RESPIRATORY PHYSIOLOGY

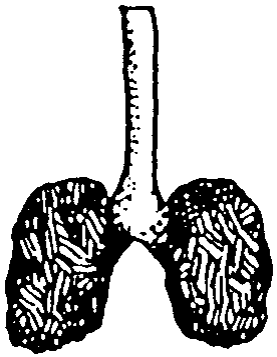
THE MECHANICS OF BREATHING

Objectives

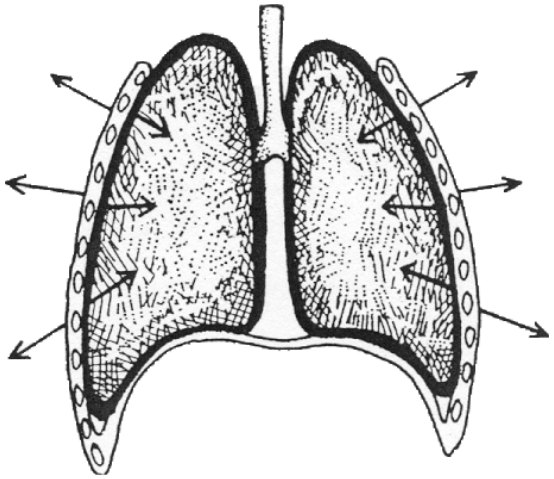
1. Define the two compartments comprising the respiratory system.
2. Describe the elastic recoil properties of the lungs and the chest wall.
3. Define the following pressures; atmospheric, alveolar, intra-pleural & transmural and the units of pressure adopted to quantify them.
4. Describe the relationship between the transmural pressure & the elastic recoil pressure of the lungs.
5. Describe the sequence of changes in muscle contraction, lung volume, intra thoracic pressures and airflow during the course of a normal quiet breath & their relationship to Boyle's Law.
6. List the major muscles of respiration & their motor innervations.
7. Describe the contraction of the respiratory muscles in terms of movement of the chest wall and chest wall dimensions during quiet & forceful breathing.

AS A MECHANICAL STRUCTURE
THE RESPIRATORY SYSTEM

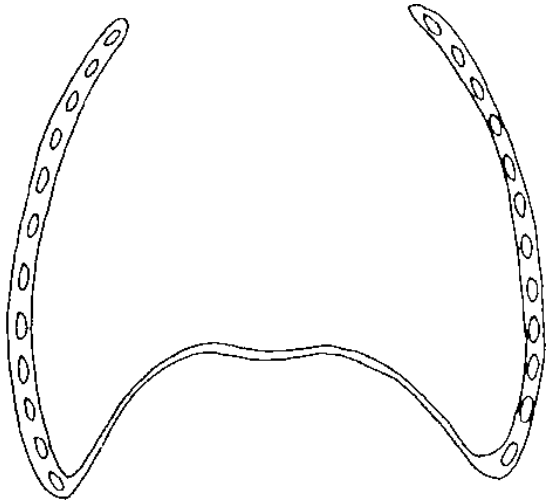
HAS TWO COMPARTMENTS WITH ELASTIC PROPERTIES



THE LUNGS



THE RESPIRATORY SYSTEM



THE CHESTWALL

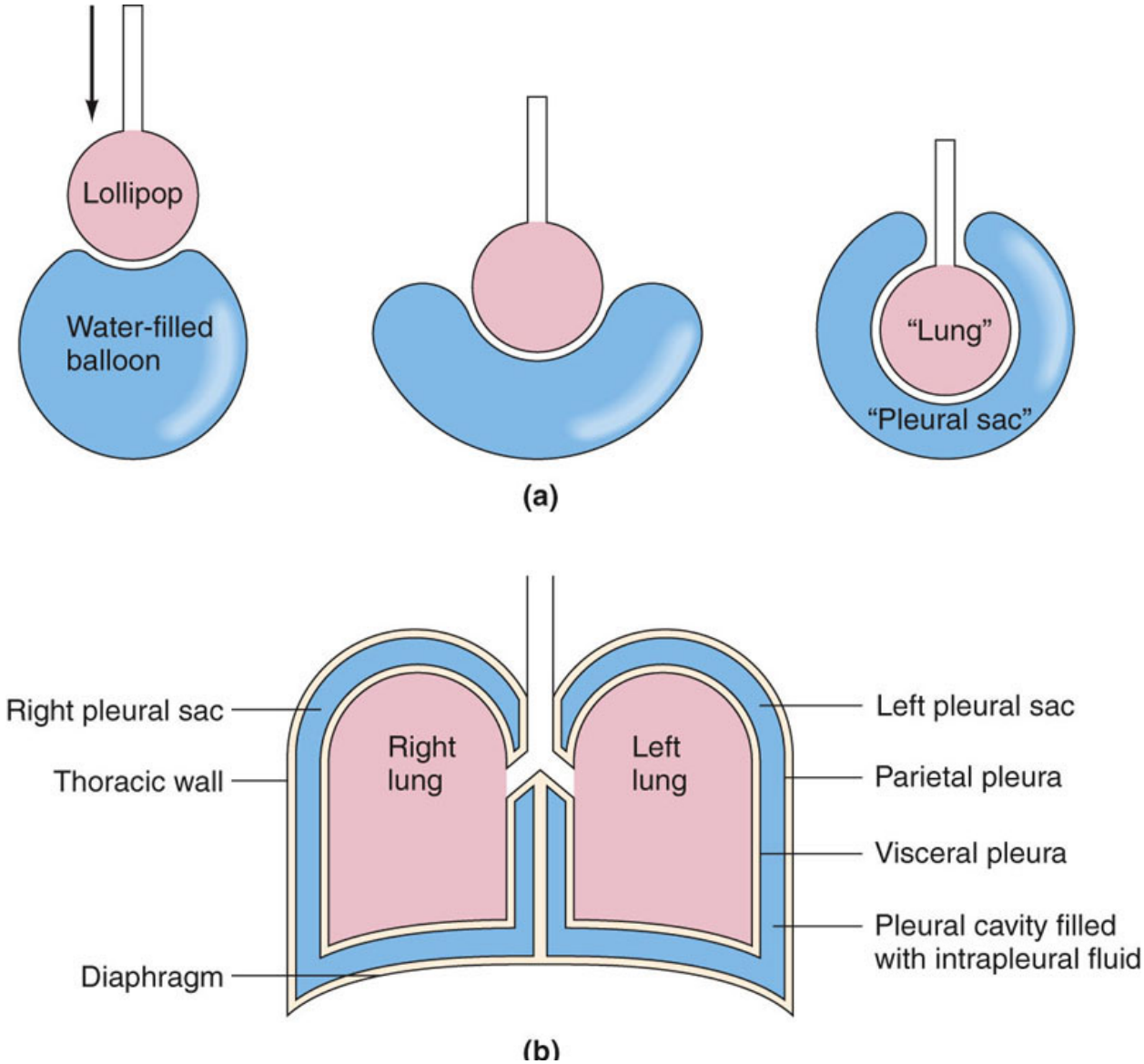
At functional residual capacity, FRC (end of a quiet expiration), the outward recoil of the chest wall is equal in magnitude but opposite in direction to the inward recoil of the lungs

THE PLEURAL CAVITY IS FLUID FILLED
& LIES BETWEEN THE LUNGS & CHEST WALL

Cohesive forces of the pleural fluid:

1. attach the two compartments to each allowing the lungs to inflate & deflate with the movements of the chest wall.

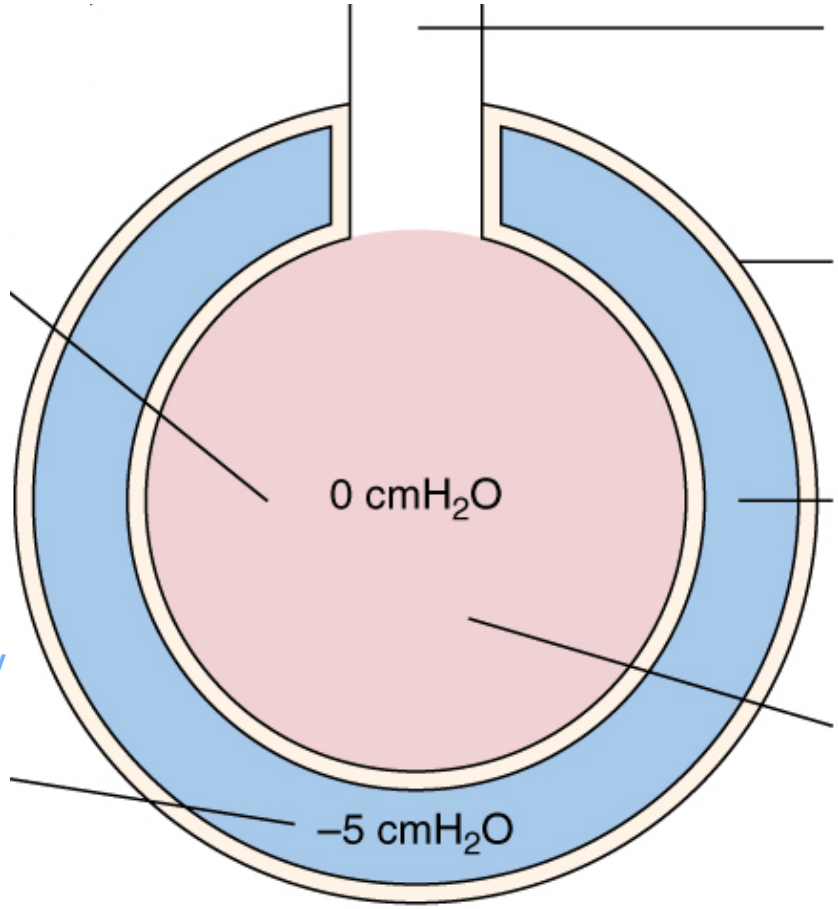
2. reduce friction as the lung tissue glides past the chest wall



IN RESPIRATORY MECHANICS

PRESSURE IS MEASURED IN

CENTIMETERS OF WATER (cm H2O)



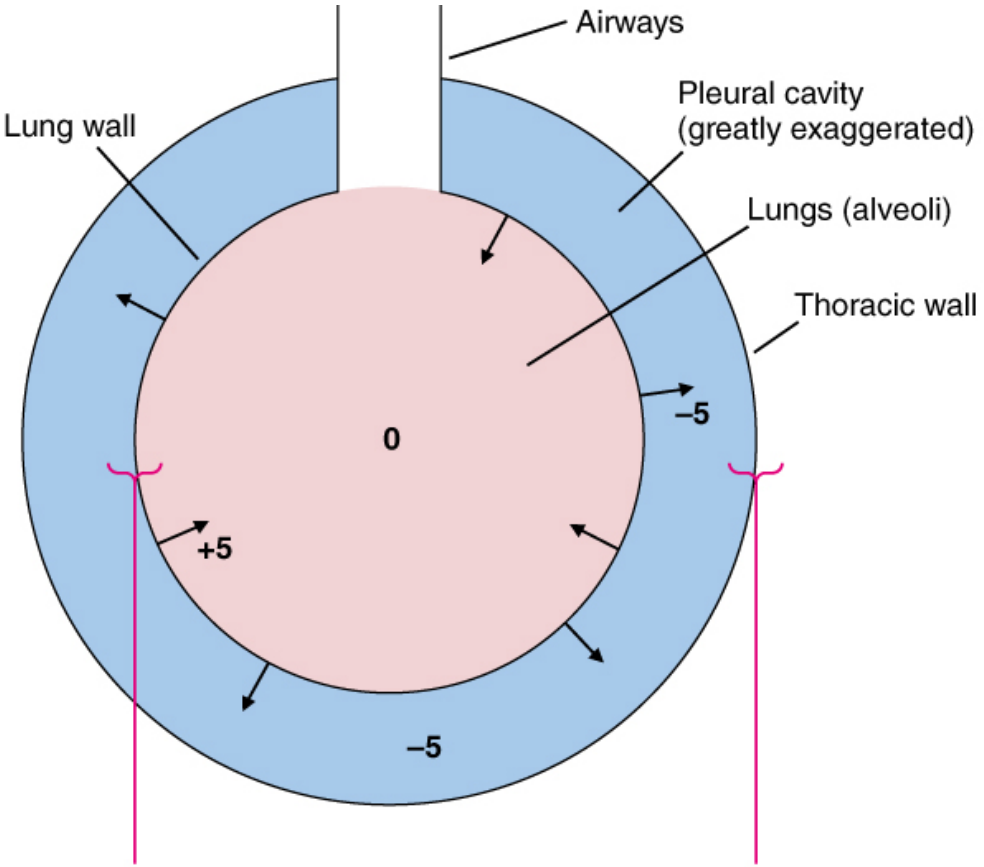
Pressure changes during a quiet breath are small & not easily measurable using mm Hg.

TRANSMURAL PRESSURE IS THE
PRESSURE INSIDE minus OUTSIDE A WALL

Across the lungs there is a 5 cm H_2O transmural (or transpulmonary) pressure (P_{tp}) keeping the airways open against their tendency to recoil inward. A pressure of the same magnitude but in opposite direction P_{tw}, keeps the chest wall from recoiling outwards.

This is at FRC when no air is flowing in or out of the lungs.

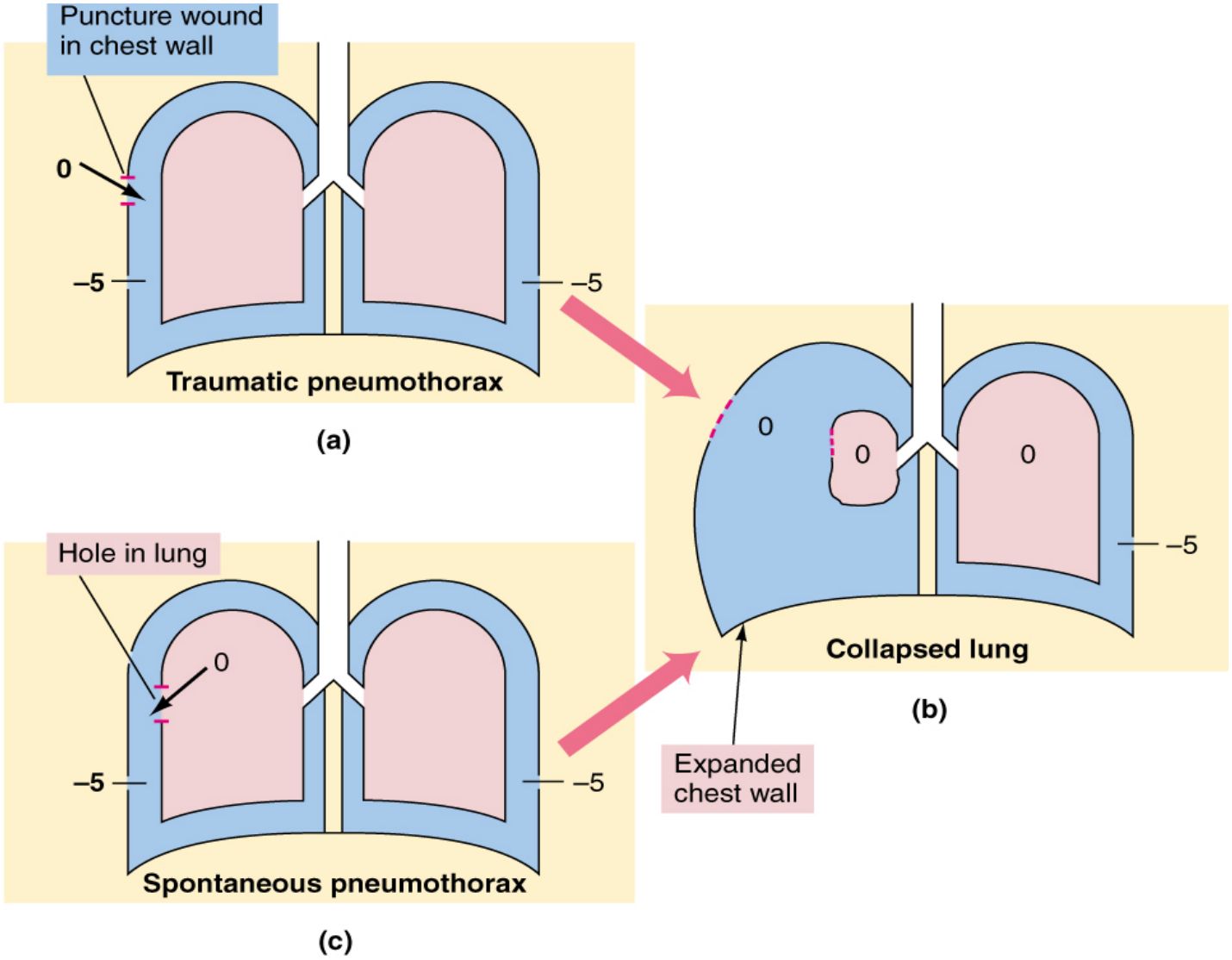
The respiratory system is at rest and its transmural pressure is zero
$P_{rs} = P_A - P_B = 0$



PNEUMOTHORAX

AIR IN THE PLEURAL SPACE

can result from puncture of the lungs/chest wall



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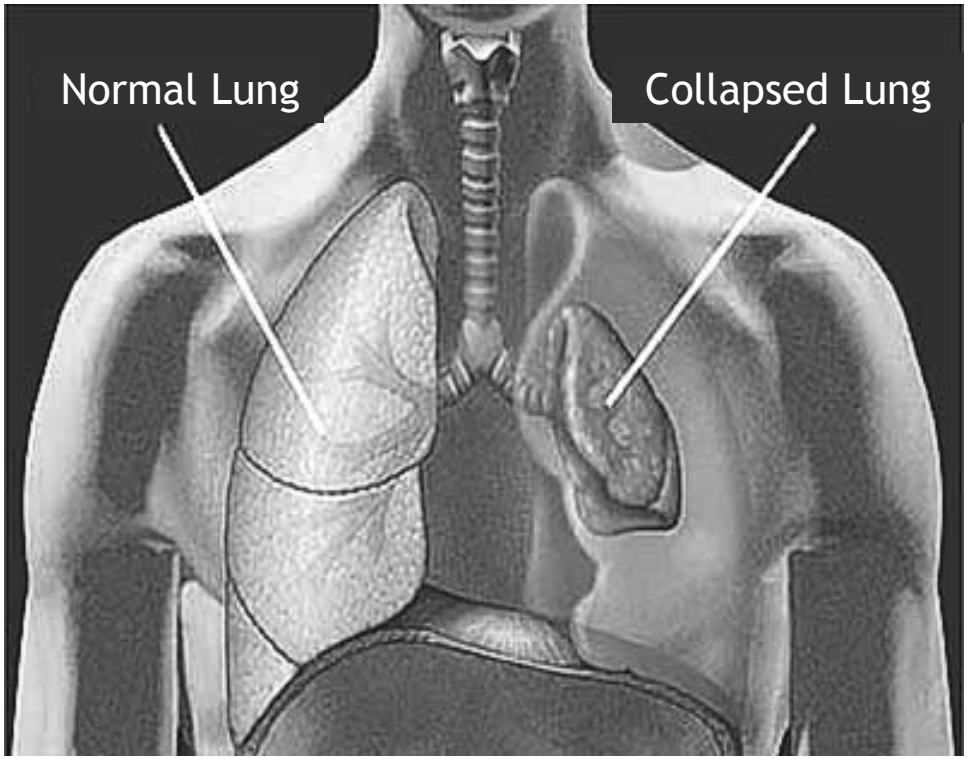


• a pneumothorax can be large or small resulting in complete or partial collapse of the lungs. The pressure outside the lung is elevated relative to the pressure in the airways.

• trauma to the chest wall or the lung lining can also result in hemothorax, blood in the pleural cavity.

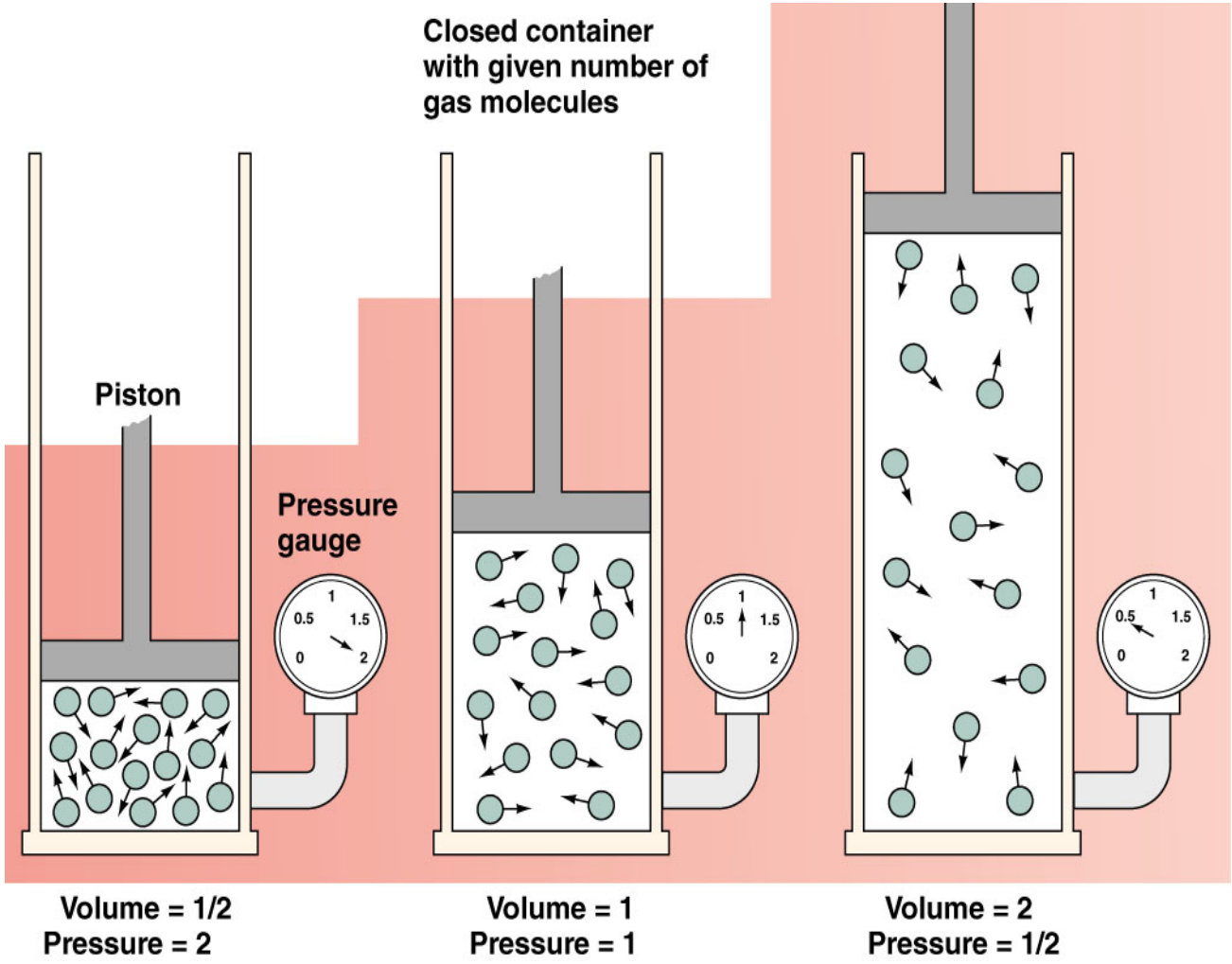
• depending on the degree, these conditions can be life threatening (e.g. tension pneumothorax)

BOYLE'S LAW

THE RELATIONSHIP BETWEEN PRESSURE & VOLUME

Pressure is the force per unit area caused by gas molecules striking walls of a container.

At constant temperature, pressure is related inversely to the volume of the container.



RESPIRATORY PRESSURES DURING A QUIET BREATH

INSPIRATION

1. The inspiratory muscles contract

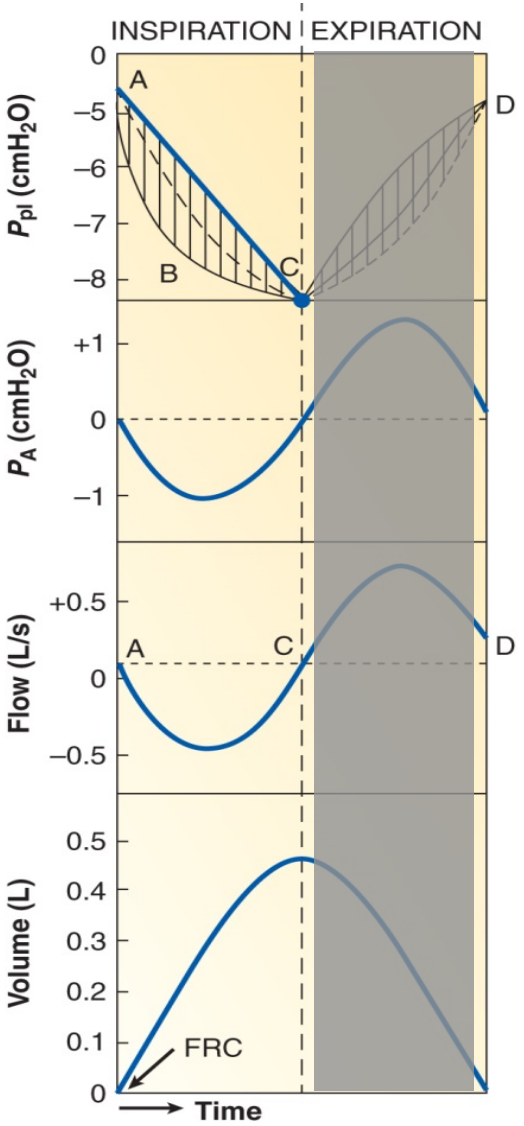
2. The chest wall expands, the following two intra-thoracic pressures ↓

   - P_{pl} (by 3 cm H_2O)
   - P_A (by 1 cm H2O)

leading to an ↑ in transpulmonary pressure (P_A- P_{pl})
↑ing the distending pressure of the lungs

3. air flows into the lungs until $P_A = P_B$

Key Concept: a change in thoracic volume leads to change in intra-thoracic pressures



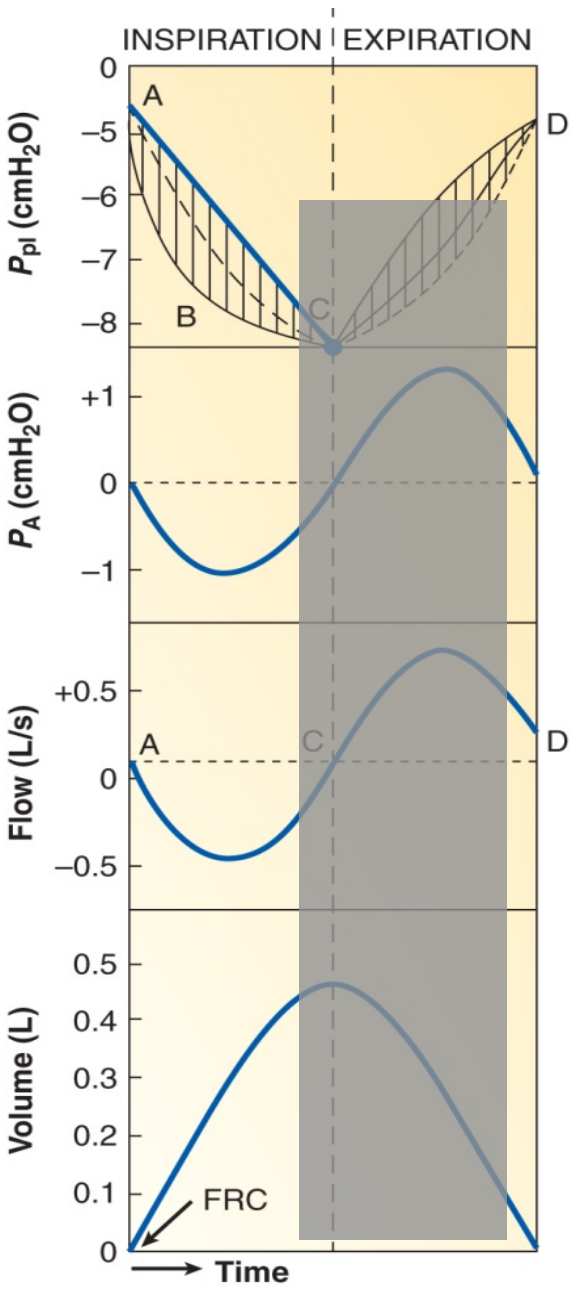
CRITICAL THINKING

Review & reflect

1. What is the driving pressure for flow of air into the lungs?
2. What created this driving pressure?
3. How come alveolar pressure decreases and then swings back up but pleural pressure decreases continuously during inspiration?

Key Concept: to inspire, we create a pressure less than atmosphere;
we are negative pressure breathers!

Dig A Little Deeper (by the end of the lecture series)
The drop in pleural pressure is describe by multiple lines, areas. What are they reflecting?



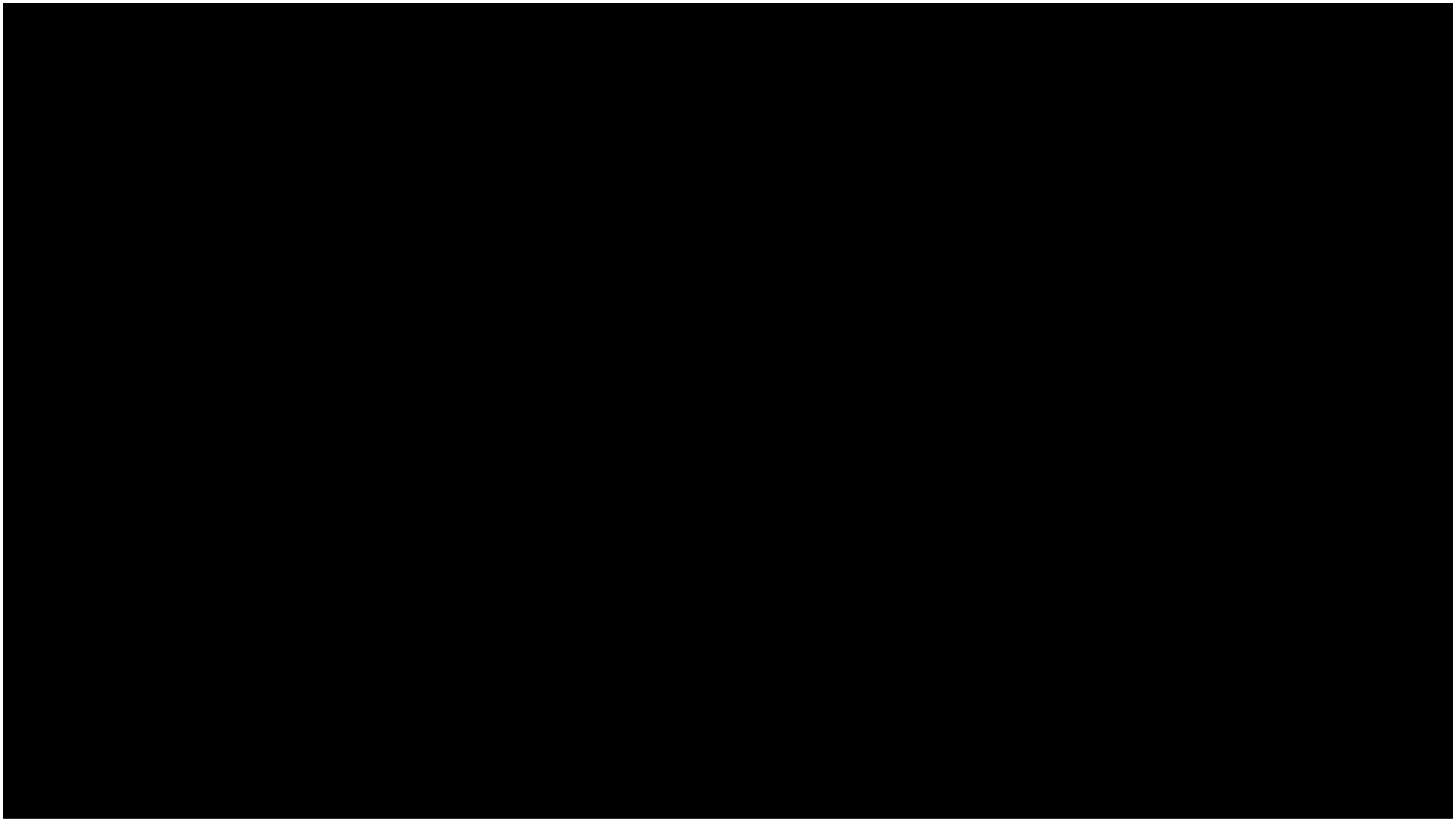
RESPIRATORY MUSCLE PARALYSIS

The Polio Epidemic of the 1940ss & 50s (10-20 million survivors today)

The Iron Lung: A Negative Pressure Breathing Apparatus

Iron lung ward at Rancho Los Amigos Hospital, CA

MARTHA MASON (1937- 1998)- 60 YEARS IN AN IRON LUNG



GLOBAL POLIO ERADICATION INITIATIVE
VACCINATING > 165 MILLION CHILDREN

World Health Organization, UNICEF, Centre of Disease Control (US) & Bill & Melinda Gates Foundation

GLOBAL POLIO ERADICATION INITIATIVE
VACCINATING > 165 MILLION CHILDREN

Endemic: Nigeria, Pakistan & Afghanistan (2012)

World Health Organisation/Global Polio Eradication Initiative

RESPIRATORY PRESSURES DURING A QUIET BREATH

EXPIRATION

1. inspiratory muscles stop contracting

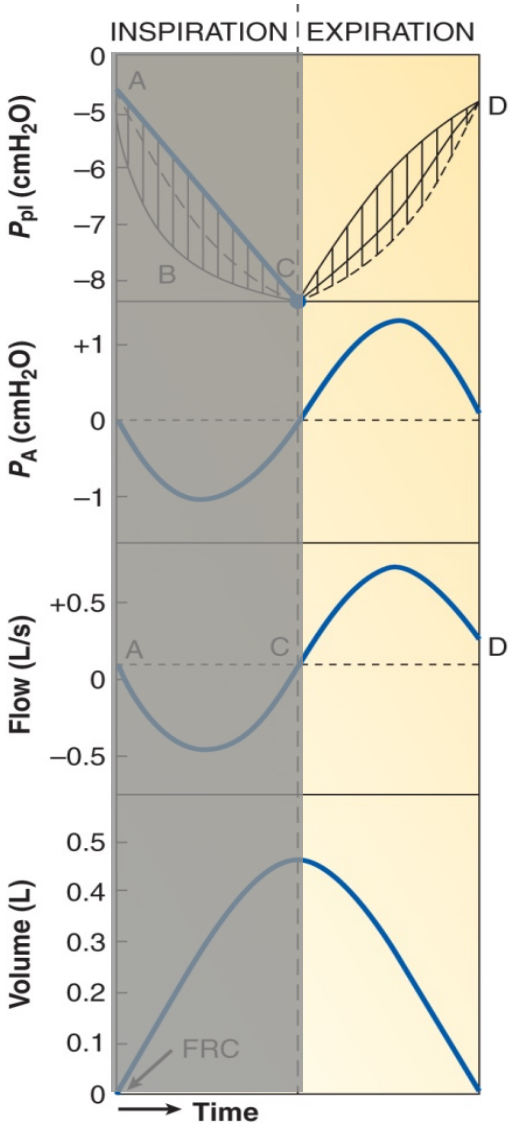
2. the lungs recoil inward (reducing thoracic volume, compressing and) increasing two intra-thoracic pressures:

- pleural pressure (P_{pl}) ↑
- alveolar pressure (P_A) ↑

- transpulmonary pressure ↓

3. air flows out of the lungs until $P_A = P_B$

key concept: Quiet expiration is passive. Recoil of the lungs increases alveolar pressure above atmospheric pressure driving air out of the lungs.



CRITICAL THINKING

review & reflect

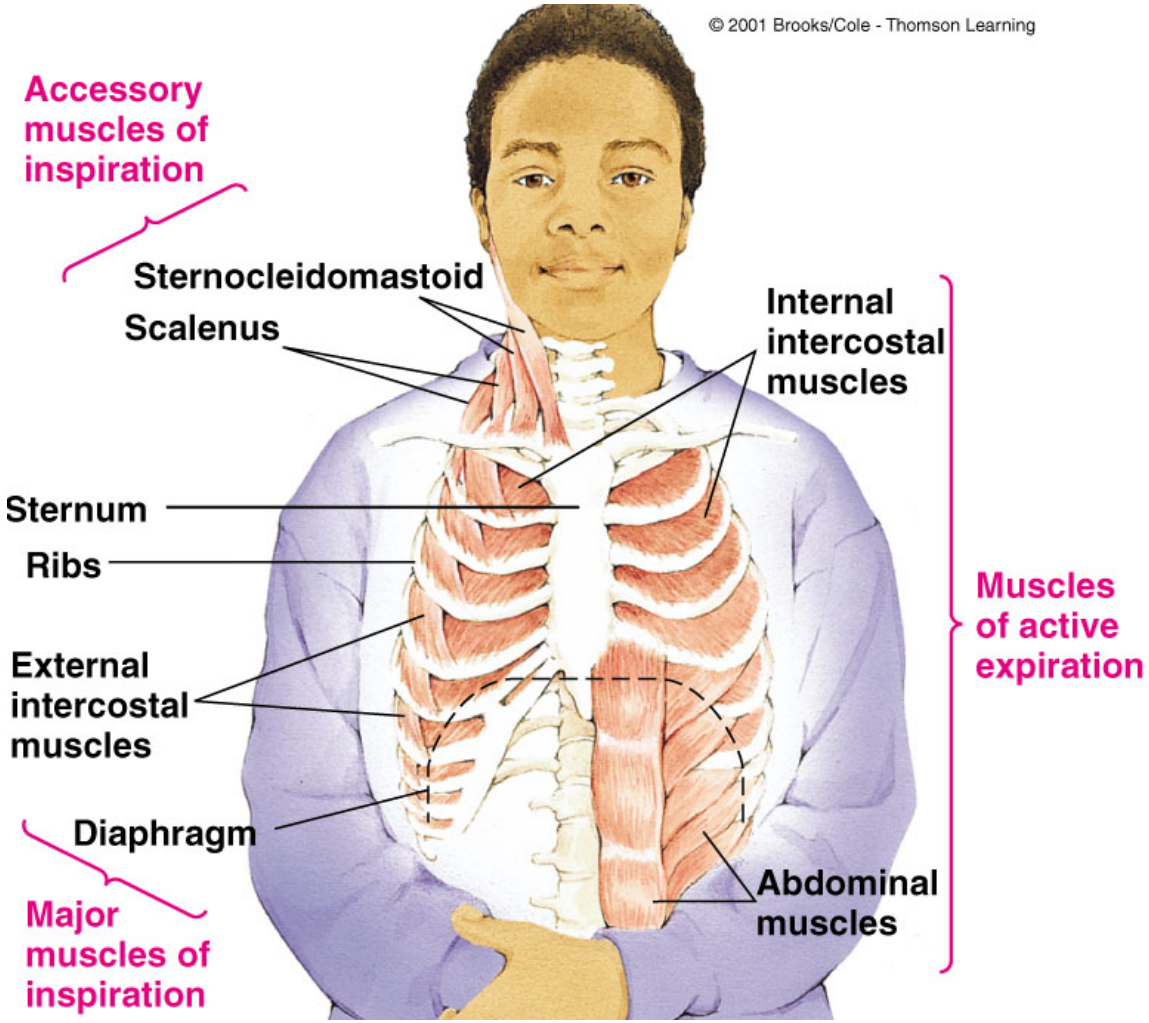
The transpulmonary pressure is always positive during a breath cycle.

1.What does this imply about the state of the lungs? Are they inflated or deflated. Are the lungs ever completely empty of air?

2.What is the relationship between the transpulmonary pressure and the elastic recoil pressure of the lungs?

A REALLY QUICK LOOK AT THE VENTILATORY PUMP

THE MUSCLES OF RESPIRATION

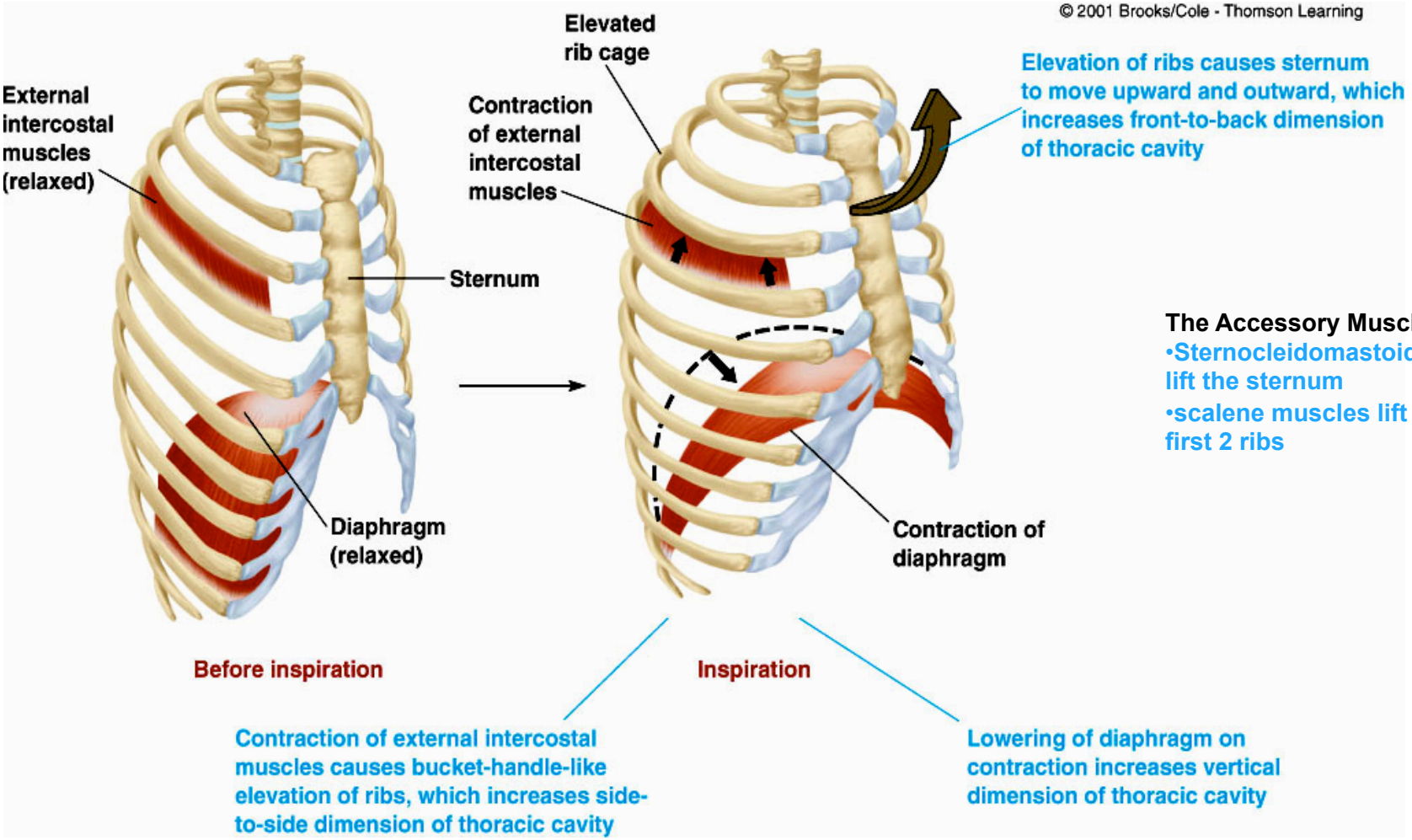


MOVEMENT OF THE DIAPHGRAM

During Normal Quiet Breathing

THE MUSCLES OF INSPIRATION

Diaphragm- External intercostals -Accessory muscles

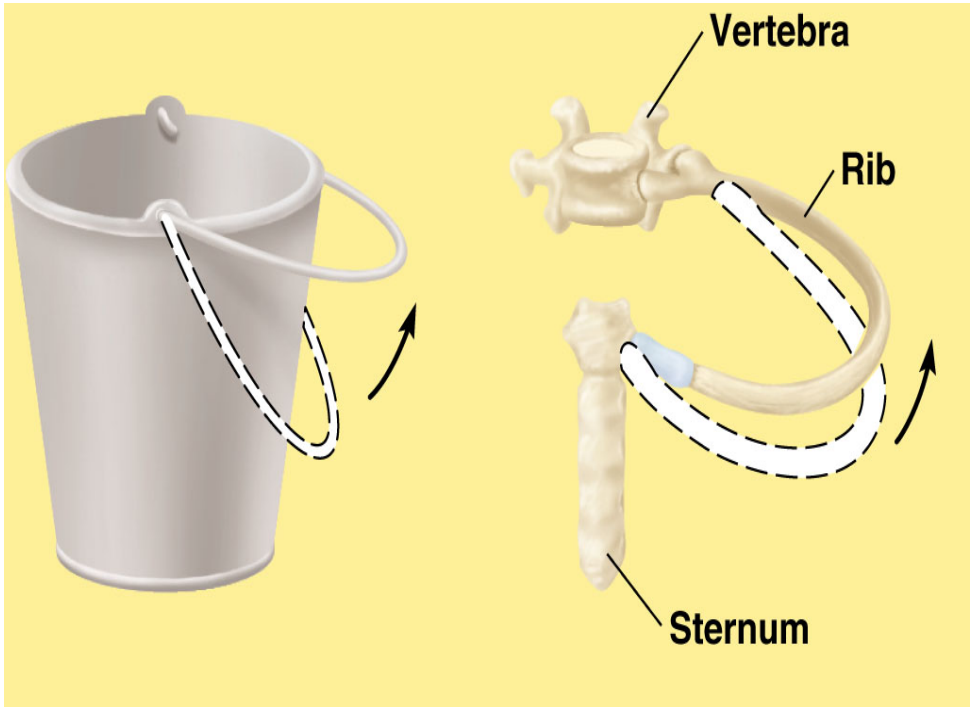


The Accessory Muscles

- Sternocleidomastoids lift the sternum
- scalene muscles lift the first 2 ribs

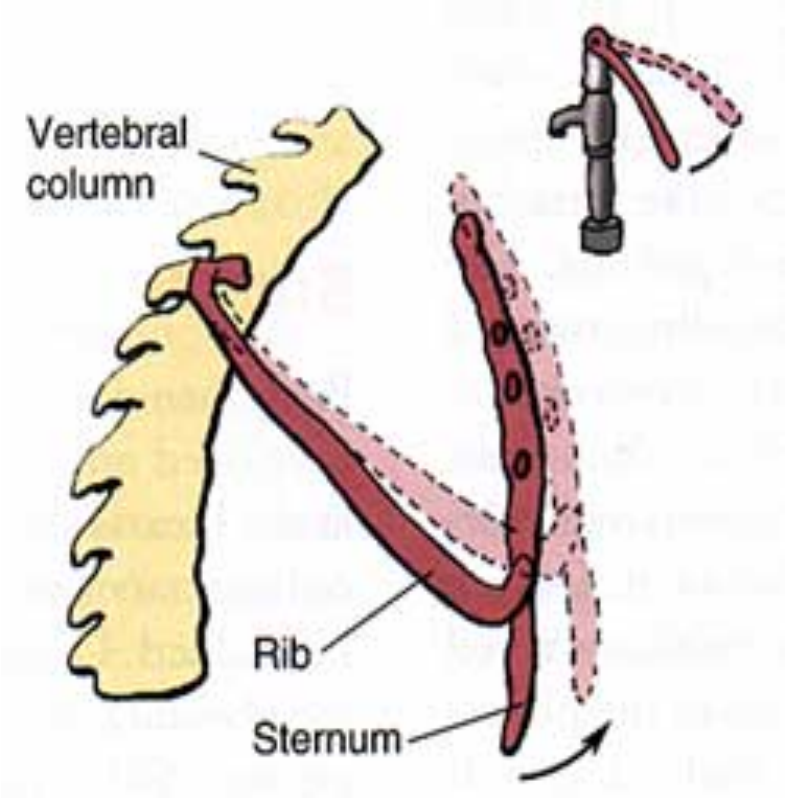
THE BUCKET HANDLE MOTION

intercostal muscles



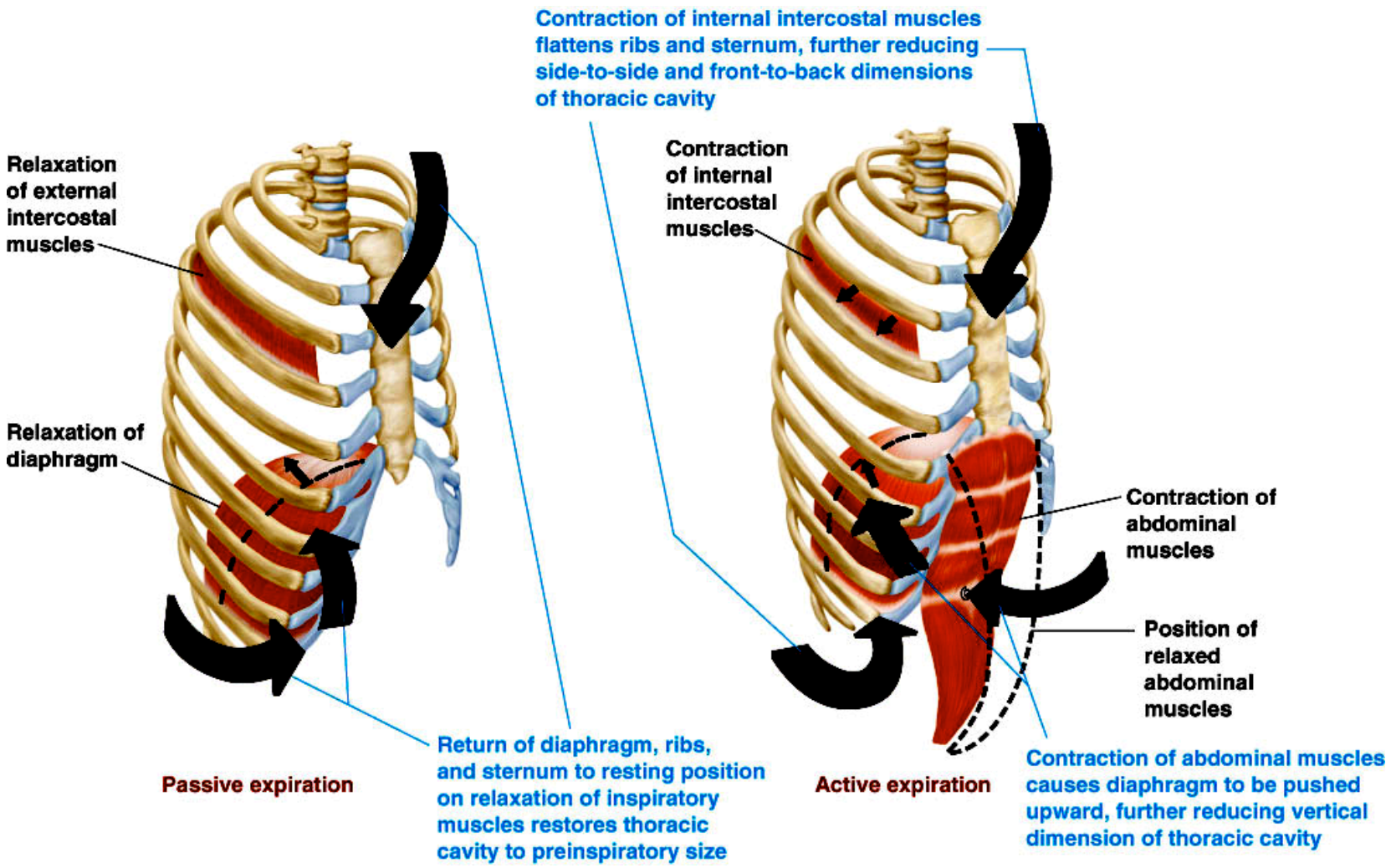
THE PUMP HANDLE MOTION

Accessory muscles

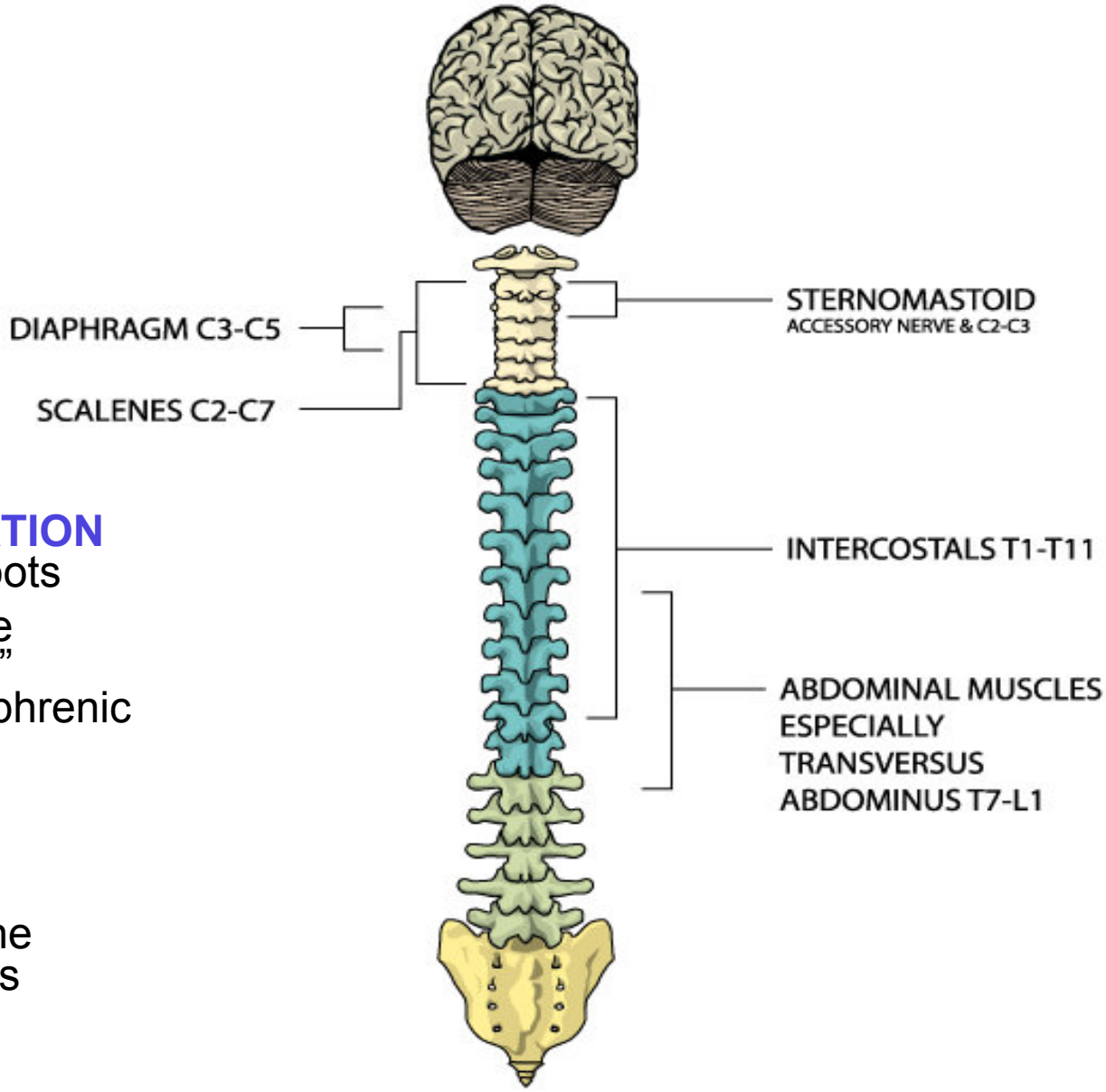


THE MUSCLES OF EXPIRATION

Internal intercostals - Abdominal muscles



Motor Innervation of the Respiratory Muscles



QUIET INSPIRATION
cervical spinal roots

C 3,4,5 “keep the diaphragm alive!” (give rise to the phrenic nerve)]

QUIET EXPIRATION
passive due to the recoil of the lungs

Normal Quiet Breathing (Eupnea)

Which respiratory muscles are used during …

Reflection & Review

1. sniffing?

2. coughing?

3. parturition, giving birth?

4. when walking down the beach trying to look slim?

5. nasal flaring?

For Reflection & Review

In cases of spinal chord injury…
which respiratory muscle(s)if any are affected
if the injury is...

1. above C3

2. C4 or higher? Remember C3,4,5 keep the diaphragm alive

3. at T1-T11?

4. below T1-T12?

Will any of these injuries affect your ability to breath? Be specific in terms of inspiration or expiration. Will any of these injuries affect your ability to cough and clear your lungs? to sniff?