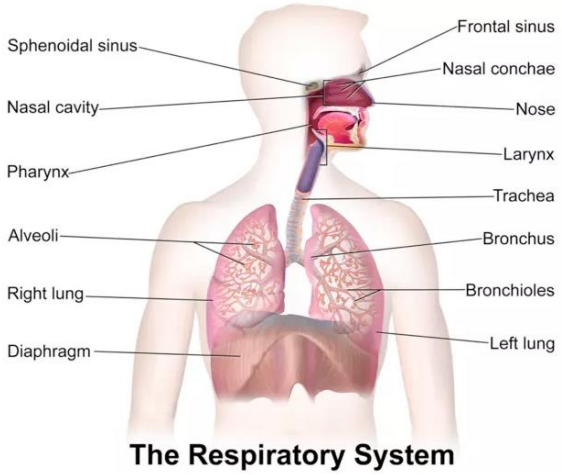
UNIT-III

THE RESPIRATORY SYSTEM - STRUCTURE AND FUNCTION

Respiration



The Respiratory System

- Respiration is defined as the biochemical process by which the digested foods are oxidized liberating the energy. In the process, oxygen is utilized and carbon-dioxide is released.
- Overall respiration process involves three process.
- **I. External respiration:** it is a simple process of exchange of gases (O_2 and CO_2) between the respiratory surface and the environment.
- **II. Transport of gases** between the respiratory surface and the body tissue.
- **III. Internal or cellular respiration**: cellular respiration occur in mitrochondria of every cell, where digested food is oxidized releasing energy in the storable form ie. ATP. And when the cell require energy for vital activities, ATP broke down into ADP+ iP + energy.

Parts of the respiratory system

Upper respiratory tract:

Nose, Nasal Cavity, Pharynx

Lower respiratory tract:

Trachea, the bronchi and the lungs

1. Nose (external nare and nasal chamber)

- Structurally the nose can be divided into the external portion which is in fact termed as the nose and the internal portions being the nasal cavities.
- Opening is known as **nostril**. The two nostrils are separated by **nasal septum**. The two nostril openings leading to two nasal chambers or cavities.

- The nasal cavity is lined with very vascular *ciliated columnar epithelium* which contains mucus-secreting goblet cells.

Function

- Prevent entry of dust particle into lungs
- Warm the incoming air entering the nasal cavity
- Moisten the dry air
- Olfactory receptor present in the roof of nasal cavity detect the smell
- Hold and sweep the microorgnisms entering the nasal chamber

2. Internal Nares and Pharynx

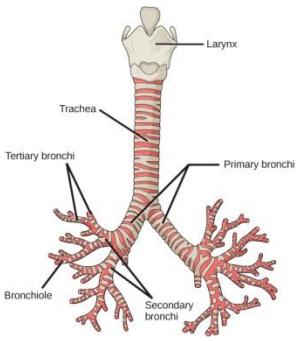
- The internal nares are the openings from the nasal cavity into the pharynx.
- The pharynx (throat) is a passageway that extends from the posterior nares, and runs behind the mouth and the larynx to the level of the 6th thoracic vertebra, where it becomes the oesophagus.
- Structurally the pharynx can be divided into three anatomical parts ie. **nasopharynx** (posterior to the nasal chambers), the **oropharynx** (posterior to the mouth), and the **laryngopharynx** (posterior to the pharynx).

3. Larynx

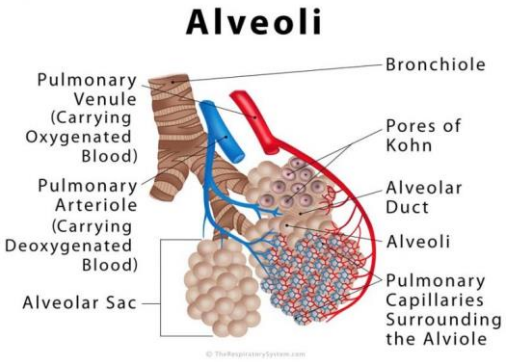
- The larynx or 'voice box' links the laryngopharynx and the trachea. It lies in front of the laryngopharynx and the 3rd, 4th, 5th and 6th cervical vertebrae.
- Until puberty there is little difference in the size of the larynx between the sexes. Thereafter, it grows larger in the male, which explains the prominence of the '**Adam's apple'** and the generally deeper voice.
- The larynx is composed of several irregularly shaped cartilages attached to each other by ligaments and membranes.
- The main cartilages are:1 thyroid cartilage, 1 cricoid cartilage, 2 arytenoid cartilages and 1 epiglottis
- The vocal cords are two pale folds of mucous membrane with cord-like free edges, stretched across the laryngeal opening. They extend from the inner wall of the thyroid prominence anteriorly to the arytenoid cartilages posteriorly.

4. Trachea

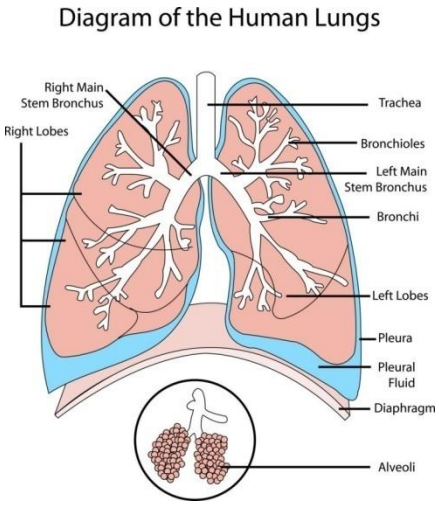
- The trachea or windpipe is a continuation of the larynx and extends downwards to about the level of the 5th thoracic vertebra where it divides at the *carina* into the right and left primary bronchi, one bronchus going to each lung.
- It is approximately **10–11 cm** long and lies mainly in the median plane in front of the oesophagus.
- The tracheal wall is composed of three layers of tissue, and is held open by between 16 and 20 incomplete **(C-shaped)** rings of hyaline cartilage lying one above the other.
- The rings are incomplete posteriorly where the trachea lies against the oesophagus.
- The tracheal mucosa consists of pseudo stratified, ciliated columnar epithelium, while its submucosa contains cartilage, smooth muscle, and seromucous glands.
- The trachea divides into the two **main bronchi** (primary bronchi) ie. the right bronchus wider, shorter and more vertical than the left bronchus.
- **The right bronchus:** This is wider, shorter and more vertical than the left bronchus and is therefore more likely to become obstructed by an inhaled foreign body. It is approximately 2.5 cm long. After entering the right lung at the hilum it divides into three branches, one to each lobe. Each branch then subdivides into numerous smaller branches.
- **The left bronchus.** This is about 5 cm long and is narrower than the right. After entering the lung at the hilum it divides into two branches, one to each lobe. Each branch then subdivides into progressively smaller airways within the lung substance.
- The bronchial walls contain the same three layers of tissue as the trachea, and are lined with ciliated columnar epithelium. The bronchi progressively subdivide into bronchioles, terminal bronchioles, respiratory bronchioles, alveolar ducts and finally, alveoli.



6. Lungs



- There are two lungs, one lying on each side of the midline in the thoracic cavity. They are cone-shaped and have an apex, a base, a tip, costal surface and medial surface.
- The **apex:** This is rounded and rises into the root of the neck, about 25 mm above the level of the middle third of the clavicle. It lies close to the first rib and the blood vessels and nerves in the root of the neck.
- The **base:** This is concave and semilunar in shape, and lies on the upper (thoracic) surface of the diaphragm.
- The **costal surface**: This is the broad outer surface of the lung that lies directly against the costal cartilages, the ribs and the intercostal muscle.
- The right lung is divided into three distinct lobes: superior, middle and inferior. The left lung is smaller because the heart occupies space left of the midline. It is divided into only two lobes: superior and inferior. The divisions between the lobes are called fissures.



- Lungs are enclosed in the **pleural cavity** lined by transparent pleural membrane. The pleura consists of a closed sac of serous membrane which contains a small amount of serous fluid.
- The lung is pushed into this sac so that it forms two layers: one adheres to the lung called visceral pleura and the other to the wall of the thoracic cavity called parietal pleura.

7. Alveoli

- Within each lobe, the lung tissue is further divided by fine sheets of connective tissue into ***lobules***.
- Each lobule is supplied with air by a terminal bronchiole, which further subdivides into respiratory bronchioles, alveolar ducts and large numbers of alveoli (air sacs).
- There are about **150 million** alveoli in the adult lung. It is in these structures that the process of gas exchange occurs.

- As airways progressively divide and become smaller and smaller, their walls gradually become thinner until muscle and connective tissue disappear, leaving a single layer of simple squamous epithelial cells in the alveolar ducts and alveoli.
- These distal respiratory passages are supported by a loose network of elastic connective tissue in which **macrophages, fibroblasts, nerves and blood and lymph vessels** are embedded.
- The alveoli are surrounded by a dense network of capillaries.
- Exchange of gases in the lung (external respiration) takes place across a membrane made up of the alveolar wall and the capillary wall fused firmly together. This is called the respiratory membrane.

Pulmonary air volume and capacities

- In normal quiet breathing there are about 15 complete respiratory cycles per minute. The amount of air exchanged during breathing is measured by an instrument called Spirometer or Resprometer.
- The amount of air present in lung under different condition is known as pulmonary air volume and the capacities of lungs to hold air varies according to conditions.
- some of the pulmonary air volume are:

1. Tidal volume (TV):

- This is the amount of air passing into and out of the lungs during each cycle of breathing.
- It is about 500 mL at rest.

2. Inspiratory reserve volume (IRV):

- This is the volume of air that can be inhaled into the lungs during normal inspiration.
- It is about 1500 ml.

3. Expiratory reserve volume (ERV): 1100ml

- This is the total volume of air which can be expelled from the lungs forcefully during normal expiration.
- It is about 1100ml.

- **4. Inspiratory capacity (IC): = TV + IRV=2000 ml**
- This is the amount of air that can be inspired with maximum effort.
- It consists of the tidal volume (500 ml) plus the inspiratory reserve volume. IC = TV + IRV
- It is about 2000ml

5. Functional residual capacity (FRC): ERV+RV=2300ML

- This is the amount of air remaining in the lungs after normal expiration.
- It is equal to ERV+ RV= 1100+1200= 2300ml. this means that exchange of gases is not interrupted between breath.
- The functional residual volume also prevents collapse of the alveoli on expiration.

6. Residual volume (RV):

- This is the volume of air remaining in the lungs after forceful expiration.
- It is about 1200ml.

7. Vital capacity (VC):3100 ML

- This is the maximum volume of air which can be expired after forceful inspiration in single breath.
- VC= TV+IRV+ERV= 500+1500+1100
- VC of athletes is more than normal person.

8. Total lung capacity (TLC):

- This is the maximum amount of air the lungs can hold after forceful inspiration.
- It is normally about 5000-6000 ml in adult.
- TLC=VC + RV.

9. Dead space:

- The lungs and the air passages are never empty.
- Out of 500ml of air inspired during normal respiration, 350ml are exchanged across the walls of the alveolar ducts.

- About 150ml of air always remains in the respiratory passage called as dead space.

Mechanism of Respiration in Human

- Entire physiology of respiration involves following steps

1. Breathing or pulmonary ventilation
2. External respiration
3. Transport of O2 to tissue
4. Internal respiration
5. Transport of CO2 from tissue

1. Breathing or Pulmonary ventilation

- This is movement of air into and out of the lungs.
- Breathing supplies oxygen to the alveoli, and eliminates carbon dioxide.
- The main muscles involved in breathing are the intercostal muscles and the diaphragm.
- There are 11 pairs of intercostal muscles occupying the spaces between the 12 pairs of ribs. They are arranged in two layers, the external and **internal intercostal muscles**.
- The diaphragm is a dome-shaped muscular structure separating the thoracic and abdominal cavities.
- Breathing depends upon changes in pressure and volume in the thoracic cavity. Since air flows from an area of high pressure to an area of low pressure, changing the pressure inside the lungs determines the direction of airflow.
- Breathing involves two process

i. Inspiration

- It takes place when the volume of thoracic cavity is increased and the air pressure is decreased.
- Simultaneous contraction of the external intercostal muscles and the diaphragm expands the thorax.
- As the **diaphragm + external intercostals contracts** (moves downward) lung volume increases.

It involves following events

- First of all, **external intercoastal muscle contracts** and internal intercoastal muscles relaxes.
- Due to contraction of external intercoastal muscles, **ribs is pulled upward**, resulting in increase in thoracic cavity size

- The thoracic cavity further **enlarges due to contraction of diaphragm**, lowering the diaphragm and increases the size of thoracic cavity.
- With increase in size of thorax, lungs expand simultaneously.
- As lungs expands, the **air pressure is reduced inside**, so equalize the pressure, atmospheric air rushes inside the lungs

ii. Expiration

It takes place when the size of thoracic cavity is reduced and air pressure is increased.

involves following events

- The **internal intercoastal muscle contracts** and external intercoastal muscles relaxes.
- Due to contraction of internal intercoastal muscle, ribs are pulled inward, resulting in decrease in size of thoracic cavity
- Furthermore the diaphragm is pushed upward due to its relaxation
- With the decrease in size of thoracic cavity, lungs is compressed
- As lungs is compressed, pressure increases, so the air is forced outside.

2. External respiration

- This is the exchange of gases by diffusion between alveoli and blood in the alveolar capillaries, across respiratory membrane.
- Diffusion of oxygen and carbon dioxide depends on pressure differences, e.g. between atmospheric air and the blood, or blood and the tissues.
- Gas exchange during the respiration process takes place in the alveolus at its surface that separates the alveolus with the capillary.
- The exchange of O_2 and CO_2 occurs through diffusion which is the net movement of gas molecules from a region that has a higher partial pressure to another region that has a lower partial pressure.
- The venous blood in alveolar capillaries contains high level of CO_2 and low level of O_2.
- CO_2 then diffuses from higher level (venous blood) to lower level (alveoli) until equilibrium is maintained. By the same process O_2 diffuses from alveoli to venous blood until equilibrium.

3. Transport of Oxygen to tissue

- Oxygen is carried in the blood to the tissue in two from:

i) Oxyhaemoglobin (98.5%): it is a chemical combination of O_2 with haemoglobin

i) Solution in plasma water (1.5%): O_2 dissolve in plasma of blood and carried to tissues.

- when the level of O_2 is high in blood, it combines with haemoglobin to from oxyhaemoglobin.
- Oxyhaemoglobin is unstable, and under certain conditions readily dissociates releasing oxygen. Factors that increase dissociation include low O_2 levels, low pH and raised temperature.

4. Internal respiration

- Internal respiration is exchange of gases which takes places in tissue, so also known as cellular respiration.
- In tissue, oxygen carried in the form of Oxyhaemoglobin get dissciated to liberating free O_2.

Hb_4O_8———dissociates to give ——— $Hb + O_2$

- The free O_2 then oxidized the glucose in the presence of respiratory enzymes to liberate CO2, water and energy.

$C_6H_{12}O_6 + 6O_2$ ———- $6CO_2 + 6H^2O$ + Energy

- Energy is utilized by the tissue for its vital activities, while the CO2 is diffused from the tissue.

5. Transport of Carbondioxide from tissue to lungs

- Carbon dioxide is one of the waste products of metabolism.
- It is excreted by the lungs and is transported by three mechanisms:

i) as Carbonic acid (H_2CO_3) (7%): some CO2 dissolved in the plasma to form carbonic acid

- carbondioxide mixed with water of blood plasma to form carbonic acid.

  $CO_2 + H_2O$——————H_2CO_3

ii) bicarbonate ions (HCO3−) in the plasma (70%)

- carbonic acid formed in blood plasma quickly ionizes to from bicarbonates and hydrogen ions in the presence of enzyme carbonic anhydrase.

  $CO_2 + H_2O$——————$H^+ + HCO^{3-}$

- bicarbonate ions combined with sodium or potassium present in blood to form sodium bicarbonate (NaHCO3) or Potassium bicarbonate (KHCO3) and transported in this form

iii) As carbaminohaemoglobin (23%):

Some CO_2 combines with Haemoglobin to form carbaminohaemoglobin in RBCs.

CO2 + $NHbNH_2$——————HbNH.COOH (carbaminohaemoglobin).

finally, CO_2 are carried to lungs and expelled out by expiration process of breathing.

REGULATION OF RESPIRATION

Breathing is an involuntary (not under our control) process. It is the process of exchange of oxygen from the atmosphere with carbon dioxide produced by the cells. A normal adult human breaths 12 -16 times/min and infant breaths about 44 times/min.

Humans have the ability to regulate breathing rate according to the needs of the body. This regulation of respiration involves both neural and chemical control. Now let's take a deep dive into the article and learn more about the regulation of respiration.

Components involved in regulation of respiration

The regulation of respiration is mainly dependent on the interactions of three components of the respiratory system. These are as follows:

Control centres

These are present in the brain stem (pons varolii and the medulla oblongata) and are responsible for the automaticity of breathing. Input for these centres comes from the higher brain centres to produce the required voluntary breathing efforts.

Sensors

These include chemoreceptors and sensory receptors.

Chemoreceptors

The chemoreceptors respond to changes in the blood carbon dioxide, oxygen, and hydrogen ion concentration by sending impulses to the control centres. This will alter the breathing pattern by affecting the effector organs.

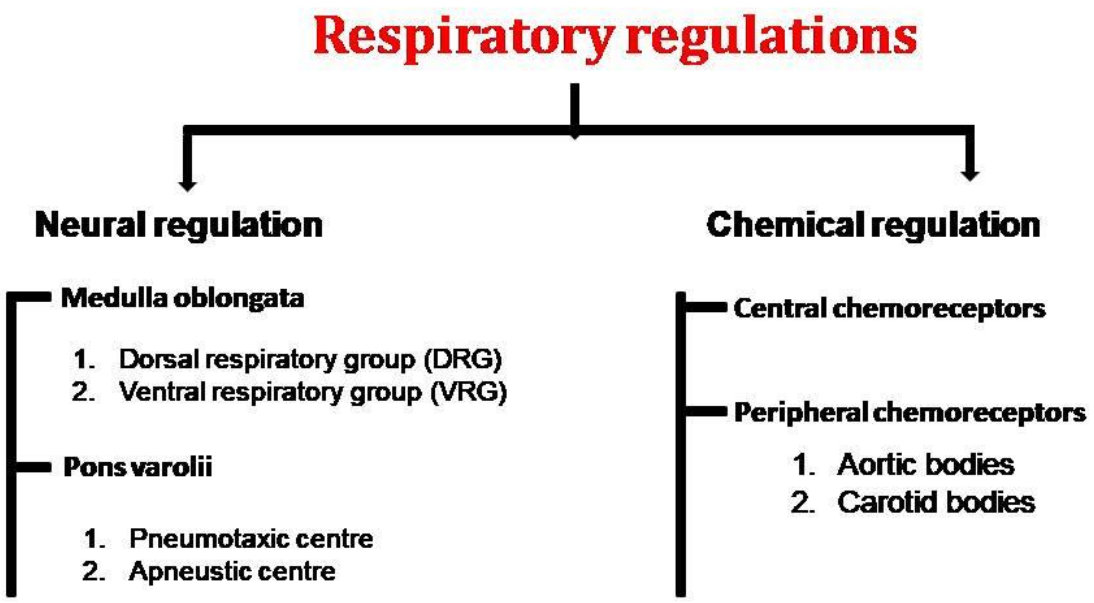
Sensory receptors

The sensory receptors are located in the upper and lower airways, the lung, and the muscles of respiration.

Effector organs

This includes the respiratory muscles like the diaphragm, the rib cage muscles (external intercostal muscles and internal intercostal muscles) and the abdominal muscles.

Types of respiratory regulations



There are two types of respiratory regulations as follows:

- Neural regulation
- Chemical regulation

Neural regulation

The respiratory rhythm is regulated by respiratory centres, which is composed of group neurons located in the hind part of the brain. The rate and depth of breathing is regulated by these respiratory centres. There are two regions in the brain which mainly regulate respiration. These are as follows:

- Medulla oblongata
- Pons varolii

Medulla oblongata

It is located in the hindbrain. It can regulate both expiration and inspiration depending on the neurons activated. It regulates respiratory rhythm according to the requirements of the body. Medulla oblongata has two respiratory centres as follows:

- Dorsal respiratory group (DRG)
- Ventral respiratory group (VRG)

Pons respiratory centres

- It is present in the pons varolii of the hindbrain. It regulates the respiratory rhythm centre.

There are two respiratory centres present in the pons varolii as follows:

- Pneumotaxic centre
- Apneustic centre

The apneustic centre

This centre lies in the lower part of the pons varolii and sends signals for inspiration for deep and long breaths. It is responsible for exciting the inspiratory centre. Stimulation of this centre results in a gradual increase in the rate of contraction of the inspiratory muscles. It increases tidal volume. It normally works in coordination with the pneumotaxic centre.

The pneumotaxic centre

It is located in the dorsal part of the pons varolii. It can slow down and reduce the functions of the respiratory rhythm centre. Signals from this centre can decrease the duration of inspiration which in turn will alter the respiratory rate. It works through the medullary centres. The pneumotaxic centre sends signals to inhibit inspiration which allows it to specifically control the respiratory rate. It reduces the activity of the phrenic nerve and inhibits the signals of the apneustic centre too. It decreases the overall tidal volume. The apneustic and pneumotaxic centres are antagonistic in function (work against each other together), thereby controlling the respiratory rate.

Chemical regulation

Centres associated with chemical regulation of respiration are as follows:

- Central chemoreceptors
- Peripheral chemoreceptors

Central chemoreceptors

These are present in the medullary oblongata region around the inspiratory centre. This area is sensitive to pCO_2 and H^+ ions concentration. Hence an increase in pCO_2 and H^+ ions activate these receptors, which in turn activate respiratory rhythm centre or the inspiratory centre. Activated rhythm centres alter the rate of respiration or inspiration. This will make necessary adjustments in the respiratory process by which these substances will be eliminated.

Peripheral chemoreceptors

These include the following:

- Aortic bodies
- Carotid bodies

These are activated by increase in pCO_2 and H^+ ions in arterial blood. These activate the inspiratory centre or respiratory rhythm centre to reverse the situation.

Aortic bodies

It includes the chemoreceptors present in the arch of aorta. Their afferent nerve fibres pass through the vagus nerve (tenth cranial nerve) to the dorsal respiratory group.

Carotid bodies

It includes the large number of chemoreceptors present in the bifurcations of the common carotid arteries. Their afferent nerve fibres pass through the glossopharyngeal cranial nerves and reach the dorsal respiratory group of neurons in the medulla oblongata.

Artificial Respiration and Resuscitation Methods

Artificial Respiration and Resuscitation Methods are emergency techniques used to restore or support breathing and circulation in individuals who have stopped breathing or whose heart has stopped beating.

1. Artificial Respiration

Definition:

Artificial respiration is a method of aiding or stimulating breathing in a person who is not breathing or is breathing inadequately.

Methods of Artificial Respiration:

1. **Mouth-to-Mouth Respiration (Rescue Breathing):**

   The rescuer breathes directly into the victim's mouth.

   Procedure:

   - Ensure airway is open (head-tilt, chin-lift).
   - Pinch the victim's nose, create a seal with your mouth.
   - Blow into the mouth until the chest rises (1 breath every 5–6 seconds in adults).

2. **Mouth-to-Nose Respiration:**

   Used if mouth cannot be opened or is injured.

   Similar process but seal is made over the nose.

3. **Bag-Valve Mask (BVM) Ventilation:**

   A manual resuscitator device used in hospitals or by trained personnel.

   Provides higher oxygen delivery than mouth-to-mouth.

4. **Mechanical Ventilation:**

   Used in ICU settings via ventilators for long-term respiratory support.

2. Resuscitation Methods

Definition:

Resuscitation refers to procedures done to revive someone from unconsciousness or apparent death, especially from cardiac arrest.

Primary Method:

Cardiopulmonary Resuscitation (CPR)

- **Indications:** Cardiac arrest, respiratory arrest, drowning, drug overdose, etc.

CPR Steps (Basic Life Support – BLS):

For Adults (2020 AHA Guidelines):

1. **Check Responsiveness:** Tap and shout.
2. **Call for Help:** Call emergency services (activate EMS).
3. **Check Breathing and Pulse (max 10 seconds).**
4. **Chest Compressions:**

   100–120 compressions per minute.

   Depth: 2–2.4 inches (5–6 cm).

   Allow full recoil.
5. **Airway:** Open airway with head-tilt, chin-lift.
6. **Breathing:** 2 rescue breaths after every 30 compressions (if trained).
7. **Use of AED (Automated External Defibrillator):**

   As soon as available.

   Follow voice prompts.

Technique	Purpose	Used When
Mouth-to-mouth	Restore breathing	Respiratory arrest
CPR	Restart heart and breathing	Cardiac & respiratory arrest
BVM ventilation	Emergency assisted breathing	EMS/hospital settings
Mechanical ventilation	Long-term respiratory support	ICU care
AED	Restore heart rhythm	Cardiac arrest with arrhythmia