

**Respiratory system.
Mechanism of lung
ventilation.**

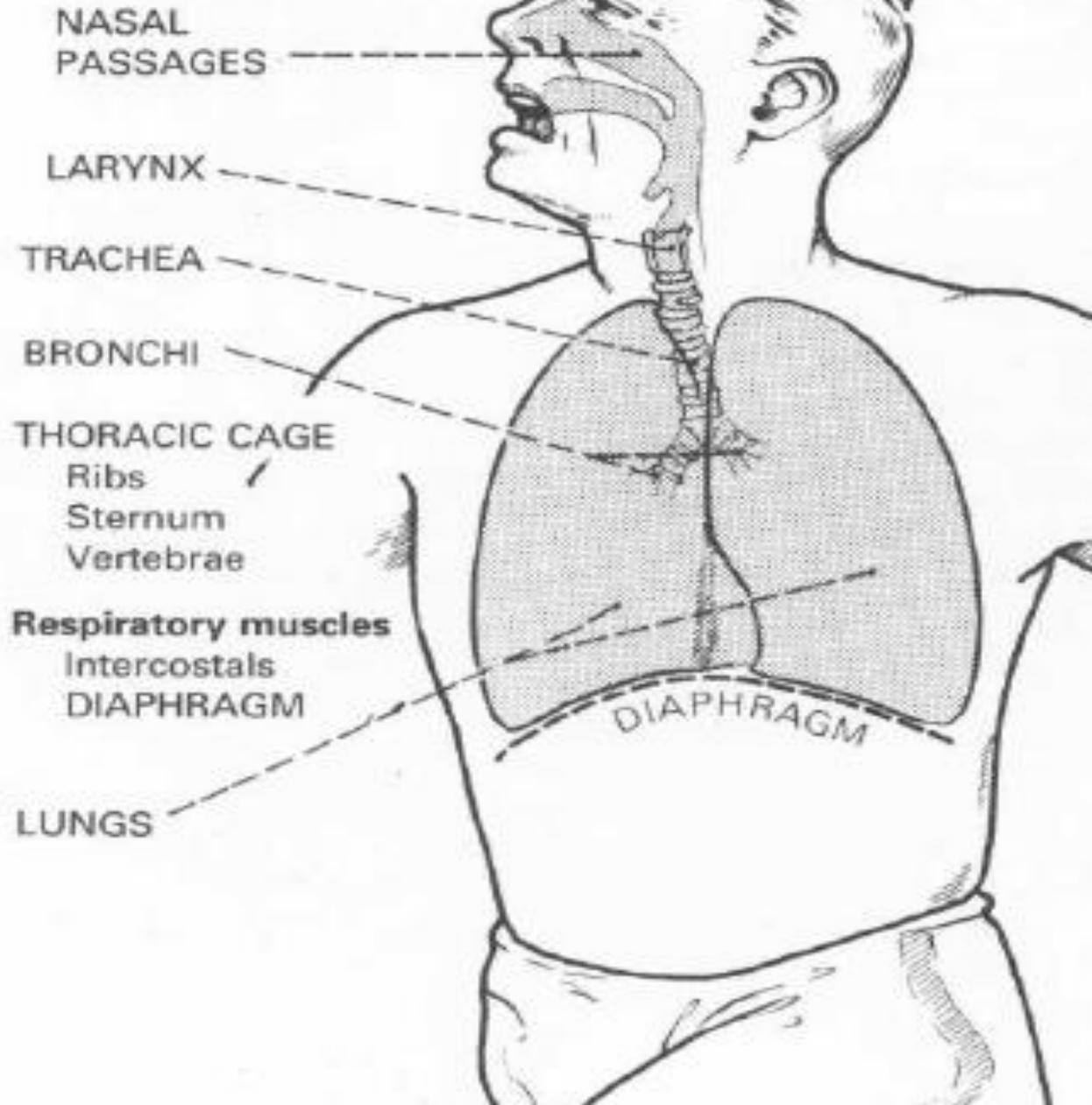
Respiratory system

- The respiratory system is divided into a respiratory zone, which is the site of gas exchange between air and blood, and a conducting zone, which conducts the air to the respiratory zone.

The exchange of gases between air and blood occurs across the walls of respiratory alveoli. These tiny air sacs, only a single cell layer thick, permit rapid rates of gas diffusion.

Respiration

- The term *respiration* includes three separate but related functions:
 - (1) ventilation (breathing);
 - (2) gas exchange, which occurs between the air and blood in the lungs and between the blood and other tissues of the body; and
 - (3) oxygen utilization by the tissues in the energy – liberating reactions of cell respiration.
- Ventilation and the exchange of gases (oxygen and carbon dioxide) between the air and blood are collectively called external respiration. Gas exchange between the blood and other tissues and oxygen utilization by the tissues are collectively known as internal respiration.



- **Respiratory tubes** conduct **air** to and from the lungs.
- **Respiratory movements**: rhythmical bellows-like movements aid intake of **air** to lungs and expulsion of **air** from lungs.
- **Respiratory surfaces** in lungs, across which exchange of **respiratory gases** occurs.
- Blood transports respiratory gases to and from all tissues of the body.

The air passages of the respiratory system are divided into two functional zones.

- The **respiratory zone** is the region where gas exchange occurs, and it therefore includes the respiratory bronchioles (because they contain separate outpouchings of alveoli) and the terminal alveolar sacs.
- The **conducting zone** includes all of the anatomical structures through which air passes before reaching the respiratory zone

- The conducting zone of the respiratory system consists of the mouth, nose, pharynx, larynx, trachea, primary bronchi, and all successive branchings of the bronchioles up to and including the terminal bronchioles.
- In addition to conducting air into the respiratory zone, these structures serve additional functions: *warming* and *humidification* of the inspired air and *filtration* and *cleaning*.

Thorax

- The thorax (or chest) is the closed cavity which contains the lungs, heart and great vessels. The thorax is lined by two thin layers of membrane – the PLEURA – the inner (visceral) layer of which covers the LUNGS. The outer (parietal) layer covers the inner wall of the thorax.
- Elastic recoil of lungs tends to pull visceral layer away from parietal layer. This creates subatmospheric or negative intrapleural pressure (about -2 mmHg).

- In **quiet inspiration**, the chest wall is tending to pull away from lungs and the intrapleural pressure becomes about -6 mmHg.
- With **forced inspiration**, it can become -30 mmHg.

NB: a negative pressure is a pressure below atmospheric pressure (760 mmHg). A positive pressure is above atmospheric pressure.

- **Capacity** of thoracic cage and the **pressure** between pleural surfaces change rhythmically about 12 – 14 times a minute with the **movements of respiration** – air movement in and out of the lungs follows the dimension changes.

MECHANISM OF BREATHING

The rhythmical changes in the capacity of the thorax are brought about by the action of skeletal muscles. The changes in lung volume, with intake or expulsion of air, follow.

In NORMAL QUIET BREATHING

INSPIRATION

External intercostal muscles actively contract: ribs and sternum move upwards and outwards because first rib is fixed, width of chest increases from side to side and depth from front to back increases.



Diaphragm contracts, length of chest increases. Capacity of thorax is increased



Pressure between pleural surfaces (already negative) becomes more negative:
from -2 to -6 mmHg





Elastic tissue of lungs is stretched



Lungs expand to fill thoracic cavity



Air pressure in alveoli is now -1,5 mmHg



Air is sucked into alveoli from atmosphere because of pressure difference.

EXPIRATION

External intercostal muscles relax: ribs and sternum more downwards and inwards, width and depth of chest diminishes. Diaphragm relaxes – ascends – length of chest diminishes. Capacity of thorax is decreased.



Pressure between pleural surfaces becomes less negative:
from -6 to -2 mmHg



Elastic tissue of lungs recoils



Air pressure in alveoli is now +1,5 mmHg (greater than atm. pressure)



Air is forced out of alveoli to atmosphere

In FORCED BREATHING

Muscles of nostrils and round glottis may contract to aid entrance of air to lungs.

Extensors of vertebral column may aid inspiration.

Muscles of neck contract – move 1st rib upwards (and sternum upwards and forwards).

Internal intercostal may contract – move ribs downwards more actively.

Abdominal muscles contract – actively aid ascent of diaphragm.

VOLUMES and CAPACITIES OF LUNG

Lung Volumes

The four nonoverlapping components of the total lung capacity:

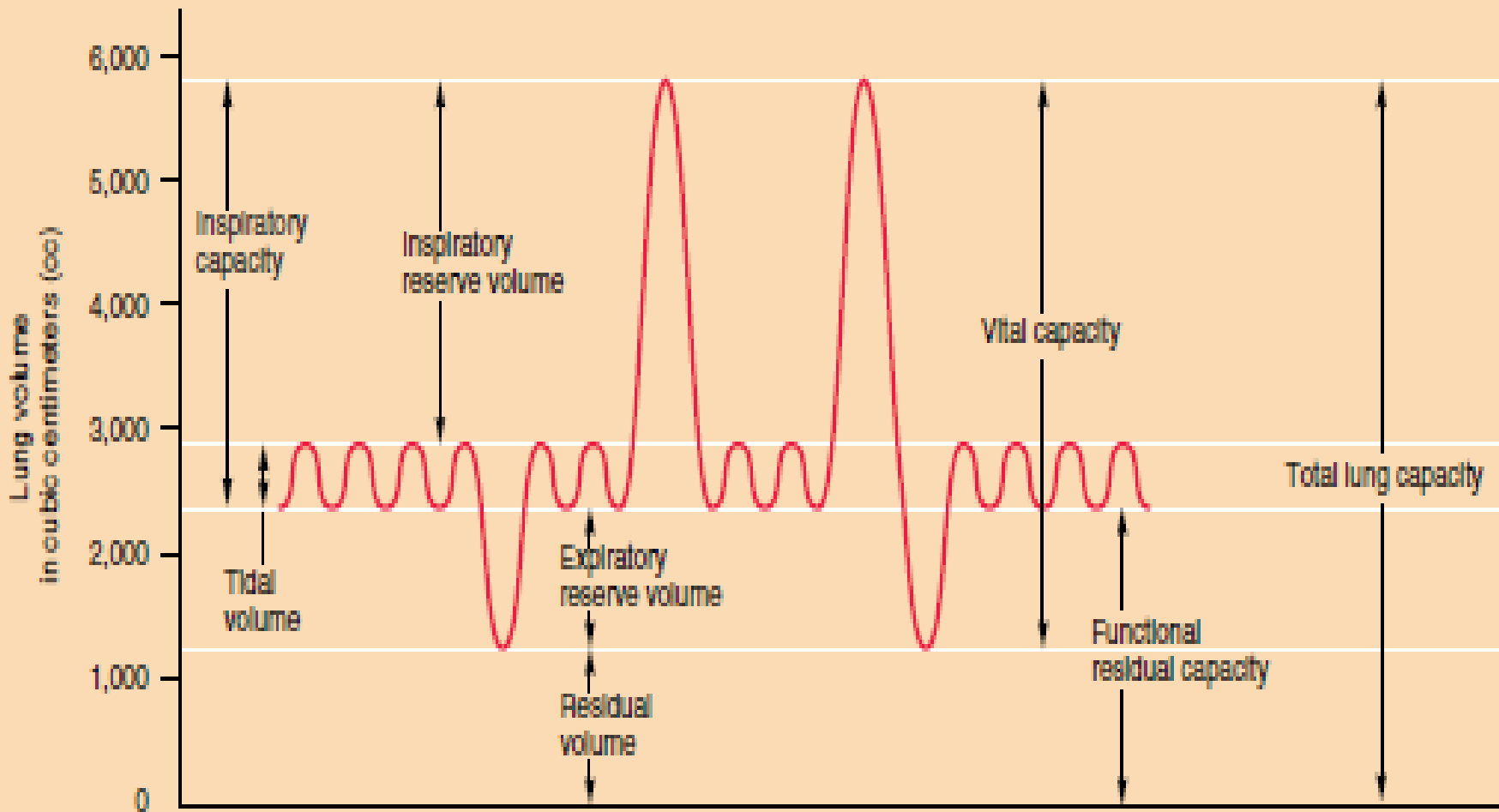
- **Tidal volume** – the volume of gas inspired or expired in an unforced respiratory cycle;
- **Inspiratory reserve volume** – the maximum volume of gas that can be inspired during forced breathing in addition to tidal volume;
- **Expiratory reserve volume** – the maximum volume of gas that can be expired during forced breathing in addition to tidal volume;
- **Residual volume** – the volume of gas remaining in the lungs after a maximum expiration.

Lung Capacities

Measurements that are the sum of two or more lung volumes

- **Total lung capacity** – the total amount of gas in the lungs after a maximum inspiration;
- **Vital capacity** – the maximum amount of gas that can be expired after a maximum inspiration;
- **Inspiratory capacity** – the maximum amount of gas that can be inspired after a normal tidal expiration;
- **Functional residual capacity** – the amount of gas remaining in the lungs after a normal tidal expiration.

SPIROGRAM



- Values for volumes and capacities are typical values but will vary with the subject's size and weight. Values are usually about 25% less in women.
- At rest a normal male adult breathes in and out about 12 times per minute. The amount of air breathed in per minute is therefore $500 \text{ ml} \times 12$ i.e. 6000 ml or 6 liters – this is the respiratory minute volume or pulmonary ventilation. In exercise it may go up to as much as 200 liters.
- In deep breathing the volume of atmospheric air inspired with each inspiration and the amount which reaches the alveoli increase.

Ventilation Terminology

- **Air spaces** – alveolar ducts, alveolar sacs, and alveoli;
- **Airways** – structures that conduct air from the mouth and nose to the respiratory bronchioles
- **Alveolar ventilation** – removal and replacement of gas in alveoli; equal to the tidal volume minus the volume of dead space times the breathing rate
- **Anatomical dead space** – volume of the conducting airways to the zone where gas exchange occurs
- **Apnea** – cessation of breathing
- **Dyspnea** – unpleasant, subjective feeling of difficult or labored breathing
- **Eupnea** - normal, comfortable breathing at rest

- **Hyperventilation** – alveolar ventilation that is excessive in relation to metabolic rate; results in abnormally low alveolar CO₂
- **Hypoventilation** – alveolar ventilation that is low in relation to metabolic rate; results in abnormally high alveolar CO₂
- **Physiological dead space** – combination of anatomical dead space and underventilated or underperfused alveoli that do not contribute normally to blood gas exchange
- **Pneumothorax** – presence of gas in the intrapleural space (the space between the visceral and parietal pleurae) causing lung collapse
- **Torr** – unit of pressure nearly equal to the millimeter of mercury (760 mmHg = 760 torr)