium delivery to macula densa
- Sympathetic nervous system activation
- Hypovolemia
- Hypotension

Feedback Mechanisms:

- **Negative Feedback** - Angiotensin II inhibits renin release
- **Short Loop Feedback** - Direct inhibition at JG cells
- **Long Loop Feedback** - Blood pressure normalization

🩺 DISORDERS OF KIDNEY

Kidney disorders can significantly impact overall health and require prompt recognition and treatment.

ACUTE KIDNEY INJURY (AKI)

Classification:

- **Prerenal** - Decreased blood flow to kidneys
- **Intrarenal** - Direct kidney damage
- **Postrenal** - Obstruction of urine flow

Causes:

- Dehydration and shock
- Nephrotoxic drugs
- Glomerulonephritis
- Urinary tract obstruction

Clinical Manifestations:

- Decreased urine output (oliguria)
- Fluid retention and edema
- Electrolyte imbalances
- Uremia symptoms

CHRONIC KIDNEY DISEASE (CKD)

Stages of CKD:

Stage	GFR (mL/min/1.73m^2)	Description
1	≥90	Normal with kidney damage
2	60-89	Mild decrease in GFR
3a	45-59	Mild to moderate decrease
3b	30-44	Moderate to severe decrease
4	15-29	Severe decrease
5	<15	Kidney failure

Common Causes:

- Diabetes mellitus
- Hypertension

- Glomerulonephritis
- Polycystic kidney disease
- Autoimmune disorders

GLOMERULAR DISORDERS

Glomerulonephritis:

- **Acute** - Sudden onset, often post-infectious
- **Chronic** - Progressive, leading to CKD
- **Nephrotic Syndrome** - Proteinuria, hypoalbuminemia, edema
- **Nephritic Syndrome** - Hematuria, hypertension, oliguria

TUBULOINTERSTITIAL DISORDERS

Acute Tubular Necrosis (ATN):

- Most common cause of AKI
- Ischemic or nephrotoxic etiology
- Recovery potential with supportive care

Interstitial Nephritis:

- Drug-induced hypersensitivity
- Inflammatory infiltration
- Usually reversible if caught early

URINARY TRACT INFECTIONS (UTI)

Classifications:

- **Lower UTI** - Cystitis, urethritis
- **Upper UTI** - Pyelonephritis
- **Complicated vs. Uncomplicated**
- **Recurrent vs. Relapsing**

Risk Factors:

- Female anatomy
- Sexual activity
- Pregnancy
- Immunosuppression
- Urinary tract abnormalities