Chapters 2, 3
Respiratory system:
- Structure and mechanics
- Clinical Applications

COMD 6305

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Divisions

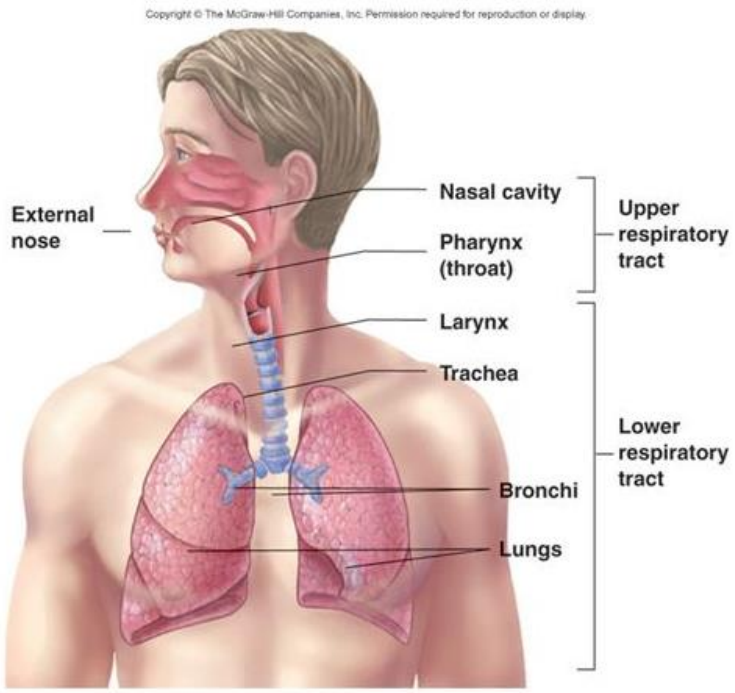
Pulmonary System

1. Upper (oral / nasal / pharynx - *described elsewhere*)
2. Lower (larynx; bronchial / lungs) ✓
3. Chest-Wall System ✓

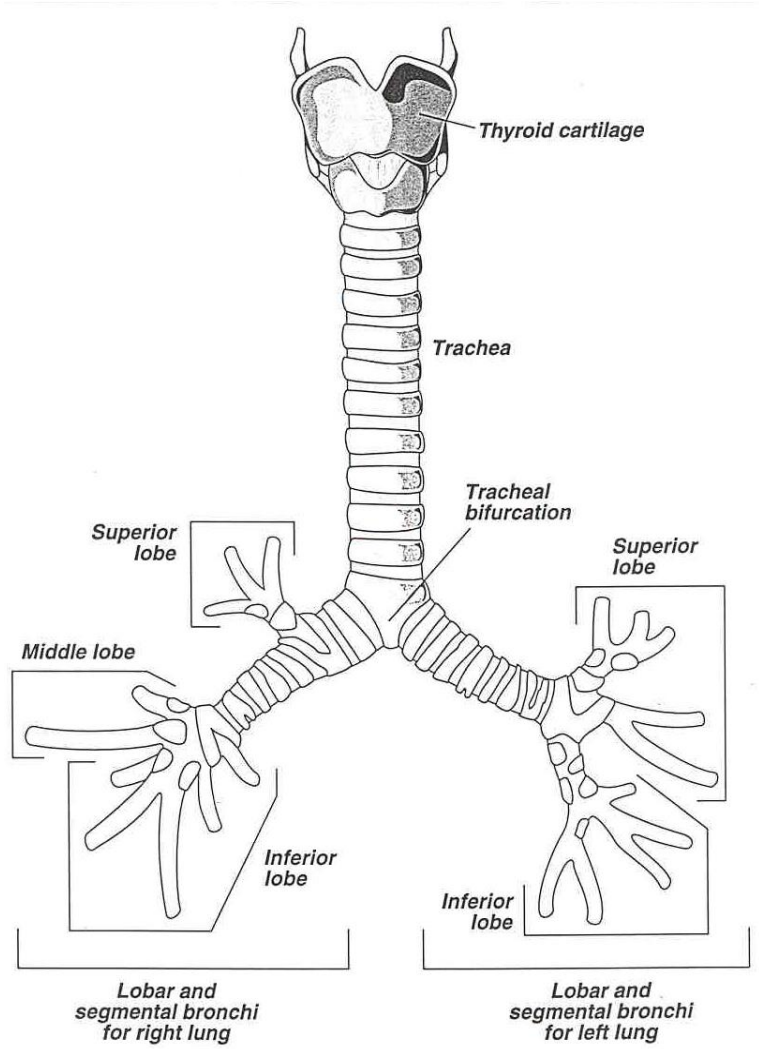
    -Rib cage

    -Abdomen

    -Diaphragm



Tracheobronchial Tree



PULMONARY SYSTEM - Respiratory Airways

Upper

Nose

Mouth

Pharynx

Larynx

Lower

Bronchial tree:

-Trachea

-Bronchi

-Bronchioles

Alveoli

Lungs

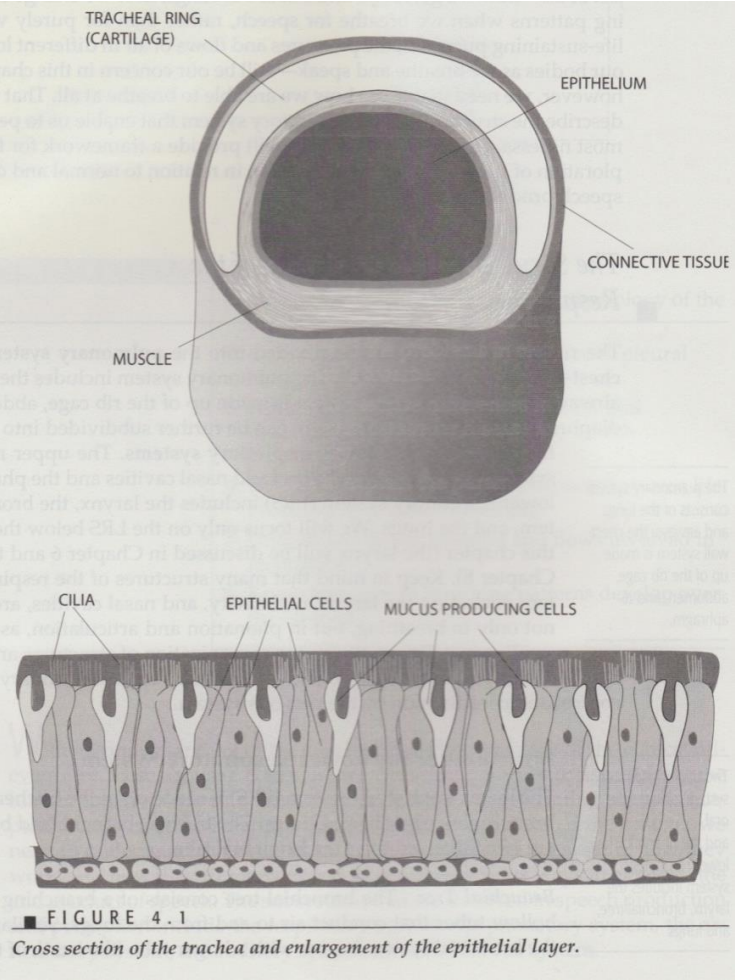


FIGURE 4.1
Cross section of the trachea and enlargement of the epithelial layer.

(Kent, Speech Sciences)

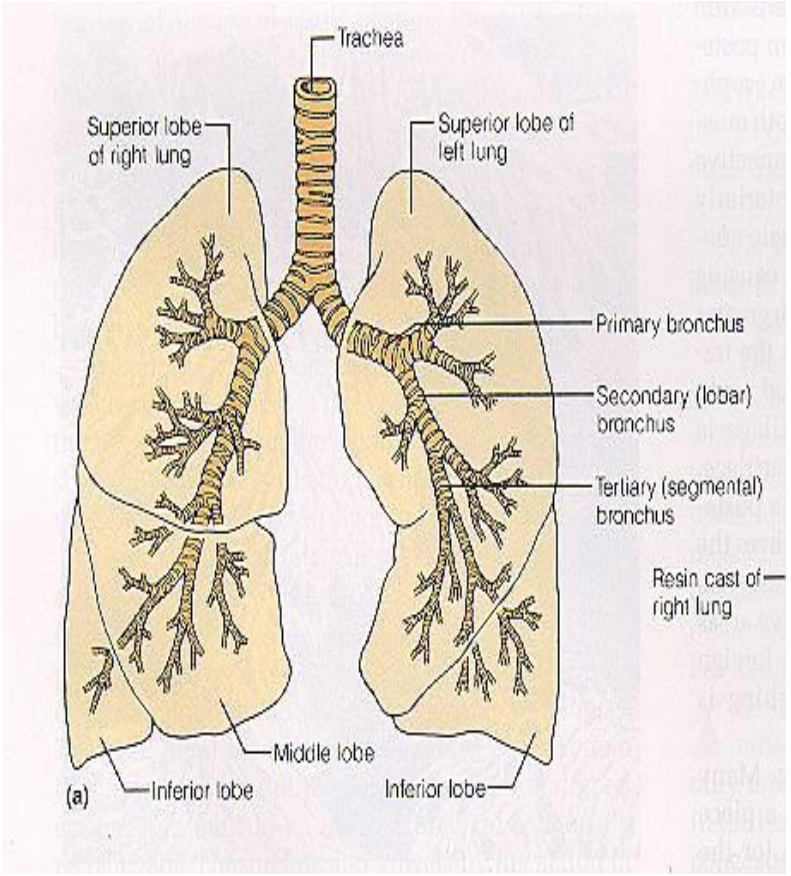
Trachea

- Tube containing 16 to 20

  "C shaped" cartilages

  (hyaline)

- Interconnected by connective tissue and muscle

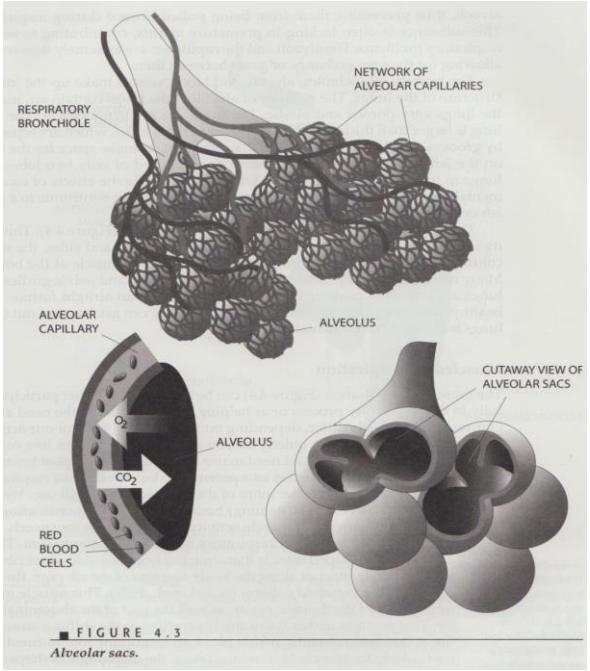


Trachea → mainstem bronchi →

Secondary bronchi → tertiary bronchi

……. (x 20 generations!)

→ alveolar ducts → alveoli



Human Lung

- Spongy in texture
- Rests on top of the diaphragm

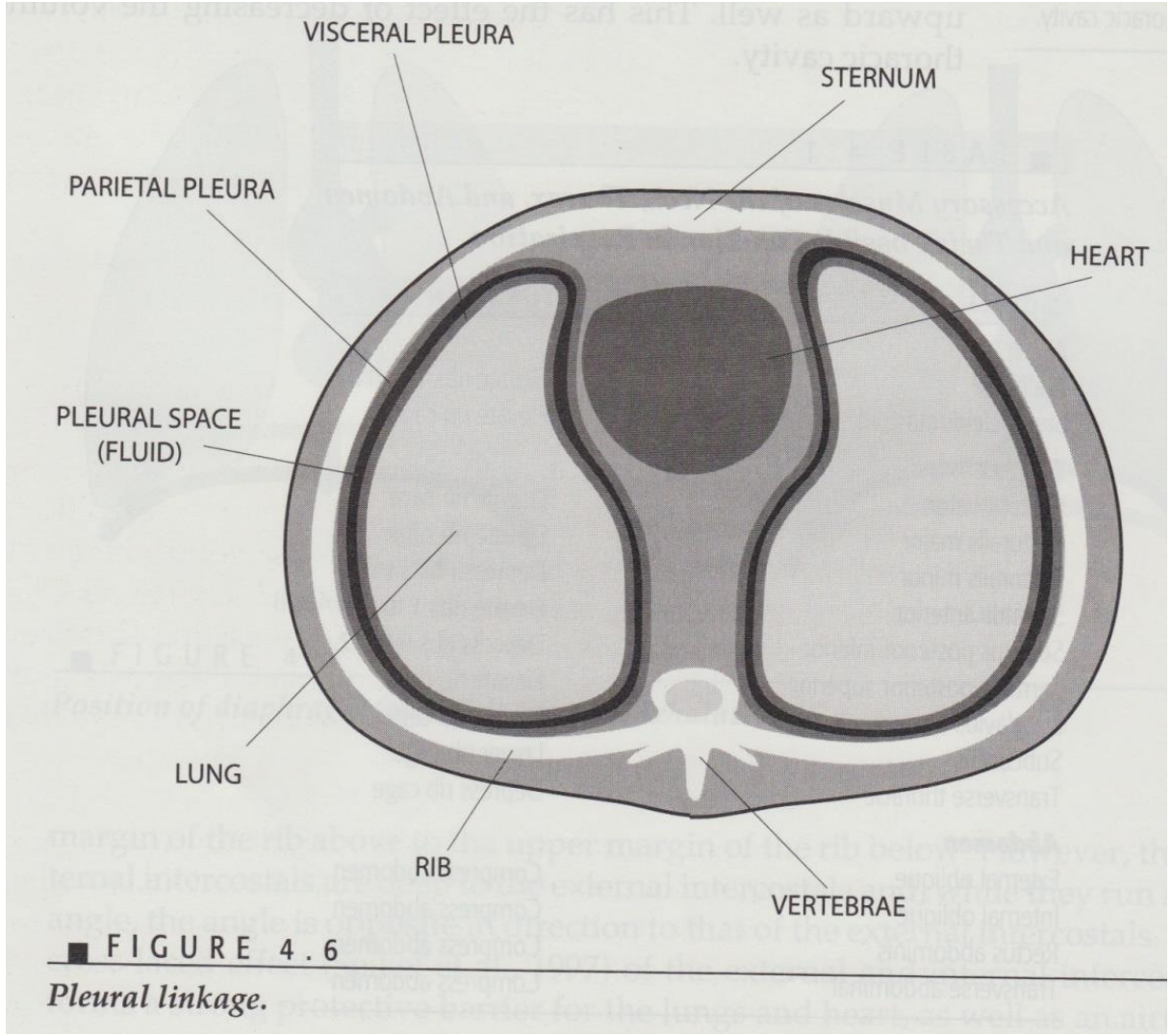


FIGURE 4.6

Pleural linkage.

Human Lung & Pleural Linkage

Lining of lungs

Allows for movement without frication

(Kent, Speech Sciences)

Parts of Pleurae – additional views

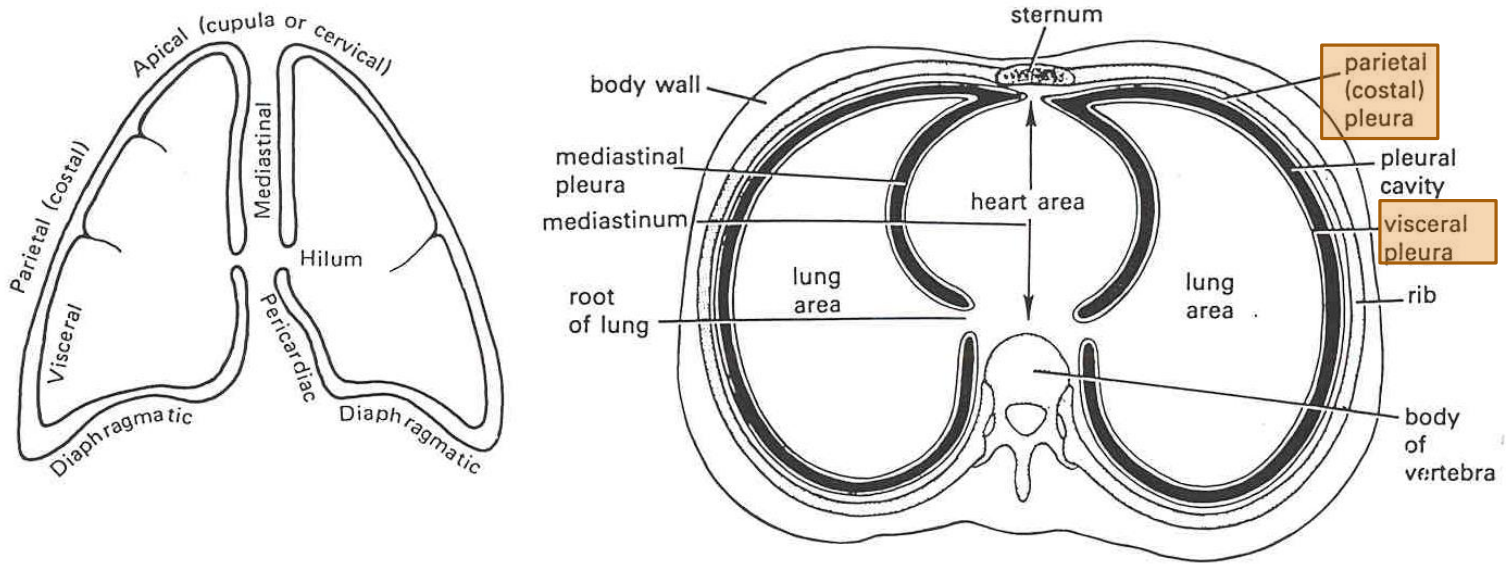


Figure 2-12. Schematic of parts of the pleurae and their reflections, as seen in a coronal section (A) and in a transverse section (B). (Transverse section from J. E. Crouch, *Functional Human Anatomy*, 3rd ed., 1978, Courtesy Lea & Febiger.)

Chest-Wall System

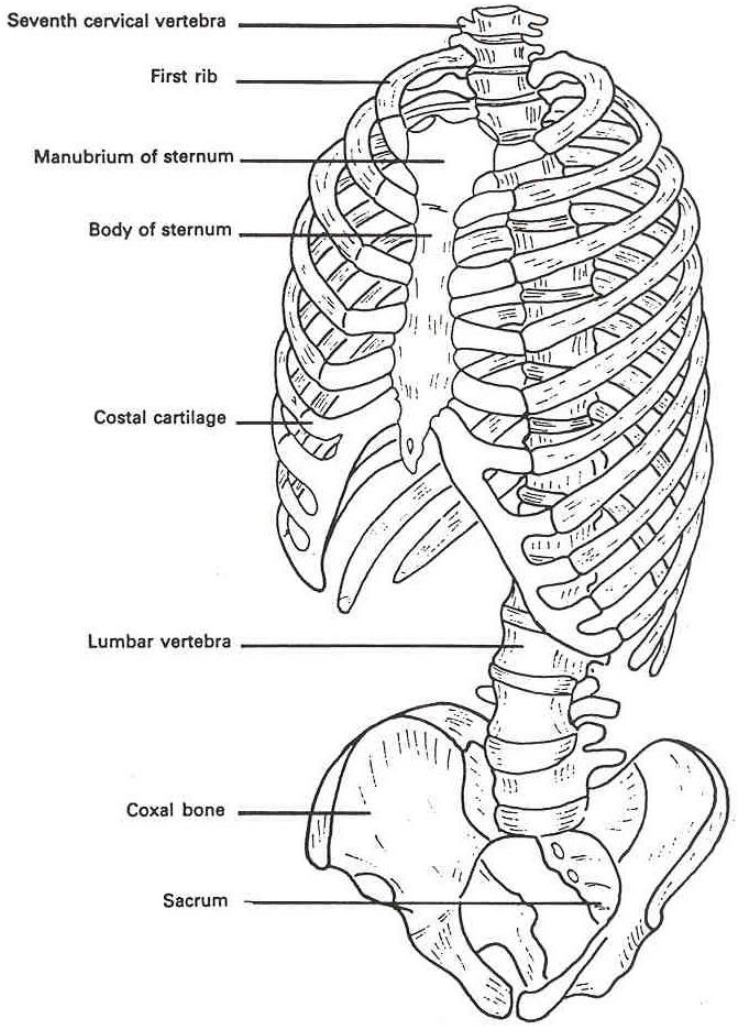
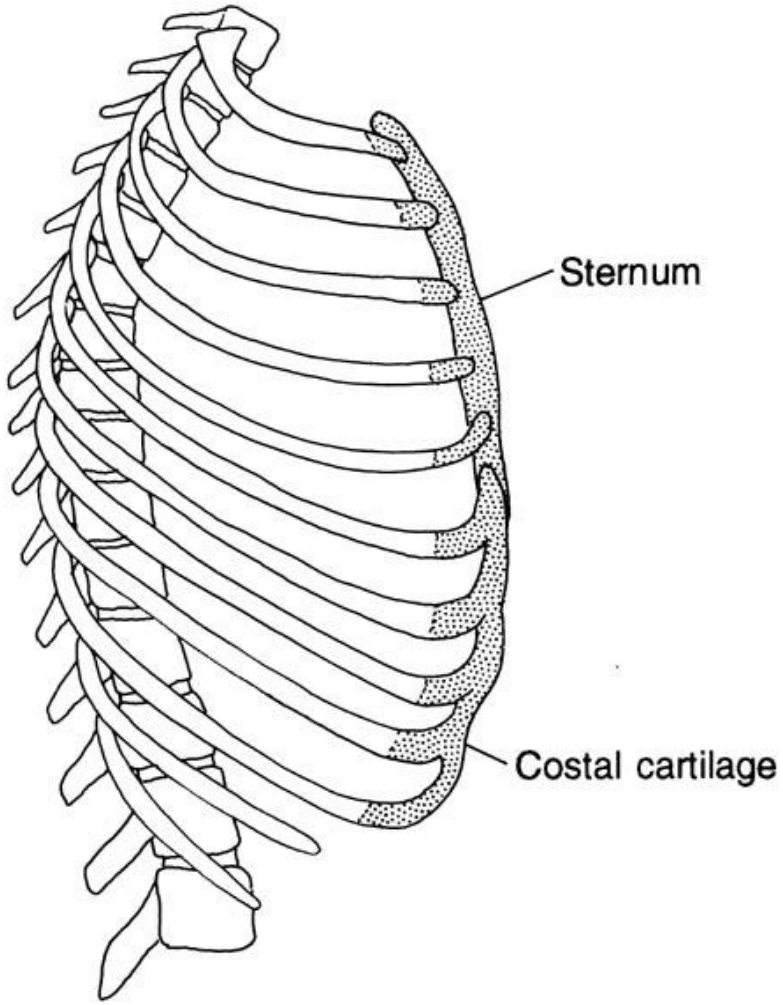


Figure 2-16. The skeletal framework for the breathing mechanism.



Rib Cage

12 ribs

All attached

by means of

cartilage to the

sternum

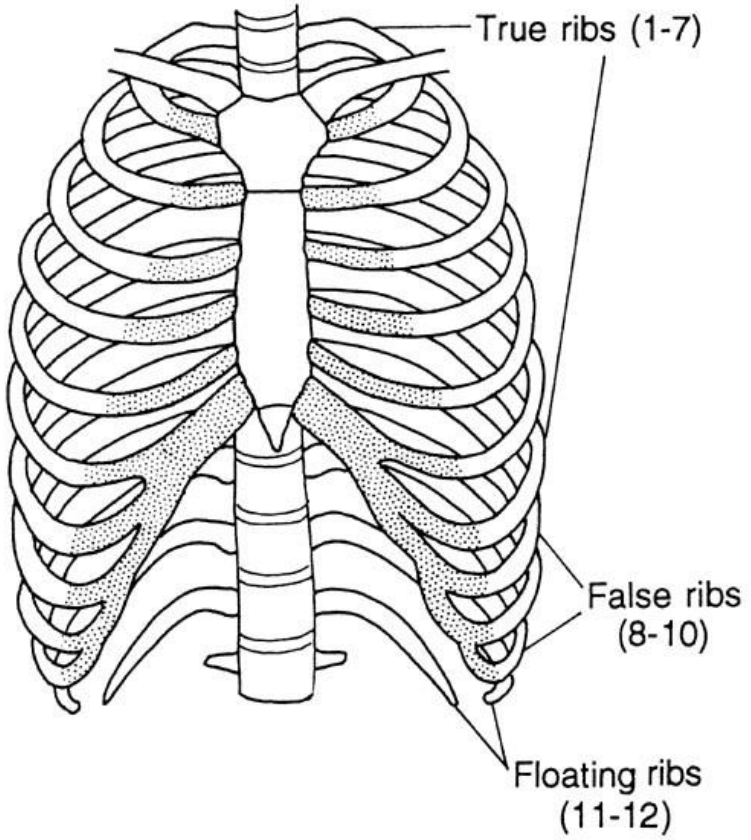
..with exception of lowest two (11 &12)

“floating”

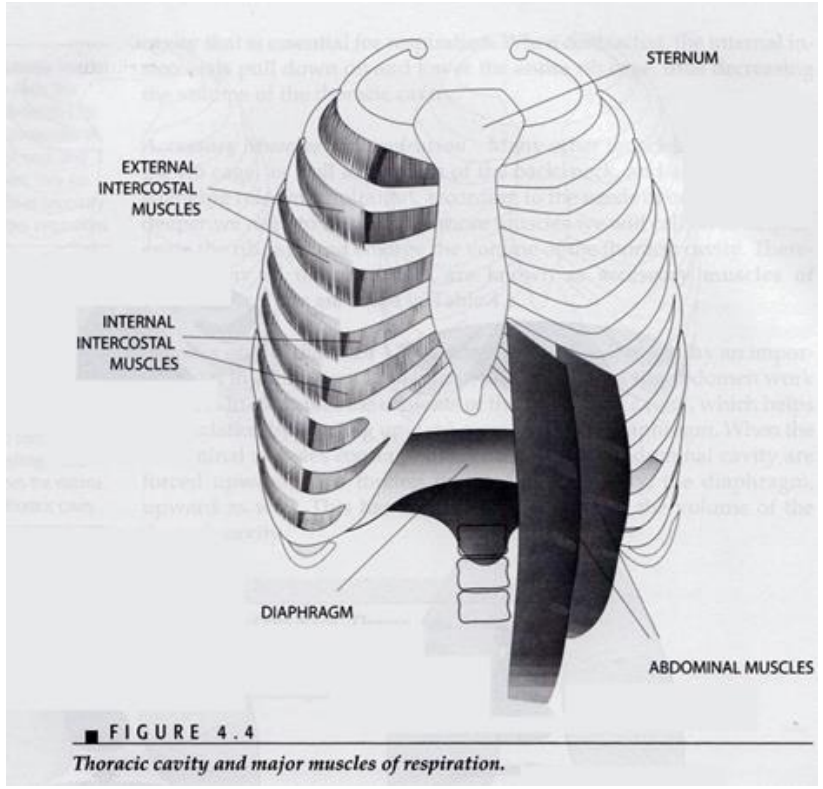
Rib Anatomy – continued

Three classes of ribs:

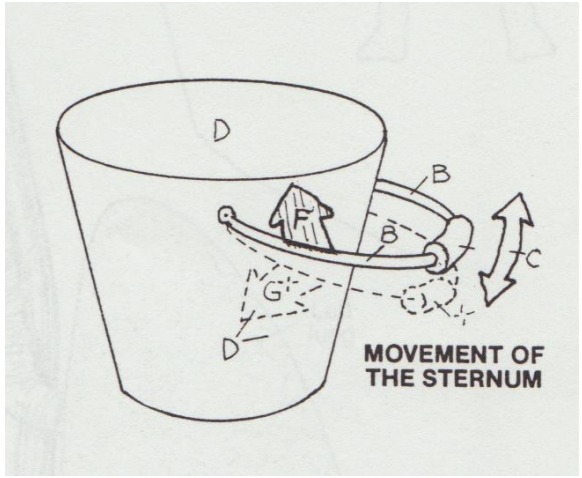
1. True ribs
2. False ribs
3. Floating ribs



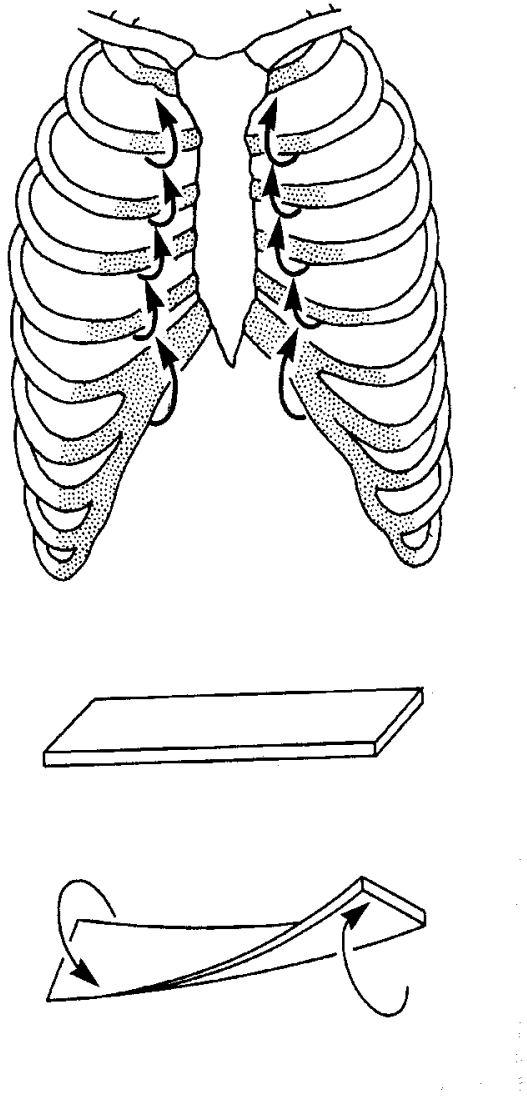
Rib Movement



■ FIGURE 4.4
Thoracic cavity and major muscles of respiration.



torquing



Torquing of rib cage during inspiration

When the rib cage is elevated during inspiration, the ribs are torqued or twisted.

Cartilage (elastic) tends to return to its original state.

Diaphragm

- Primary muscle of inspiration
- Dome shaped
- Divides thoracic from the abdominal cavity
- When contracted, pulls ribcage down and forward
- Also involved in sneezing and hiccups

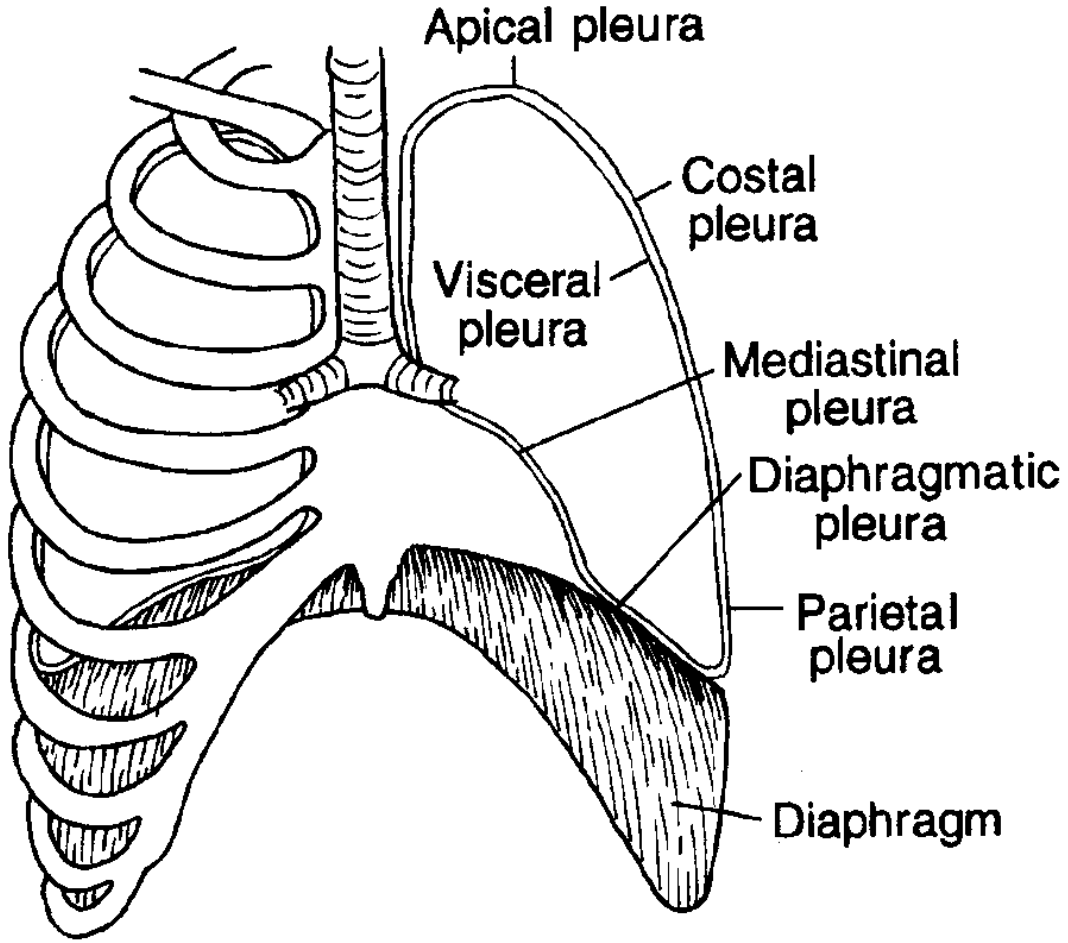


FIGURE 3–22. Pleural linings of the lungs and thorax. Parietal pleurae include costal, diaphragmatic, mediastinal, and apical pleurae. Visceral pleurae line the lungs.

Diaphragm – continued

Innervated by the phrenic nerve.

Can be under voluntary control

However, generally regulated by the autonomic nervous system.

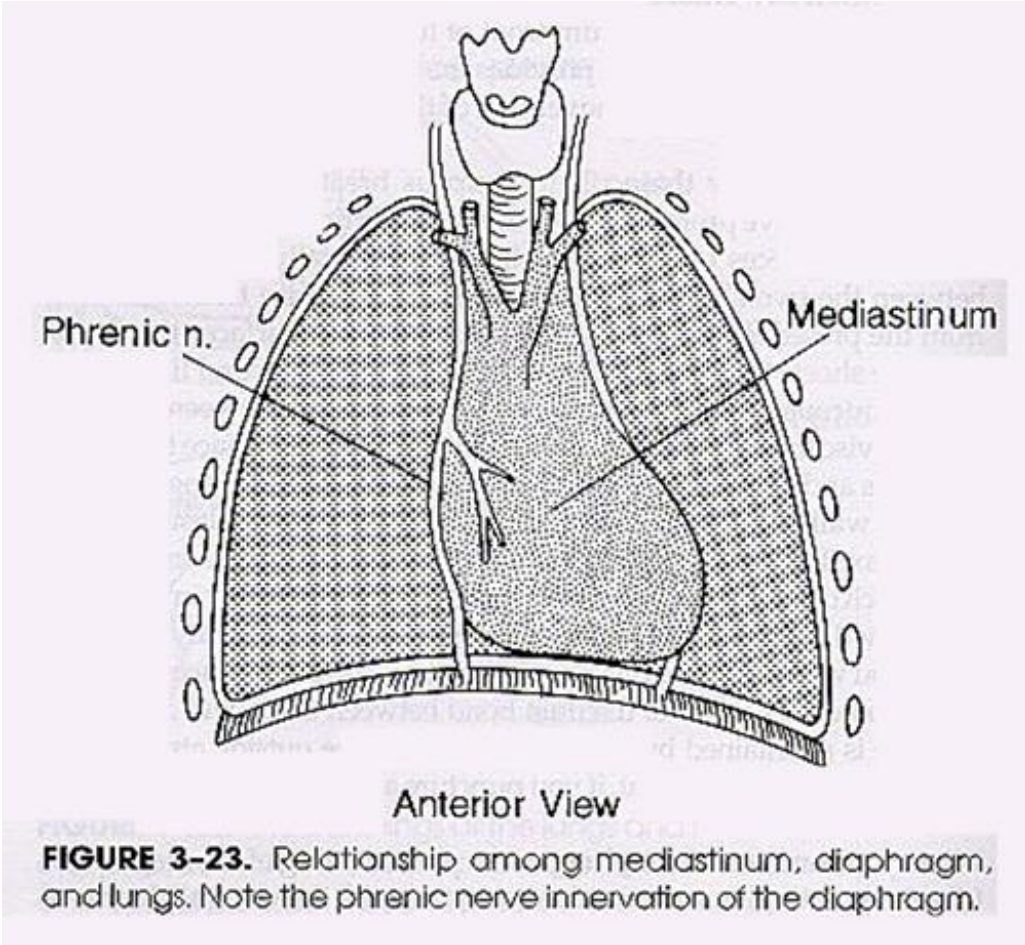


FIGURE 3-23. Relationship among mediastinum, diaphragm, and lungs. Note the phrenic nerve innervation of the diaphragm.

Diaphragm – position, shape

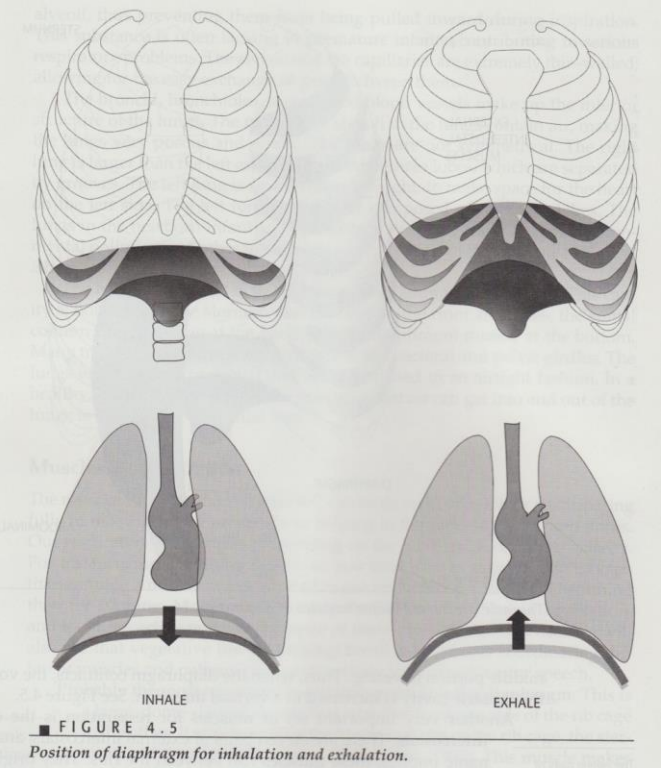


FIGURE 4.5
Position of diaphragm for inhalation and exhalation.

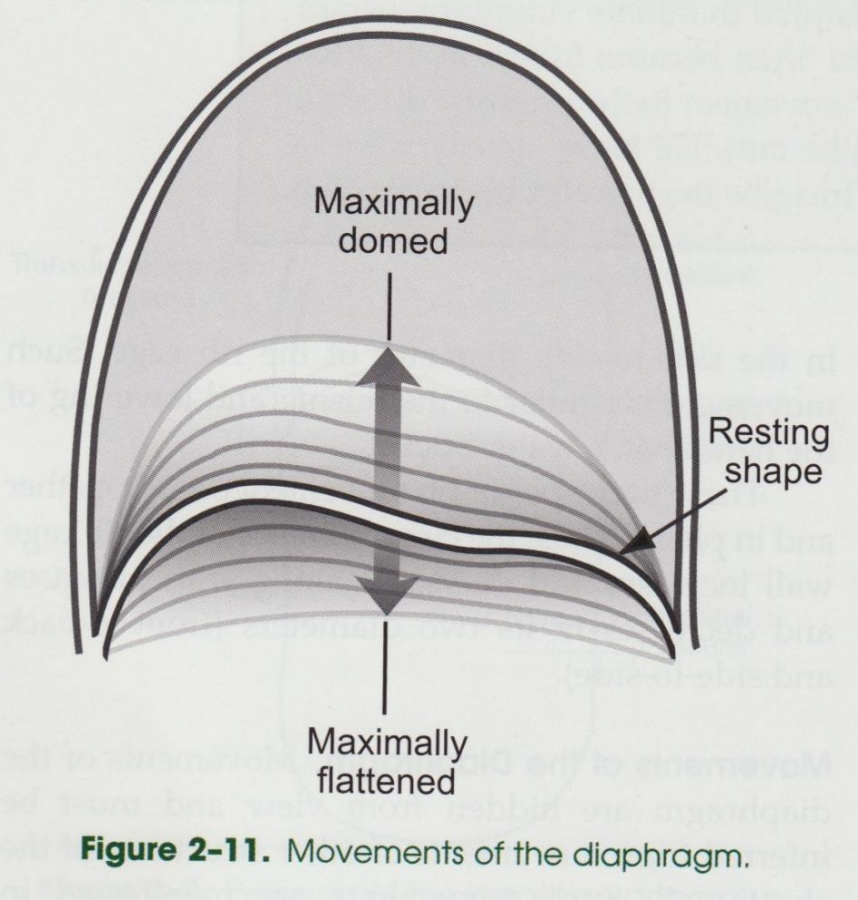
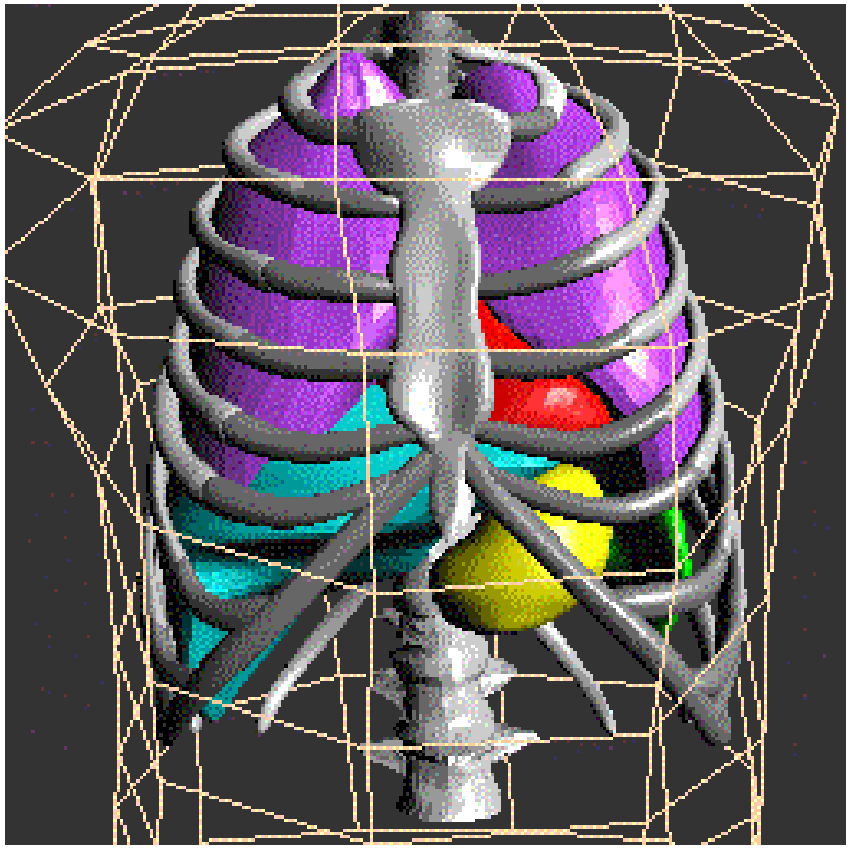


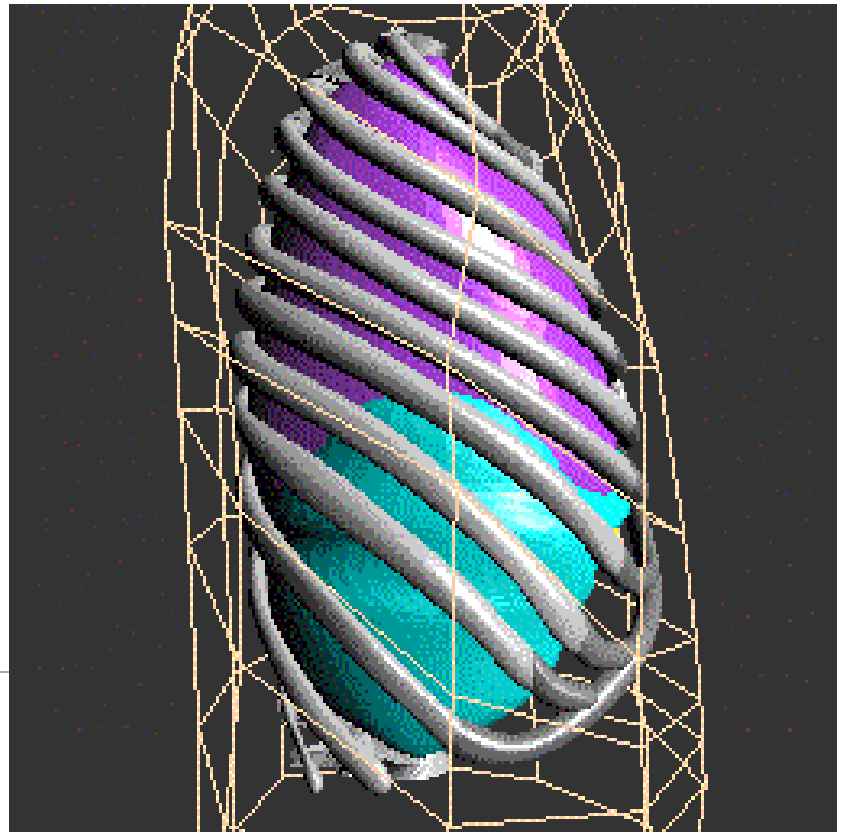
Figure 2–11. Movements of the diaphragm.

Lung-Thorax Unit

- The lungs and thorax are held together by a “pleural linkage”
- At resting position lungs are somewhat expanded and the thorax somewhat compressed.
- Thus, the force of the lungs to collapse is opposed by an equal and opposite force of the thorax.



Lungs in thorax



Muscles of Breathing

- Breathing (changing volume of lungs)
- Posture (core stabilization)
- Movement (bending, turning, etc.)

Muscles of **Inspiration**

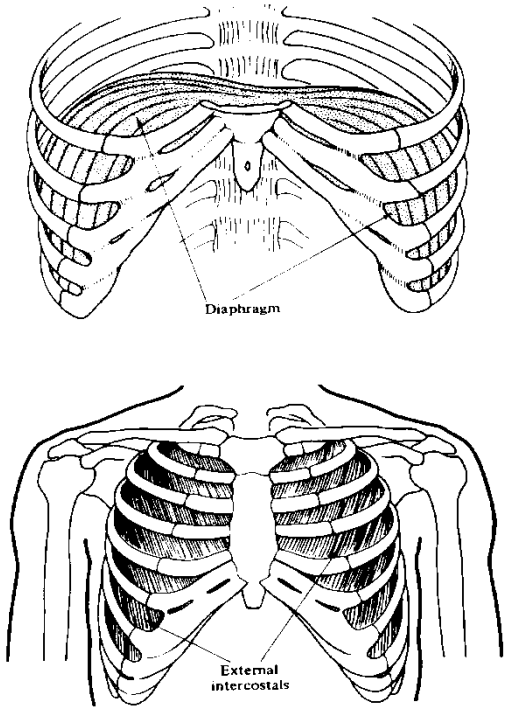


FIGURE 1–8. Muscles of quiet inspiration.

Quiet Tidal Breathing:

- Diaphragm (already discussed)
- External Intercostals ✓

  (11 pair)

Forced Inspiration

Requires the use of the accessory muscles to help increase thoracic volume.

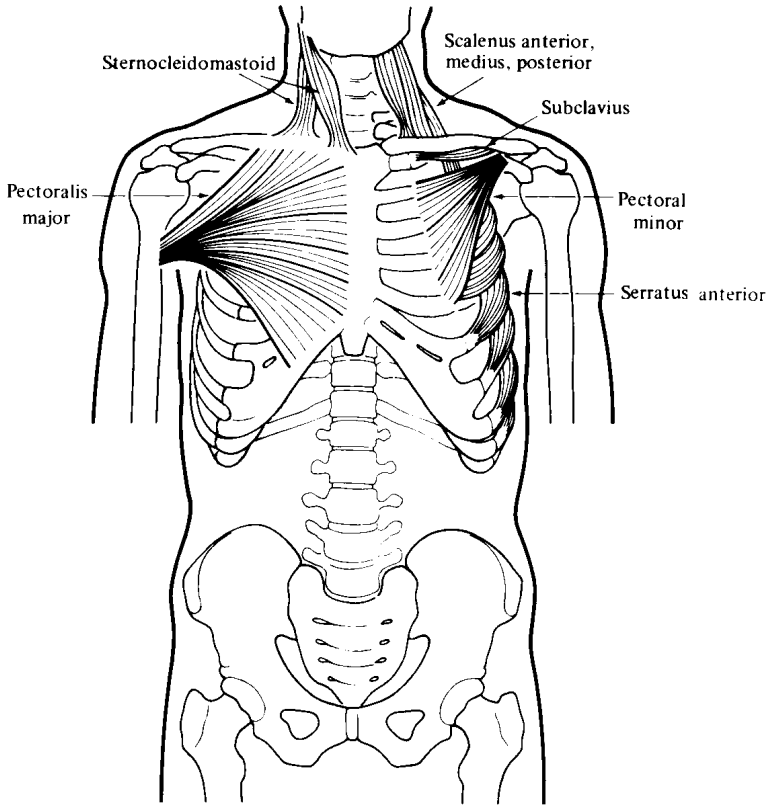


FIGURE 1–9. Accessory muscles of inspiration.

Accessory Muscles of Inhalation: Anterior

- Sternocleidomastoid
- Scalenus - Anterior, Medius, Posterior
- Subclavius
- Pectoralis Major
- Pectoralis Minor
- Serratus Anterior

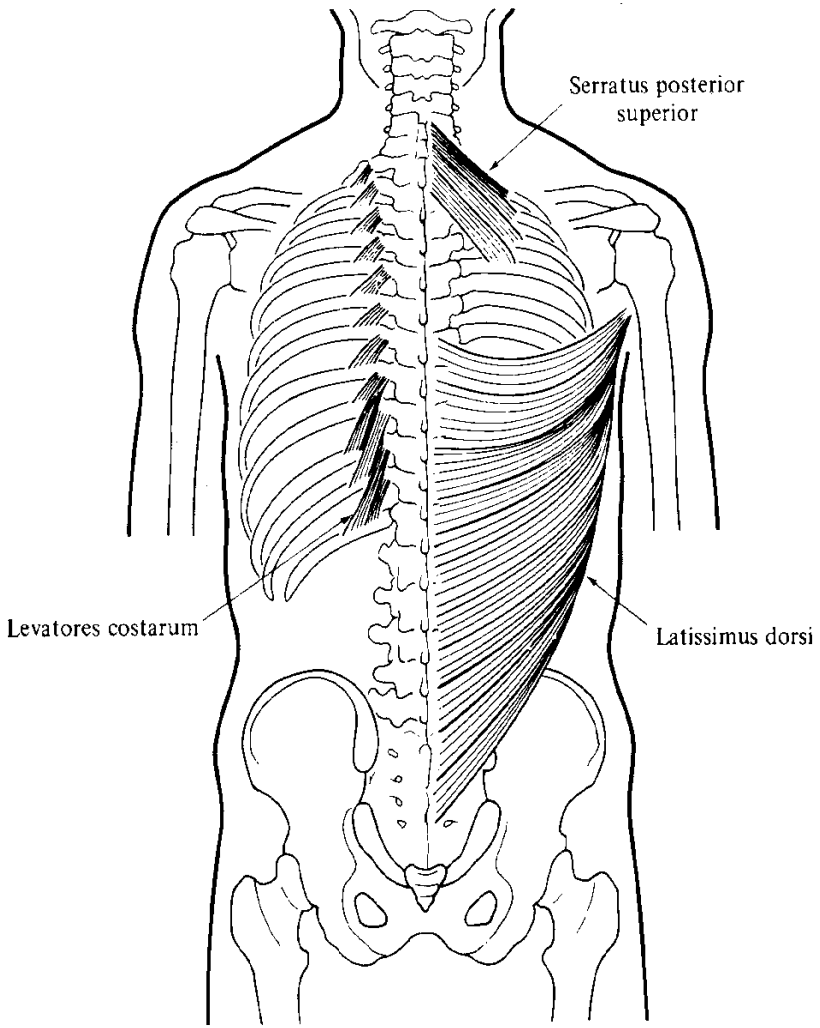


FIGURE 1–10. Accessory muscles of inspiration.

Accessory Muscles of Inhalation: Posterior

- Levatores Costarum
- Serratus Posterior Superior
- Latissimus Dorsi

Expiration: Passive

.. achieved through passive forces and does not require muscular effort.

Forced (Active) Expiration:

Uses muscular effort

Muscles Involved in Expiration
2 Important Functions:

To lower the ribs or sternum or both, decreasing the antero-posterior and transverse dimensions.

To raise abdominal pressure and force the diaphragm upward, decreasing the vertical dimensions of the thorax.

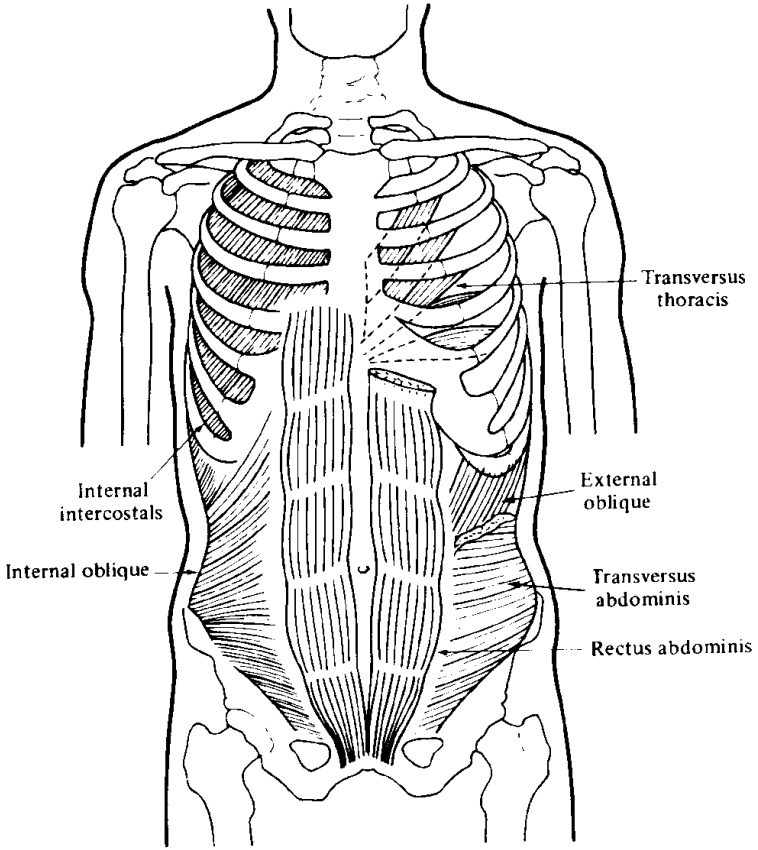


FIGURE 1–11. Muscles of expiration.

Muscles of Forced Expiration: Anterior

- Internal Intercostals
- Transverse Thoracis
- Internal Oblique
- External Oblique
- Transverse Abdominis
- Rectus Abdominis

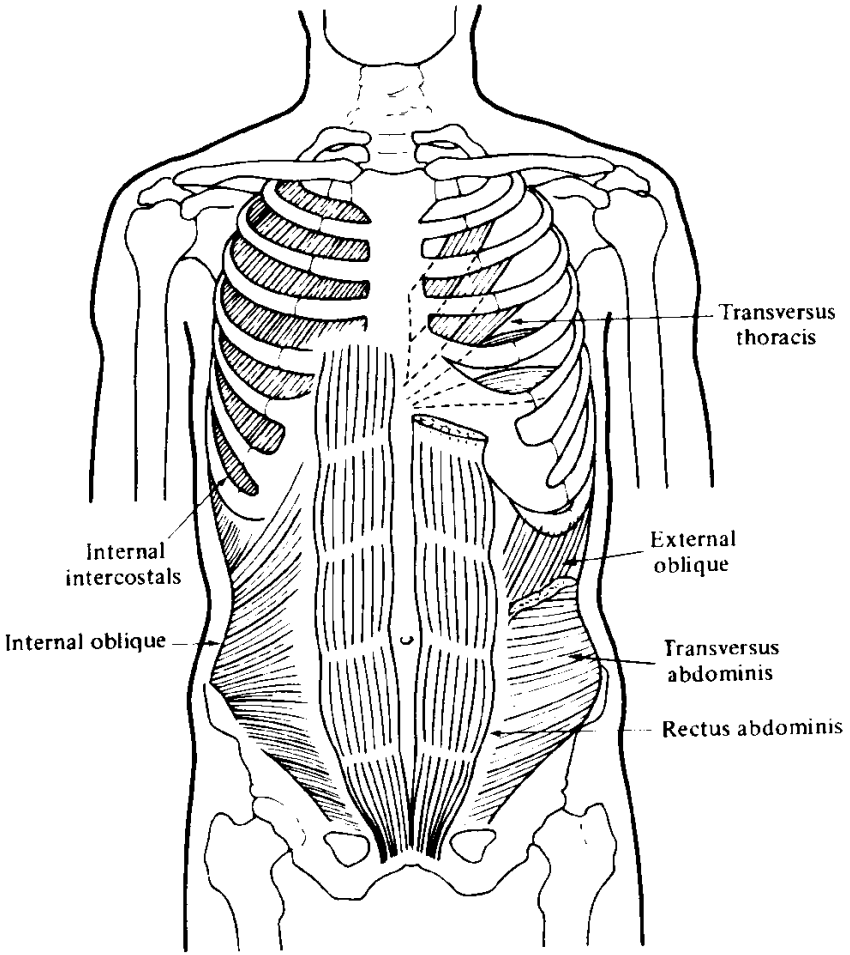


FIGURE 1–11. Muscles of expiration.

Muscles of Forced Expiration: Posterior

- Subcostals
- Serratus Posterior Inferior
- Quadratus Lumborum

Three related concepts

1. Breathing: mechanical motion resulting in forces and a rate of change of displacement
   Diaphragm contracts-pressure changes-gas moves

2. Ventilation: movement of gas to & from lungs

3. Respiration: gas exchange
   Three levels -- external, internal ,cellular

Respiratory Cycle

Adults complete 12 to 18 cycles (one inspiration and one expiration) per minute in tidal breathing

Around every 4-5 sec

Note the SPEECH breath can be quite different, with very long expirations

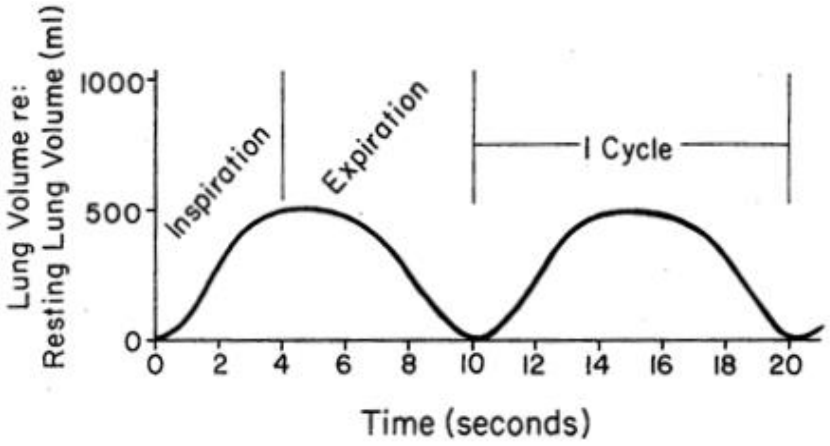
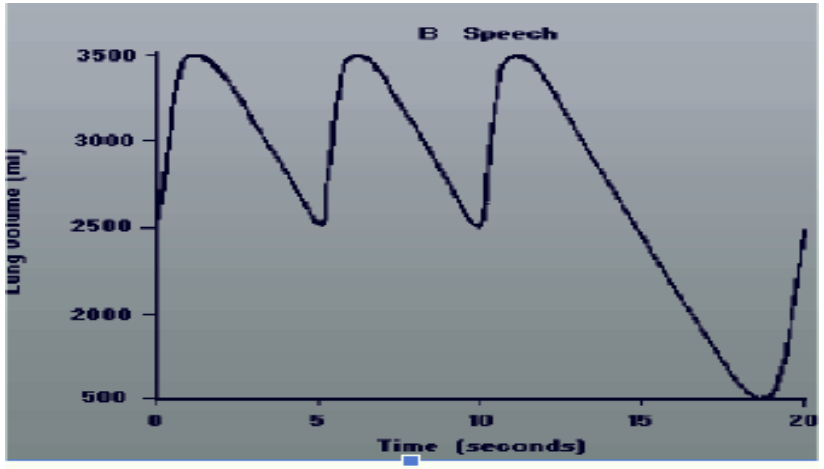


FIGURE 4–4. Volume display of two cycles of quiet respiration.

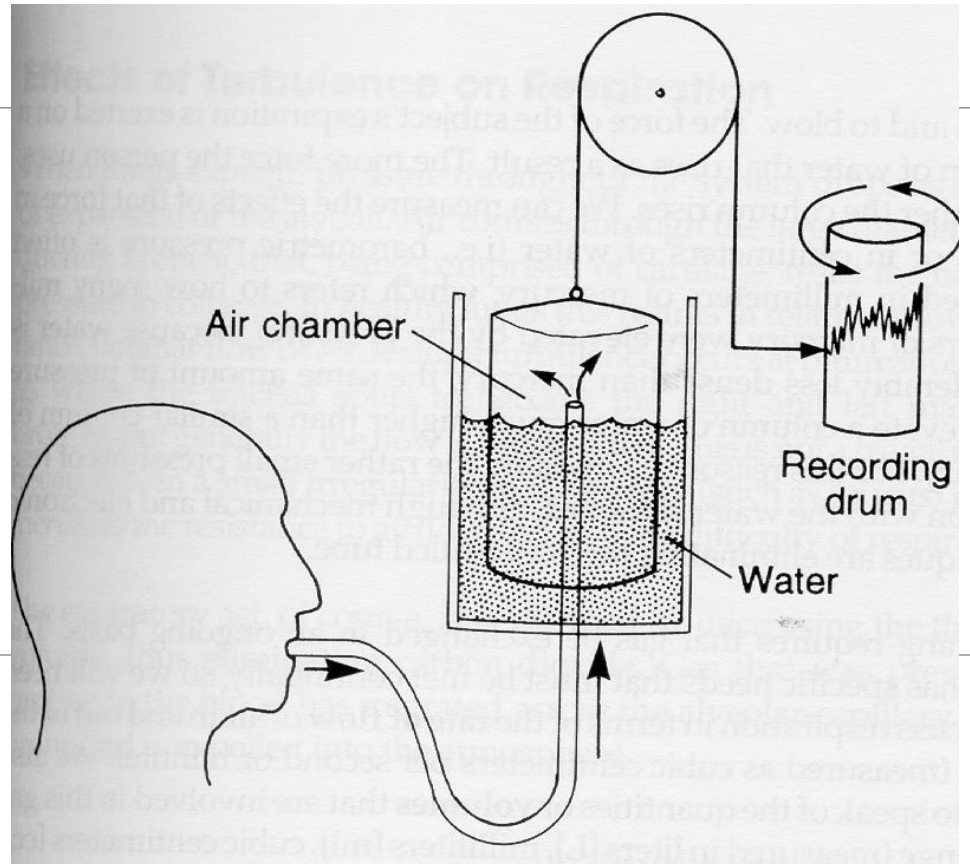


Lung Volumes & Capacities

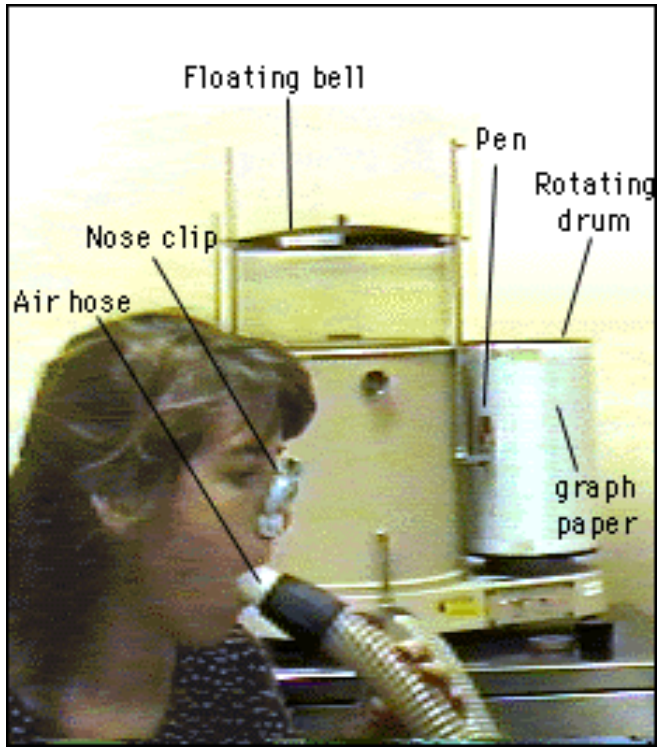
Lung volumes refers to the amount of air each compartment can hold.

Capacities refers to combinations of lung volumes that express physiological units.

Wet Spirometer



Spirometry – continued



[How to take a lung function test]

Spirometry - limitations

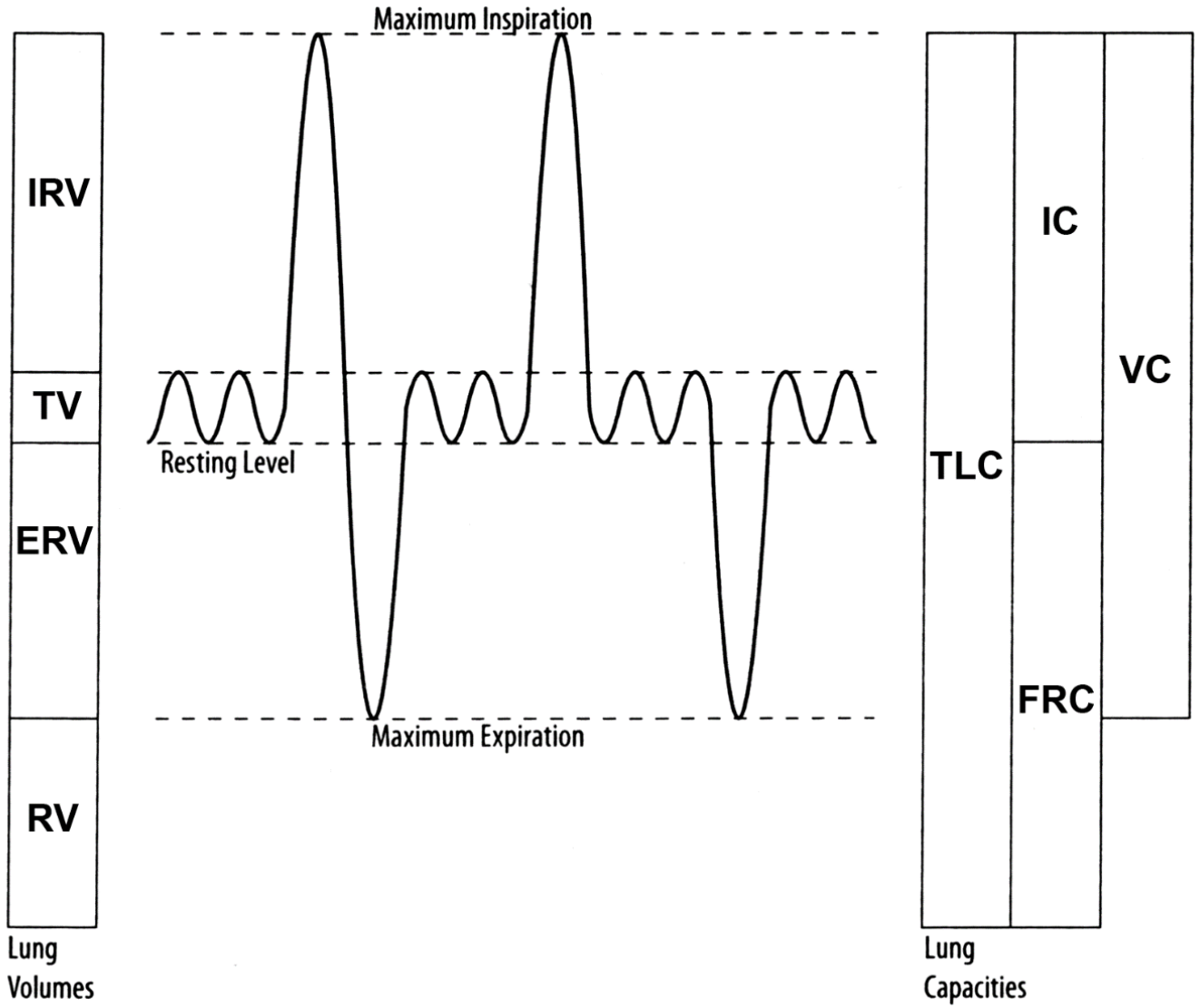
- Can NOT determine absolute lung volumes, because it cannot measure the amount of air in the lung (only the amount entering or leaving).

- Thus, info about functional residual capacity (and volumes computed from FRC*), must be computed via different means, such as body plethysmography or gas dilution.

* NOTE: FRC includes RV (residual volume)

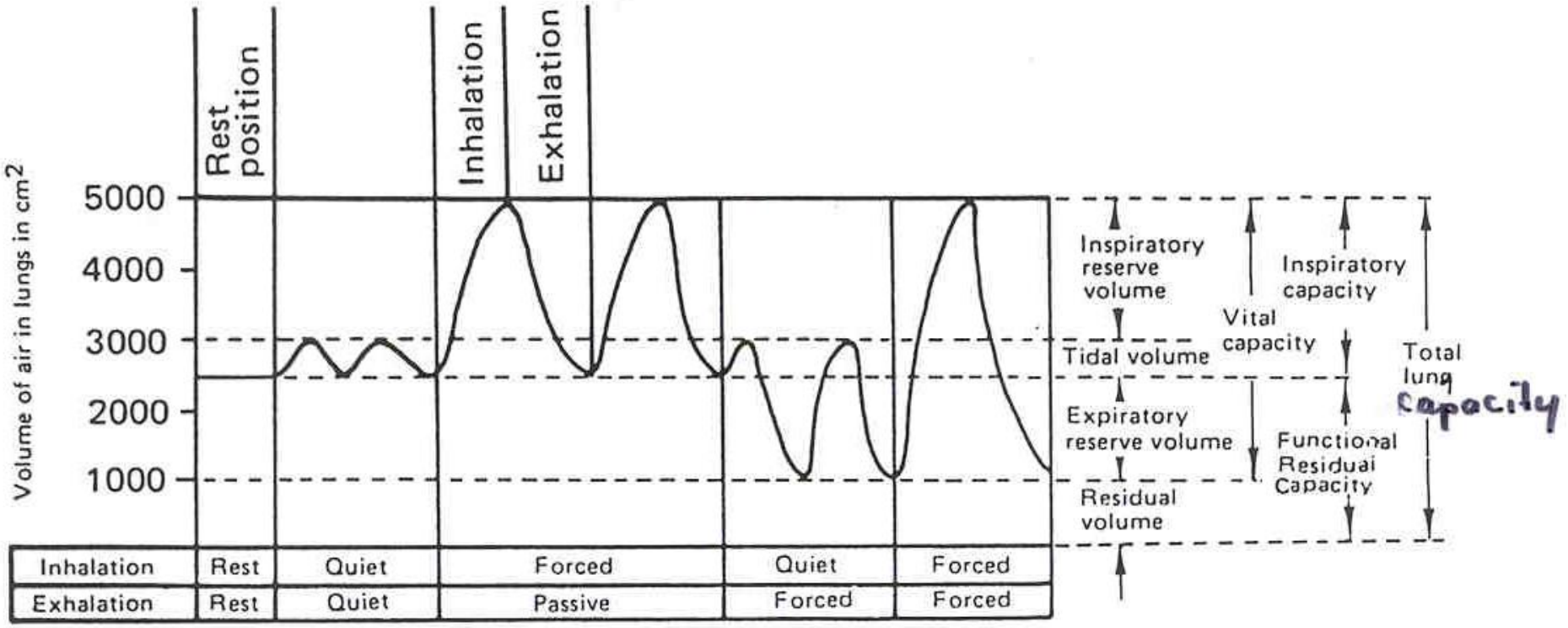
Lung Volumes & Capacities

✓Informative video



From *Evaluation and Management of Speech Breathing Disorders: Principles and Methods* (p. 36), by T.J. Hixon and J.D. Hoit, 2005, Tucson, AZ: Reddington Brown.

Pulmonary subdivisions

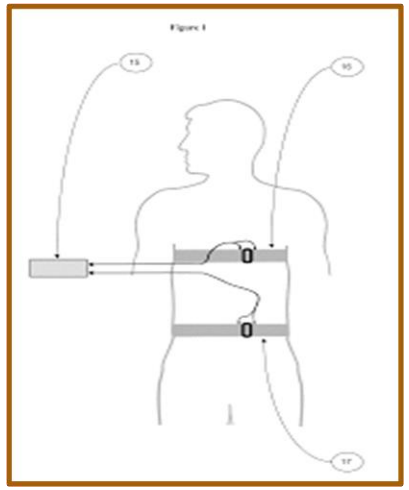


Plethysmography

Means of obtaining absolute volume of air within the lungs (TLC)

“Whole body” – uses large cannister

Respiratory inductive type – uses chest and/or abdomen sensors



Capacities & Age

- Increase from infancy to puberty
- Reach adult values around age 16
- Decrease with advanced age

Lung Volumes and Vital Capacity

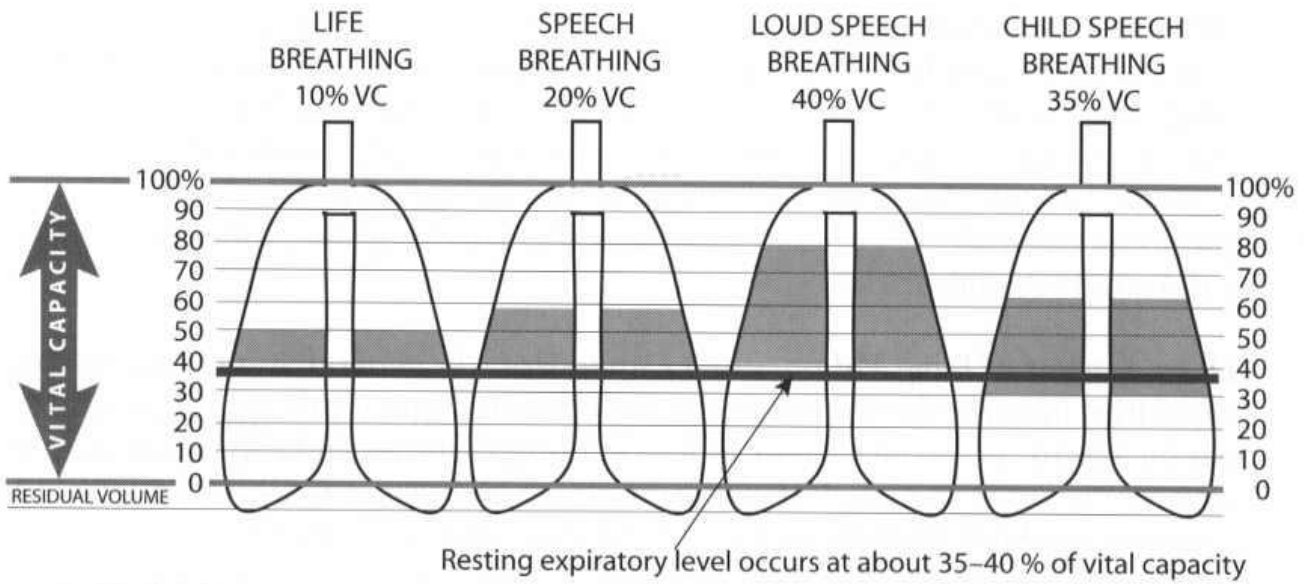
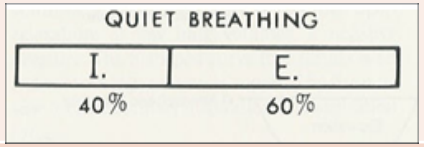
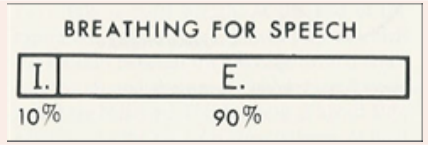


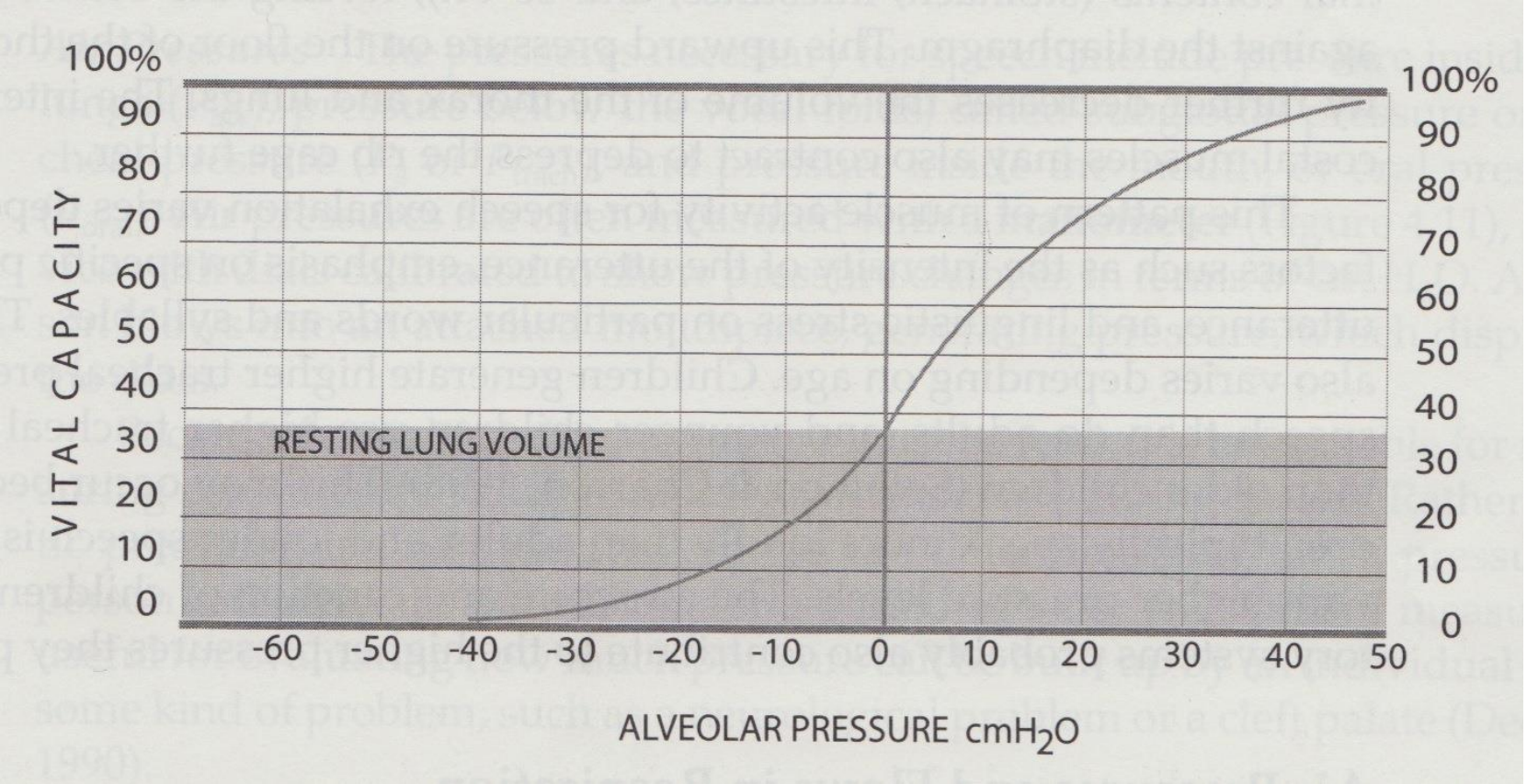
FIGURE 4.9

Schematic of Lung Volume as a Percent of Vital Capacity

5 Changes for Speech Breathing

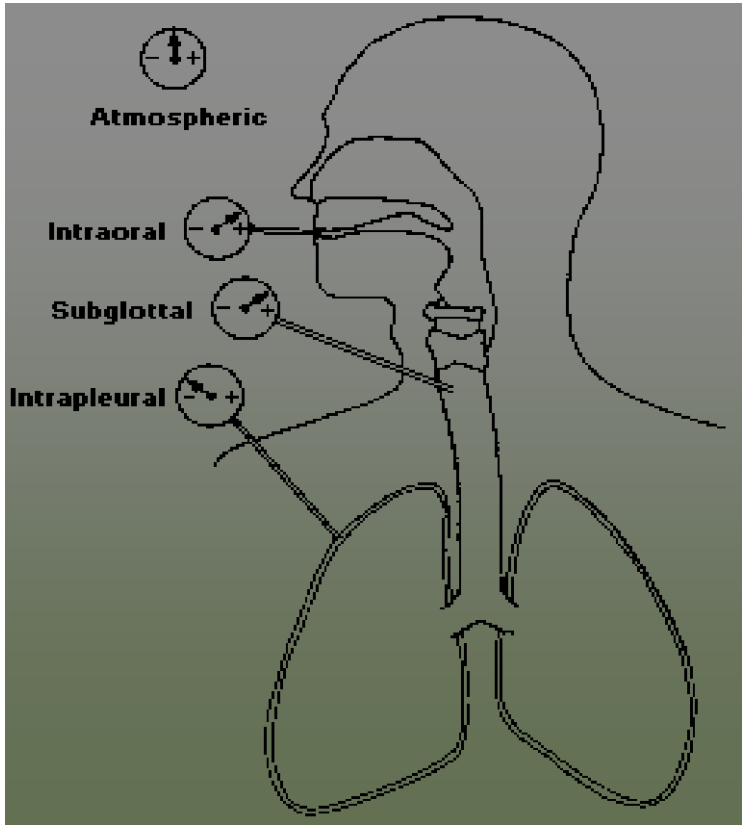
		Everyday →	SPEECH
1	"Location, location, location"		
2	Ratio of inhalation vs. exhalation time		
3	Air volume moved	10% VC	~ 20% VC
4	Exhalation muscle activity	Passive	Active – checking to control recoil
5	Chest wall	Abdomen displaced outward relative to ribcage	Abdomen displaced inward

Relaxation Pressures



See Relaxation_pressure_curve.ppt for more info

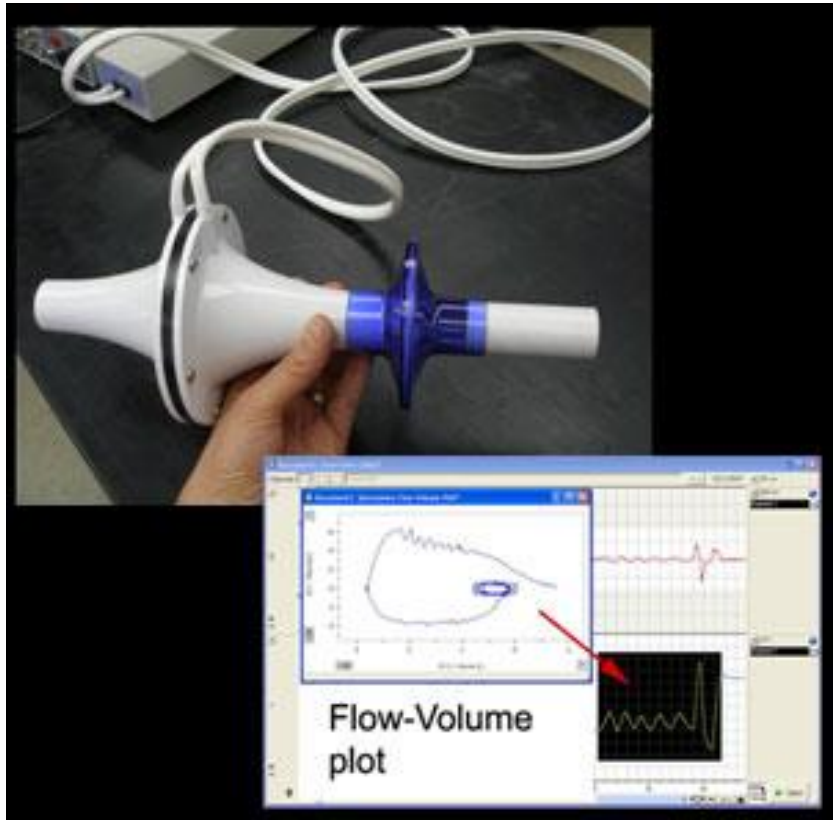
Pressures



(Review from chapter #1 ☺)

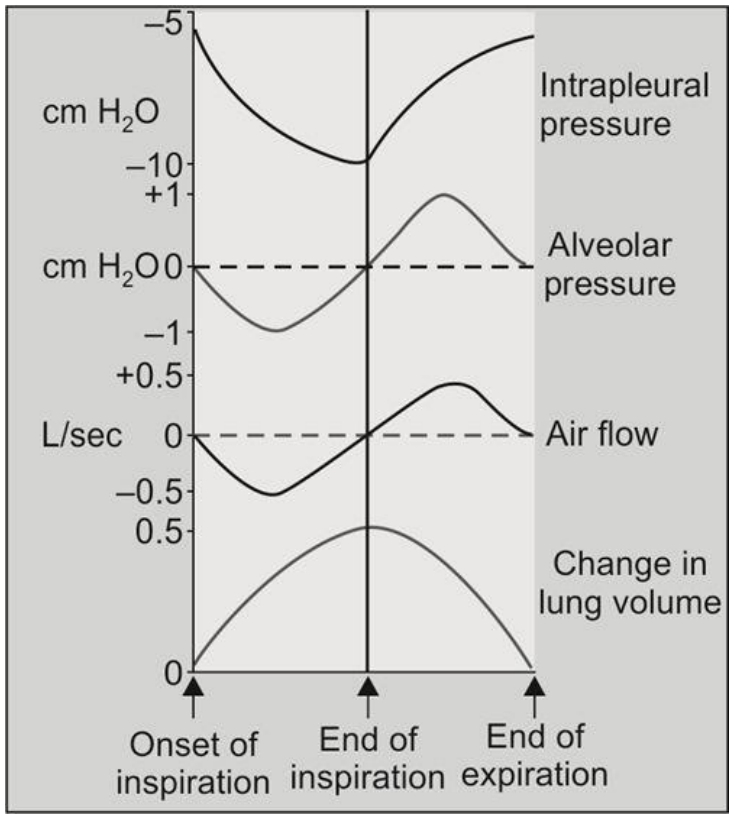
Measurement of Airflow

$$\text{Airflow} = \frac{\text{Pressure gradient}}{\text{Airways resistance}}$$



Pneumotachograph

Air Flow & Alveolar Pressure in Quiet Breathing



At transition from inspiration to expiration (and expiration → inspiration) the pressure inside lungs = Atmospheric pressure

Metabolic (respiratory) Demands

- Hypoventilation (under-breathing): excess of CO_2 (dizziness, blurred vision, numbness & tingling), e.g., in sleep apnea

- Hyperventilation (over breathing): too little CO_2 (impaired cellular respiration, tissue damage, death), “panic attack”

Effects of Posture on Speech

- In supine position, the ability to completely inflate the lungs is affected.

- The resting lung volume is reduced from about 38% VC → 20%

Effects of age on speech

Huber, J. (2008) Effects of utterance length and vocal loudness on speech breathing in older adults. *Respiratory Physiology & Neurobiology, 164*, 323-330.

- Older adults → shorter utterances and showed different adjustments for loud speech
- Reduced respiratory reserve affects speech breathing patterns in typical aging
- Due to decreased pulmonary elastic recoil and respiratory muscle strength

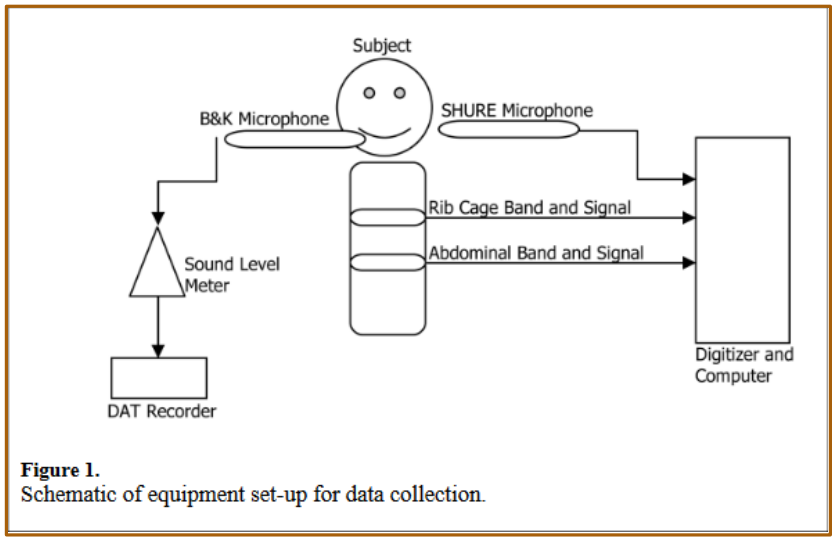


Figure 1.
Schematic of equipment set-up for data collection.

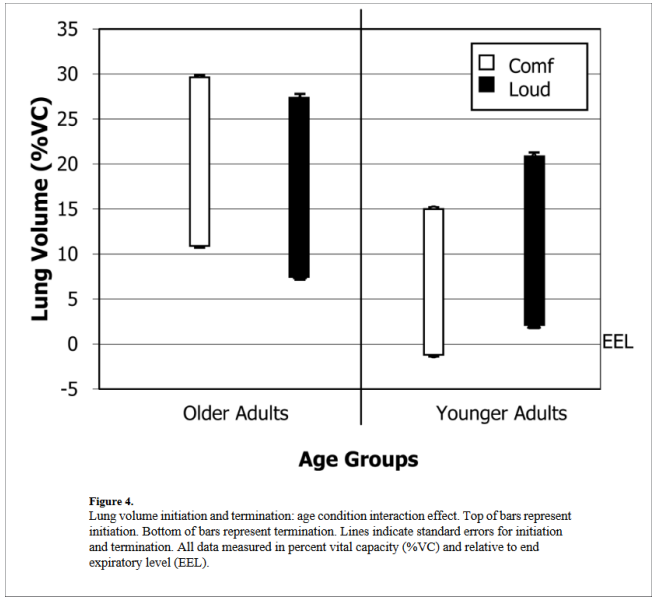


Figure 4.
Lung volume initiation and termination: age condition interaction effect. Top of bars represent initiation. Bottom of bars represent termination. Lines indicate standard errors for initiation and termination. All data measured in percent vital capacity (%VC) and relative to end expiratory level (EEL).

Clinical Applications (Chap 3)

Invasive vs. Noninvasive Ventilation

Invasive

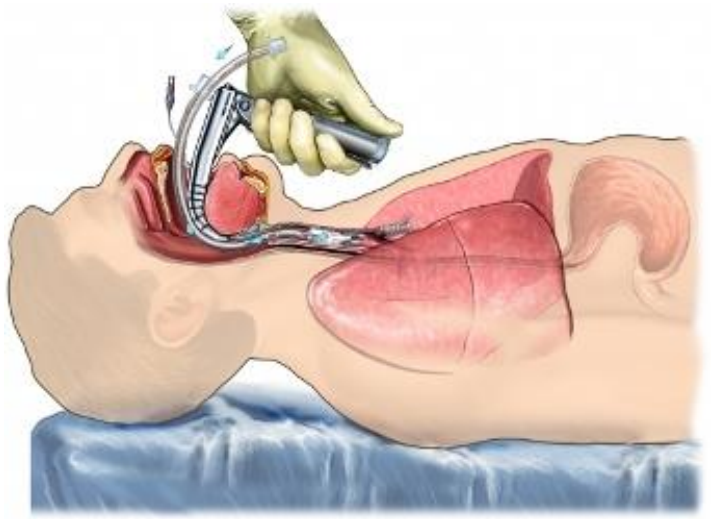
- Intubation
- Tracheostomy
- Mechanical Ventilation

Noninvasive

- CPAP

Endotracheal Intubation

- An endotracheal tube may be used briefly during general anesthesia for surgery, but may be in place for much longer in cases of respiratory failure or neurological injury.
- Can injure posterior parts of the vocal folds.
- When severe, → breathy-pressed phonation



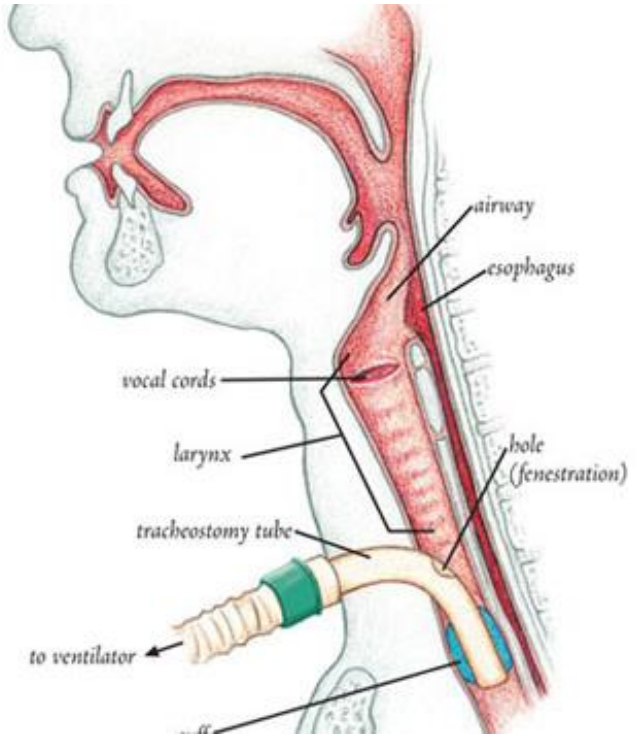
Procedure demonstrated in this video

Tracheostomy - purpose

- Assure a patent airway
- Protect the lungs from potential threats (obstruction)
- Allow easily removal of secretions from trachea and lower airway
- Permit long-term ventilatory support

‘Trach’ placement

- Usually performed at bedside in ICU- sometimes in the OR
- Small incision made through the 2nd, 3rd, and 4th tracheal rings
- Inserted below the level of the vocal folds



Tracheostomy - videos

- Surgery animation (1 minute)
- Clinical complications, including speech and language delays
- Respiration and voice exercises with a Passy-Muir valve

Occasional complications with “trach” tubes

- Difficulty speaking at first
- Collection of mucus at site
- Uncomfortable feeling, re-adjustment

Mechanical ventilation

GOALS:

- Relieve
- Rest
- Decrease work
- Ventilation
- Oxygenation

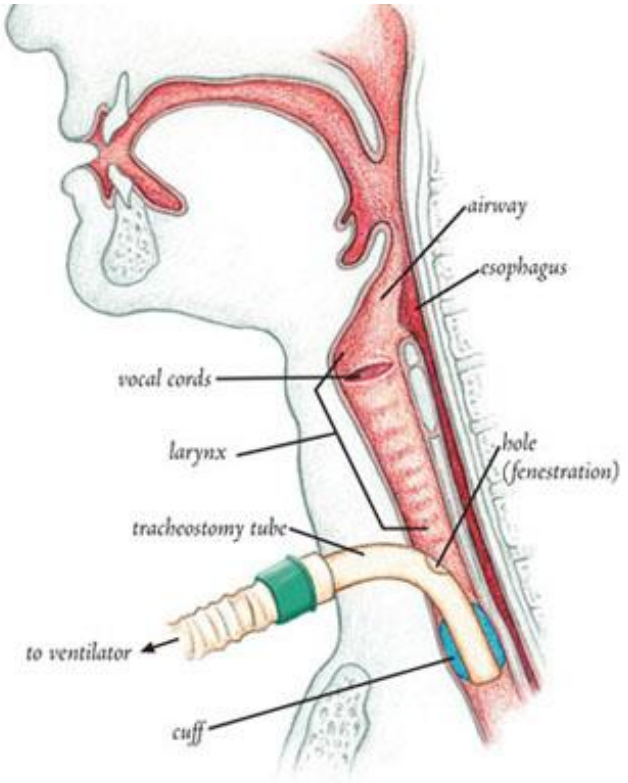
Mechanical ventilator

- Automatic mechanical device

- Providing all or part of the work to move gas into and out of the lungs

Mechanical Ventilation

- Air pumped in mechanically
- Big increase in P_{trach}



Noninvasive Ventilation

- Delivers positive pressure to airway via tight fitting nasal or full facial mask
- Reduces patient's work of breathing
- Continuous Positive Airway Pressure (CPAP)

"A CPAP confessional…."

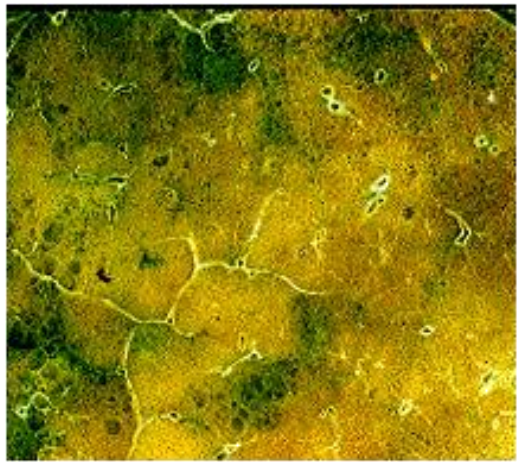
Respiratory problems

- **Obstructive** - restricts expiration: emphysema, asthma, chronic bronchitis, cystic fibrosis
- **Restrictive** - restricts lung inflation, thus - obesity, myesthenia gravis, pulmonary fibrosis
- **Central** – caused by neurological dysfunction in brain; can cause hyper- or hypo-ventilation

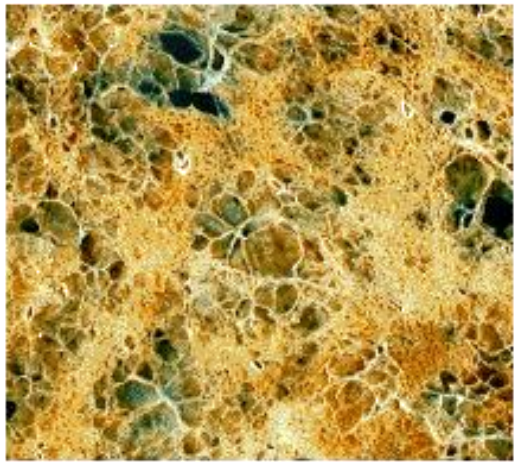
Chronic Obstructive Pulmonary Disease (COPD)

- Group of lung diseases
- *Expiratory* limitation or obstruction
- Examples:
  - Emphysema
  - Chronic bronchitis
  - Cystic fibrosis

Obstructive lung disease example: Emphysema



Normal Lung - Gross



Emphysemic Lung - Gross

- Dilation of the alveolar spaces and destruction of the alveolar walls.
- Much of the elastic recoil of the lung is also lost; a chronically over-inflated lung
- High total lung capacity, FRC, and residual volume= compromised expiratory flow

Restrictive lung disease example: Pulmonary fibrosis

67-year-old male with idiopathic pulmonary fibrosis

- Restrictive lung diseases = lung volumes are reduced.
- Reduced total lung capacity, VC and resting lung volume (FRC), but with preserved airflow and normal airway resistance.

Parkinson' Disease

FOUR hallmark symptoms:

1) Tremors of the hands, face and limbs

2) Rigidity (stiffness)

3) Postural instability (reduced balance)

4) Bradykinesia (slow movement)

~ 89% of individuals with PD will develop speech and swallowing disorders

Parkinson's Disease - Respiration

- Decreased respiratory support
- Different chest wall shape than normal
- Reduced movement of rib cage and more abdominal displacement (thus, reduced VC in some)
- Often cannot build up enough P_{oral}
- This in turn may cause problems with speech, especially certain sounds (e.g., fricatives)

Respiratory strategies?

- *Teach to speak in short phrases*
- *Breath in and out as much and as forcefully as possible and for as long as possible*
- *Take deep breaths frequently*
- *Speak at the beginning of the exhalation without wasting breath and sustaining vowels as long as possible*

(-Ramig, 2005)

LSVT

- Lee Silverman Voice Therapy
- An example of a current methodology - well documented, “evidence based”
- “Think Loud”
- Emphasizes high phonatory-respiratory effort
- Benefits claimed for other speech subsystems

“Talk with intent”

- Similar therapy

Cerebellar Disease

- Normal TLC, low VC
- Abrupt changes of chest wall/abdomen/rib cage
- "Inspiratory gasps"
- Speech often initiated below normal lung levels

- Treatment: *Instruct to begin on higher lung volumes?*

Cervical Spinal Cord Injury

- Reported to have smaller-than-normal VC, inspiratory capacity, ERV
- Resting tidal volume and breathing rate may be normal
- Begin and end exhalations at larger lung volumes
- Fewer normal syllables per breath

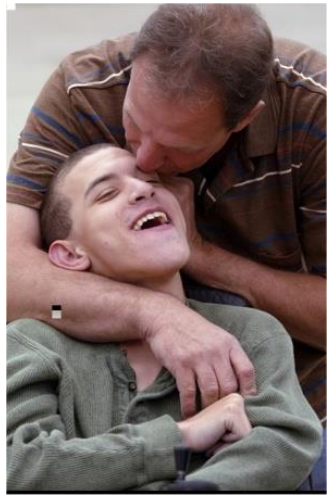
- Treatment: *Work on chest wall development, body positioning, muscle strengthening, and coordination exercises?*

Cerebral Palsy (CP)

- Spastic – shallow inhalations; forced uncontrolled exhalations (MOST COMMON)
- Athetoid – irregular breathing; bursts of air during inhalation/exhalation
- Ataxic – irregular rate, rhythm, and tidal breathing
- Mixed – spastic and athetoid

Cerebral Palsy (CP) – continued

- All parameters of respiratory function may be affected
- Shape of chest wall is key variable



CP – speech, AAC

- AAC demo
- Tom Rogers – prone 2008
- Tom Rogers – seated, 2010

CP therapy suggestions

- Strengthening muscles of chest wall
- Strengthening respiratory muscles
- Respiratory exercises (inspire deeply and exhale in a slow and controlled manner)
- Improved postural support
- Abdominal trussing

(-Solomon and Charron, 1998)

Neurologic Disease

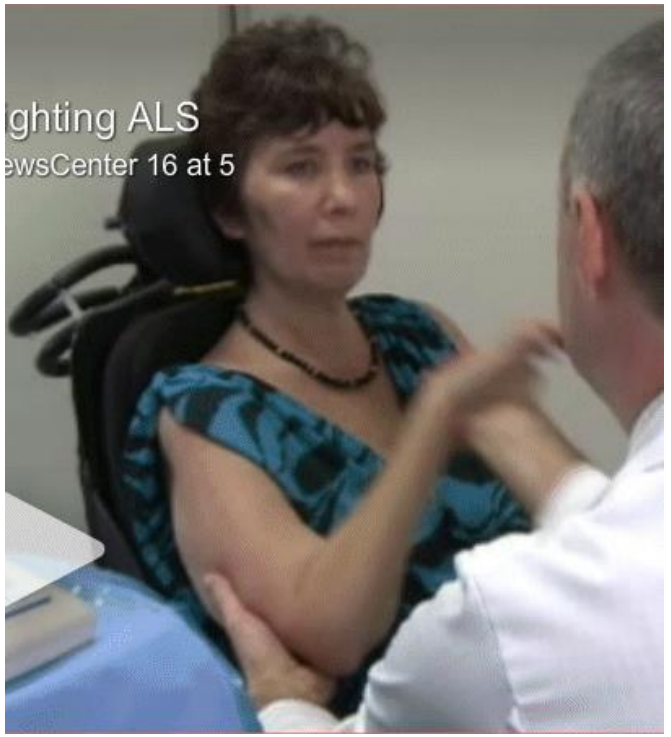
- Amyotrophic Lateral Sclerosis
- Guillian-Barre Syndrome Traumatic Brain Injury
- Dysarthria after football injury
- Hesitant speech requires patience

ALS

- Progressive neurological disorder
- Degenerative neuromuscular disease involving upper motor neurons (cortex) and lower motor neurons in the brainstem & spinal cord
- Patients make decision to undergo tracheotomy and/or mechanical ventilation (for respiratory status)
- Unknown etiology: viral, toxic, & genetic possibilities

ALS –new breakthroughs

- Diaphragmatic pacing system for ALS
- Assessing bulbar (LMN) function (UTD, Harvard Univ.)



ALS- more breakthroughs

NEUDEXTRA (RX)

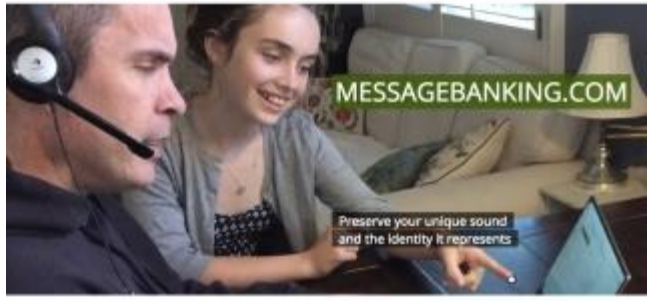
For pseudobulbar affect

(uncontrollable laughter, crying)

Improved speech?

MESSAGEBANKING.COM

Helps patients preserve important messages for their loved ones



TBI

- Often results in dysarthria, primarily of the spastic, ataxic, flaccid, or mixed spastic-ataxic types
- *Combined LSVT and respiration therapy reported to be helpful*
- Improvements in vocal sound production level and sentence intelligibility reported

(-Solomon, McKee, Garcia-Barry, 2001)

“Aerodynamic and respiratory kinematic measures during speech”

* VIDEO

Elaine T. Stathopoulos, State University of New York

Key Terms:

- Rothenberg Mask
- Air Flow
- Air Pressure
- Air Volume
- Pneumotachograph
- U-tube water manometer
- Inverse Filtering
- Wideband Airflow Signal
- Intra-oral pressure
- Oral Airflow
- Glottal Airflow