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Respiratory Mechanics I

M1 – Cardiovascular/Respiratory Sequence

Louis D'Alecy, Ph.D.

Fall 2008

Wednesday 11/12/08, 10:00 Respiratory Sequence

40 slides, 50 minutes

1. Introduction
   a) Text
   b) Testable content
   c) Respiratory disease
   d) Anatomy
2. Functions of Respiratory System
3. Mechanics of Ventilation I

PULMONARY PHYSIOLOGY
BY
Levitzky 6th ed

"…a solid background in the aspects of pulmonary physiology essential to understanding clinical medicine."

Testable Content

Levitzky's Chapter Objectives

Handouts, Keywords and Lecture Content

Quiz # 3 11/16/07 will include both cardiovascular and respiratory questions.

REMINDER:

Final **Comprehensive** with

Cardiovascular & Respiratory

RESPIRATORY DISEASE (1)

Tuberculosis

Greatest single infectious cause of mortality world wide. 2 million deaths/yr

Chronic Obstructive Pulmonary Disease (COPD) Forth leading cause of death in US.

Bronchitis
Emphysema

Cystic Fibrosis Most common lethal congenital disease

Asthma Most common chronic childhood illness

<u>RESPIRATORY DISEASE (2)</u>

Pneumonia

A leading cause of death among children throughout the world. Estimated 4 million children die per yr.

Influenza

Can be fatal, especially among the very young or very old.
1918 pandemic estimated to have killed 20-40 million world wide

Respiratory Distress Syndrome

Major problem in prematurely born infants

Acute Respiratory Distress Syndrome (ARDS)

Fatal in about 60% of cases

RESPIRATORY DISEASE (3)

Respiratory Distress Syndrome

Major problem in prematurely born infants

Diffuse Interstitial Pulmonary Fibrosis

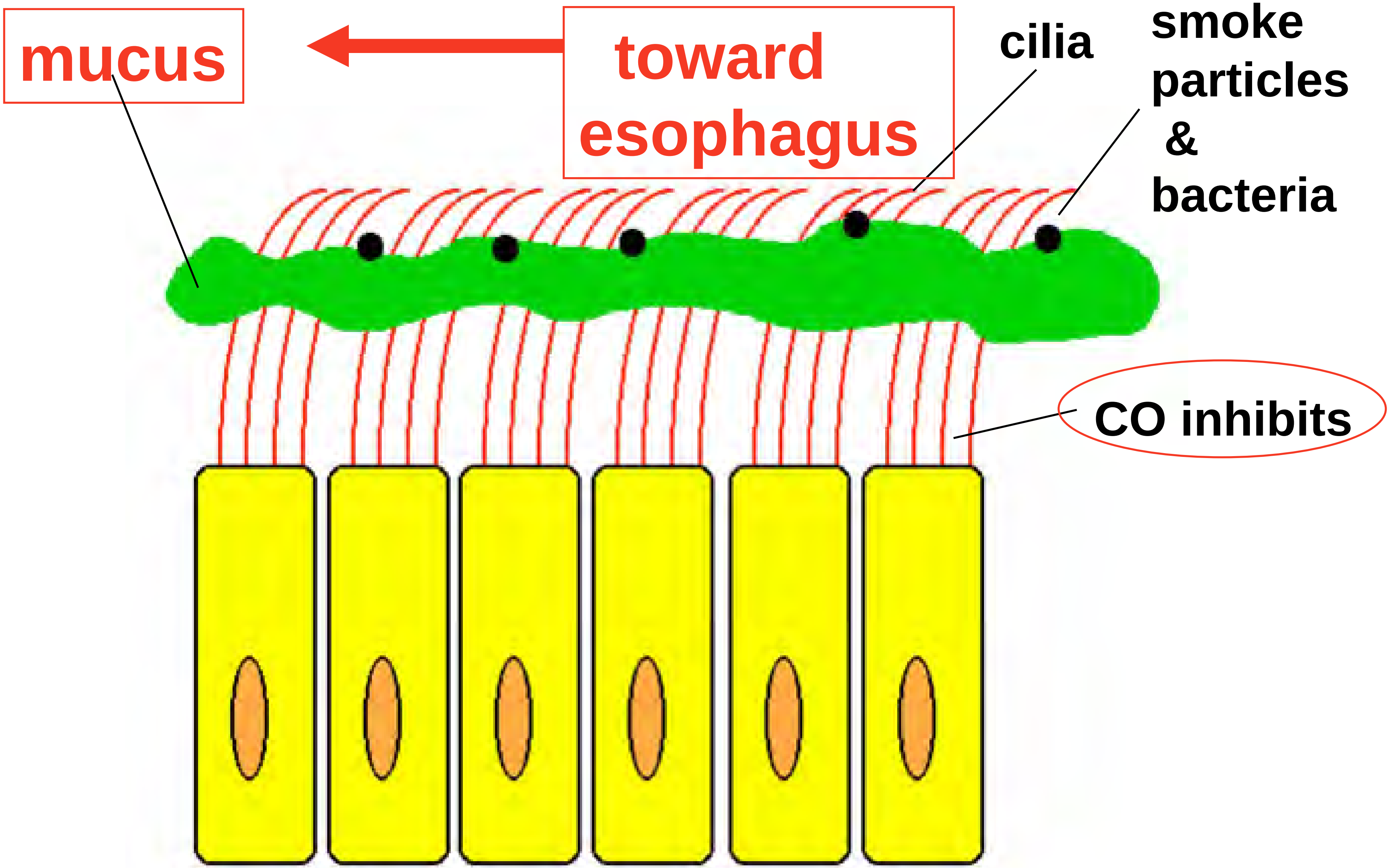
Anemia

Pulmonary Embolism

Pulmonary Hypertension

Common Cold

MUCUS ESCALATOR



ciliated airway epithelium

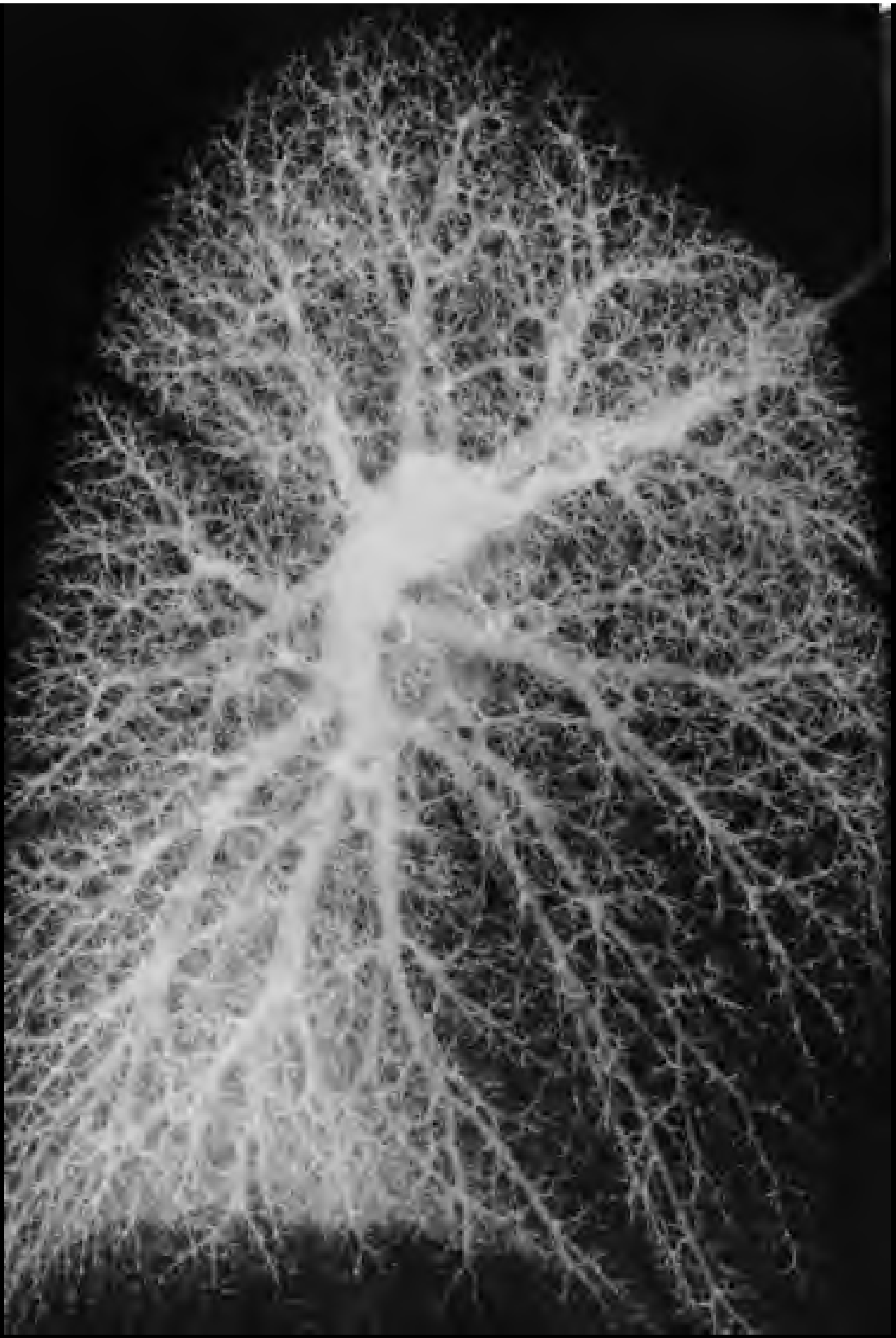
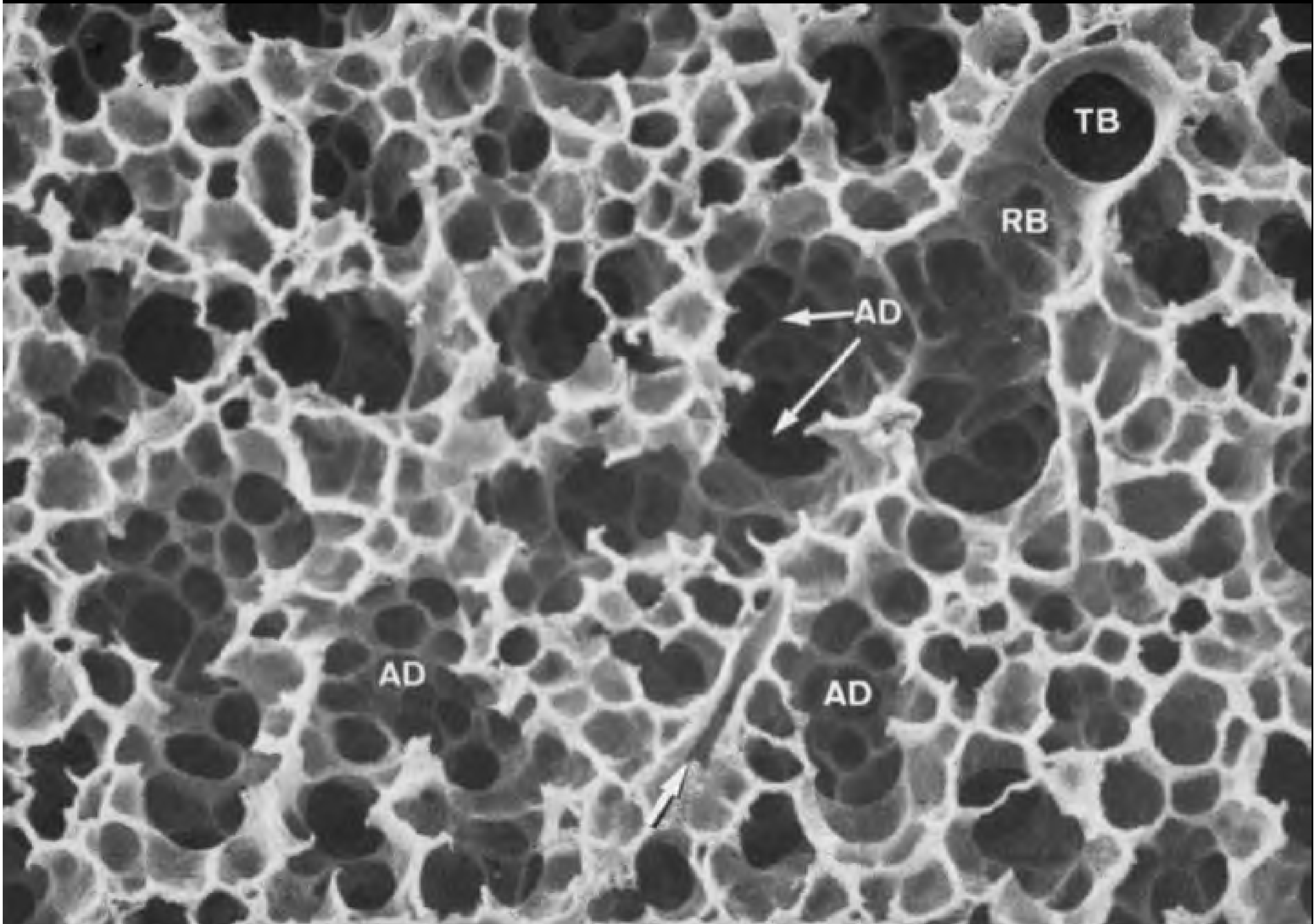


Image of alveoli removed

Please see: http://www.3dscience.com/img/Products/3D_Models/Human_Anatomy/Alveoli/supporting_images/3D_Model_Anat_Alveoli3_web.jpg


TB
RB
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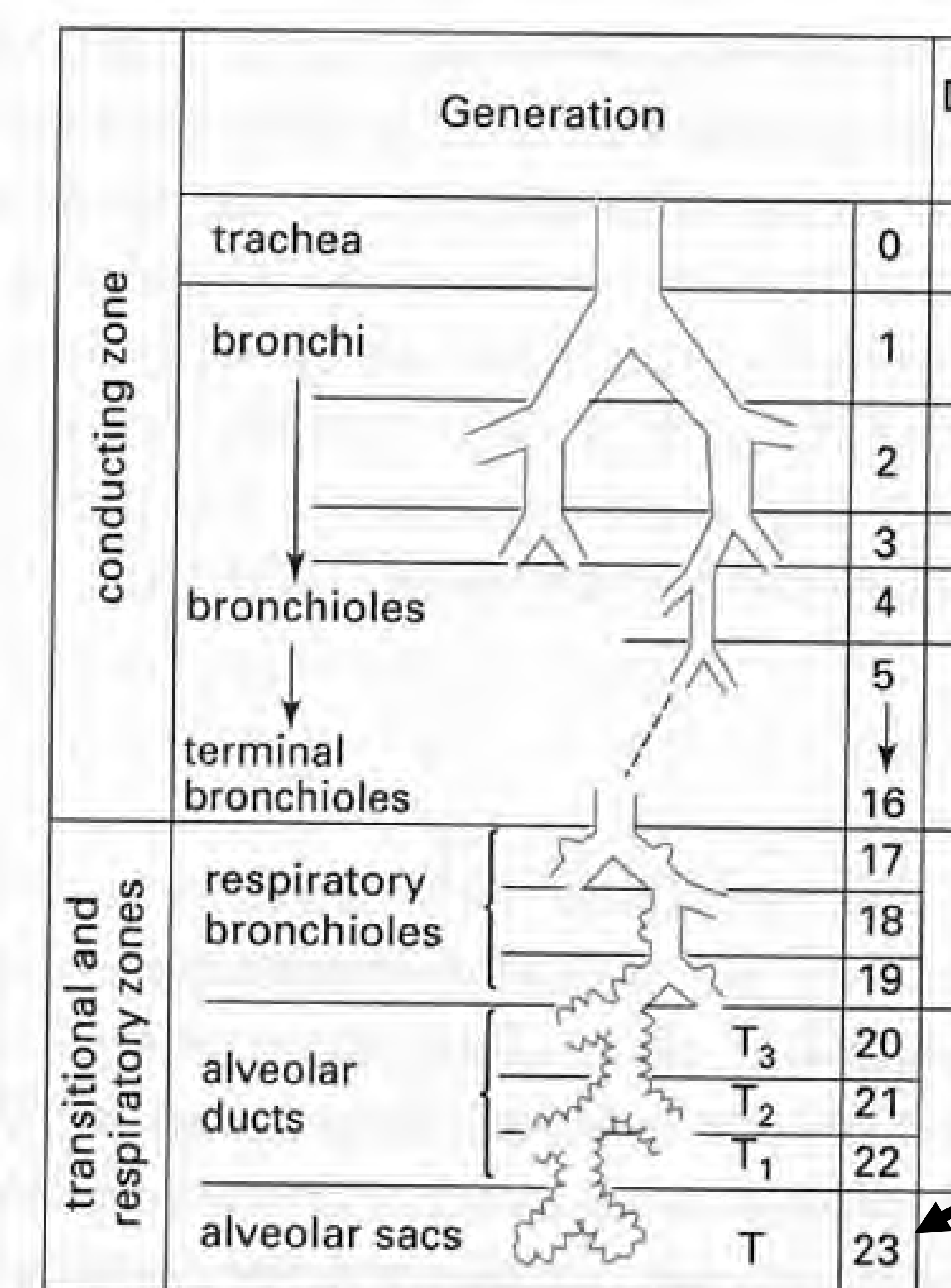
AD
AD

Image of alveoli vasculature removed

Please see: http://www.virtualcancercentre.com/uploads/VMC/DiseaseImages/2293_alveoli_450.jpg

ALVEOLI ARE INTERFACE BETWEEN CARDIOVASCULAR AND RESPIRATORY SYSTEMS

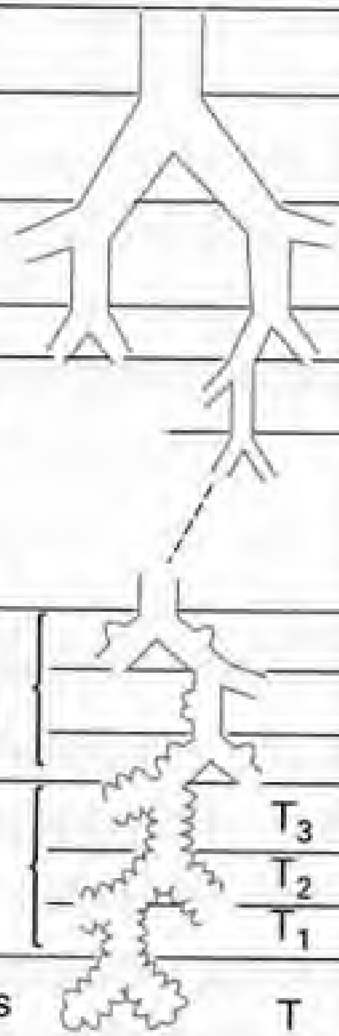


Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

2.54 cm^2 ~ Dime!

AREA for Diffusion

10^4 cm^2 ~ Tennis court



Zone	Generation			Diameter, cm	Length, cm	Number	Total cross-sectional area, cm^2
conducting zone	trachea		0	1.80	12.0	1	2.54
	bronchi		1	1.22	4.8	2	2.33
	↓		2	0.83	1.9	4	2.13
			3	0.56	0.8	8	2.00
	bronchioles		4	0.45	1.3	16	2.48
	↓		5	0.35	1.07	32	3.11
			↓	↓	↓	↓	↓
	terminal bronchioles		16	0.06	0.17	6×10^4	180.0
transitional and respiratory zones	respiratory bronchioles		17	↓	↓	↓	↓
			18				
			19	0.05	0.10	5×10^5	10^3
	alveolar ducts	T_3	20	↓	↓	↓	↓
		T_2	21				
		T_1	22				
	alveolar sacs	T	23	0.04	0.05	8×10^6	10^4

 Levitzky. Pulmonary Physiology. McGraw-Hill, 2003. 6th ed.

Fig. 1-5

PHYSIOLOGY=
Functions of Respiratory System (1)

- 1. Delivers oxygen to blood
- 2. Eliminates carbon dioxide
- 3. Regulates blood pH

All depend upon bulk flow and diffusion

Image of alveolus structure removed

Please see: http://www.kscience.co.uk/as/module1/pictures/alveolus.jpg

Air Ventilation = 4 L/min

Blood CO = 5 L/min

PHYSIOLOGY = Functions of Respiratory System (2)

- 4. Traps and dissolves blood clots
  - (PE = PULMONARY EMBOLUS)
- 5. Forms speech sounds (phonation)
- 6 Facilitates smell (olfaction)
- 7. Defends against microbes
- 8. Adds or removes chemical
  - » messengers

STEPS IN **RESPIRATION**

Bulk flow--> Diff--> Bulk flow--> Diff--> Use

(1) Ventilation: Exchange of air between atmosphere and alveoli by *bulk flow* Air

(2) Exchange of O_2 and CO_2 between alveolar air and blood in lung capillaries by *diffusion*

(3) Transport of O_2 and CO_2 through pulmonary and systemic circulation by *bulk flow* Blood

(4) Exchange of O_2 and CO_2 between blood in tissue capillaries and cells in tissues by *diffusion*

(5) Cellular utilization of O_2 and production of CO_2

STEPS IN RESPIRATION

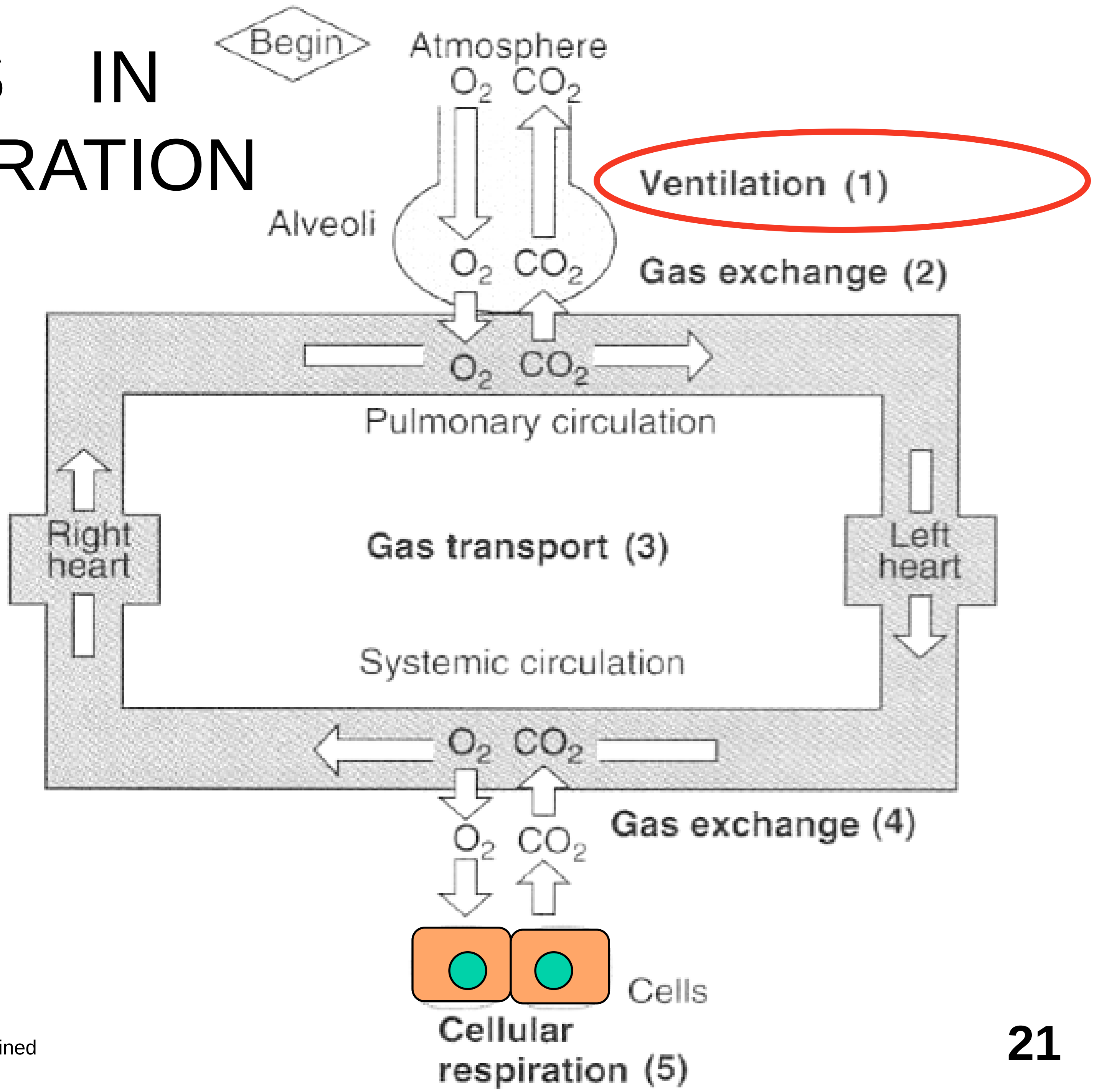
1

2

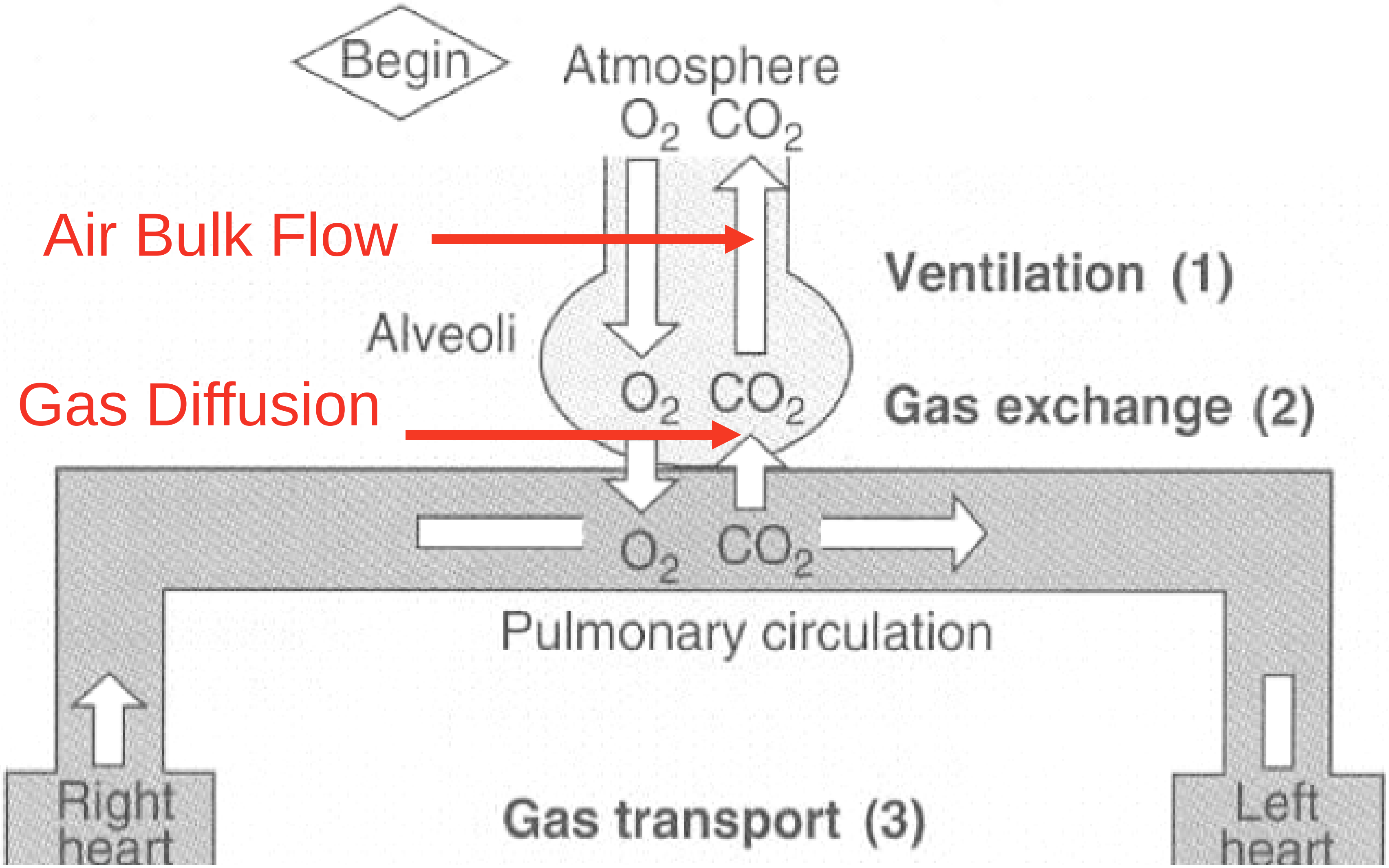
3

4

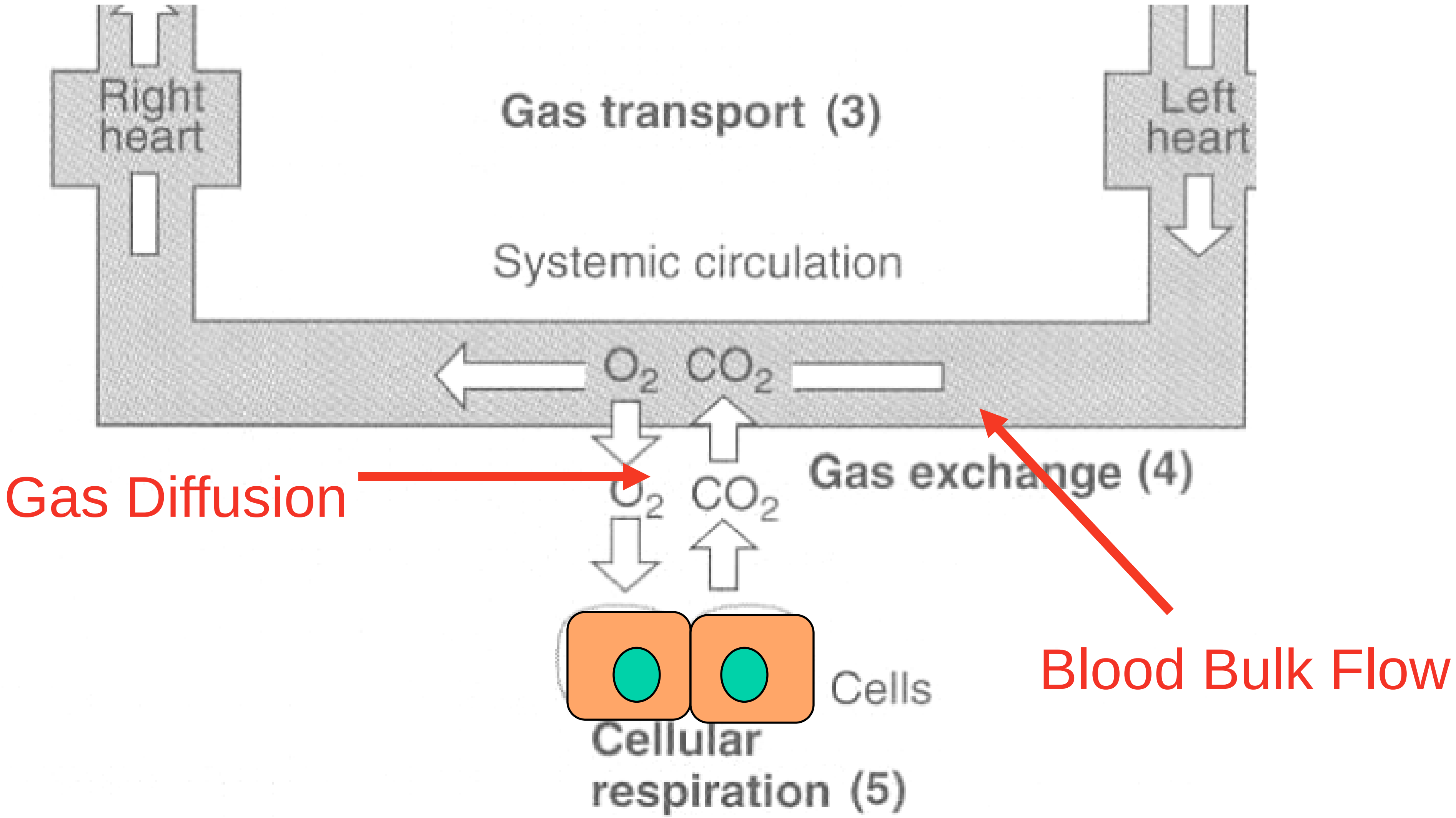
5



STEPS IN RESPIRATION



STEPS IN RESPIRATION



PD-INEL Source Undetermined

Bulk Flow Equation
Same for blood and air

$$\textbf{Flow} = \frac{\Delta P}{R}$$

Flow is directly proportional to the pressure difference.

“pressure gradient” or ΔP

Flow is directly proportional to **ΔP**

and

directly proportional to

airway radius to 4th power $\mathbf{r}^{4}$

Radius later.

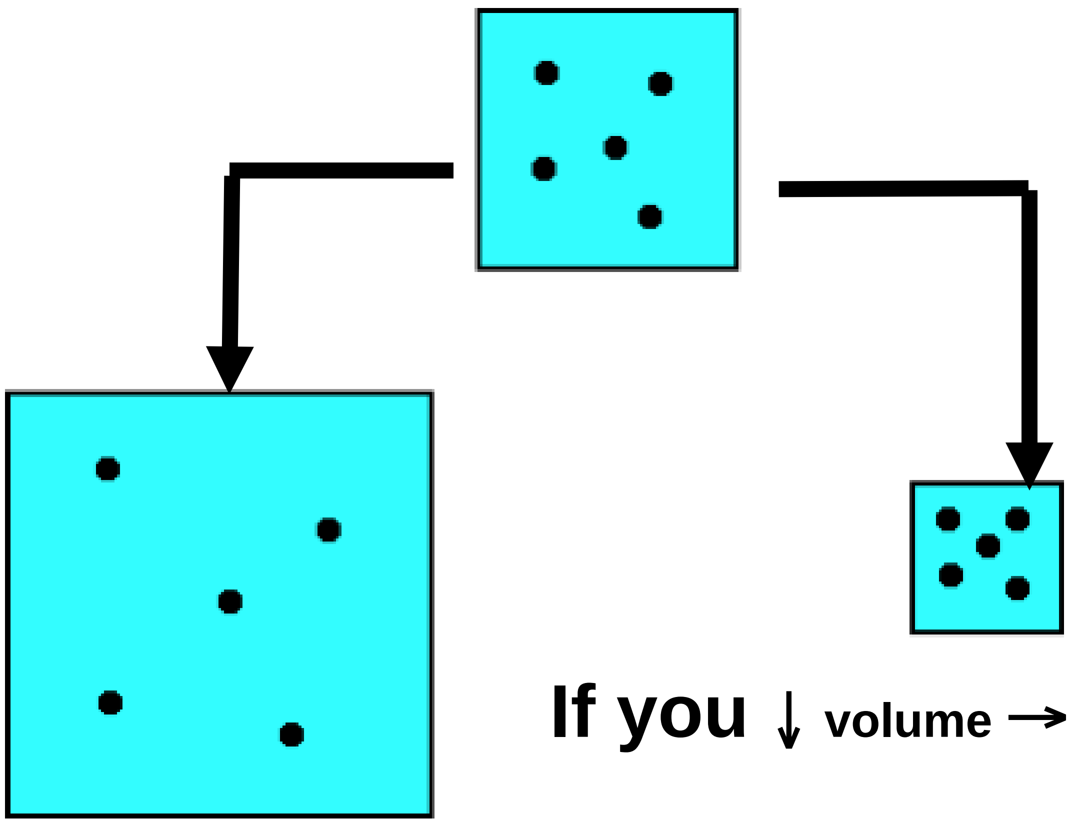
At rest No ΔP !!!! Thus no flow.

So how do we move air

in and out? Make a ΔP !!

<u>BOYLE'S LAW:</u>

At constant temperature, the pressure of a gas is inversely proportional to its volume.



If you ↓ volume → ↑pressure

Thus

If you ↑volume → ↓pressure

RESPIRATORY PRESSURE UNITS =

cm H_2O or mm Hg

1 cm H_2O = 0.76 mm Hg

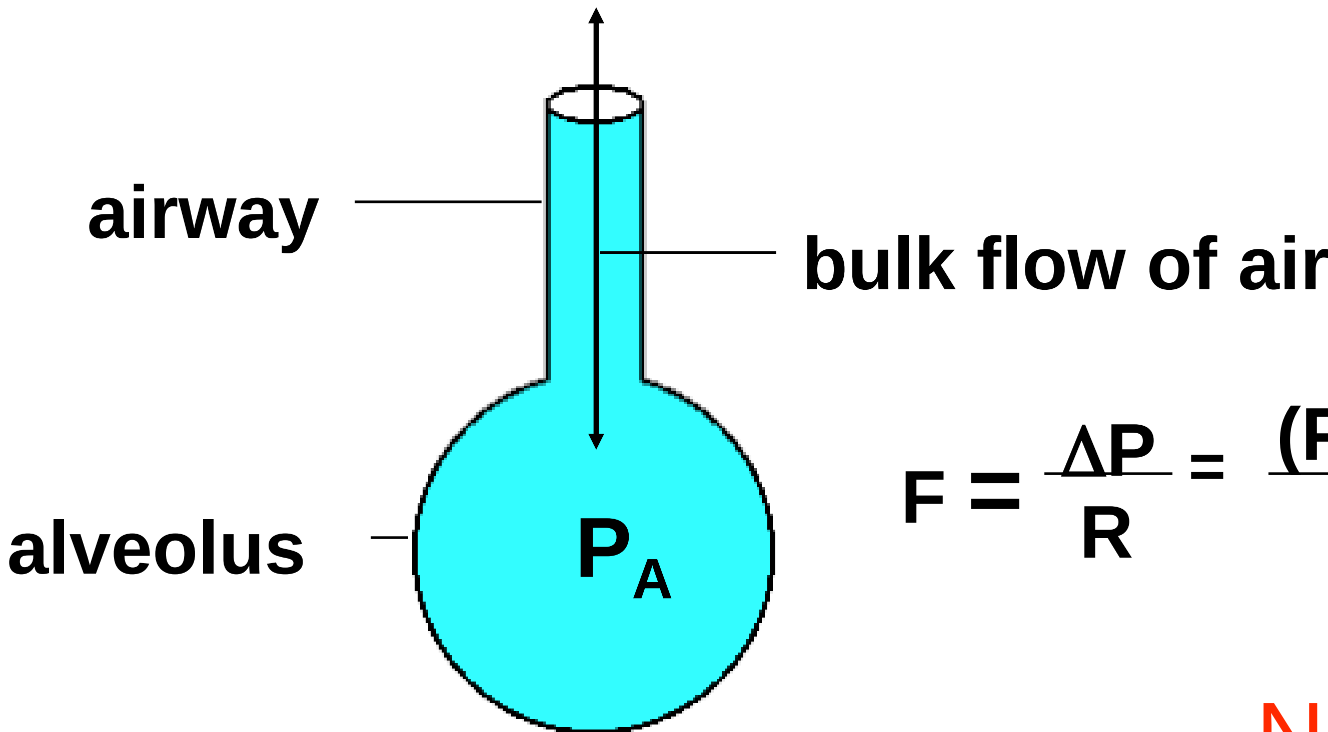
1 mm Hg = 1.36 cm H_2O

*****atmosphere 1 atmos = 760 mm Hg
BUT set to Zero… cm H_2O or mmHg ****

Pressure = force/area = dynes/cm^2

1 mm Hg = 1 Torr = 1333.22 dynes/cm^2

Pressure outside = $P_o = P_b$ = = atmospheric pressure = zero



$$F = \frac{\Delta P}{R} = \frac{(P_o - P_A)}{R}$$

Need to

Inspiration	$P_A < P_o$	$\downarrow P_A$
Expiration	$P_A > P_o$	$\uparrow P_A$

P_{out} = constant

Thoracic Cavity at Rest (equilibrium) between breaths

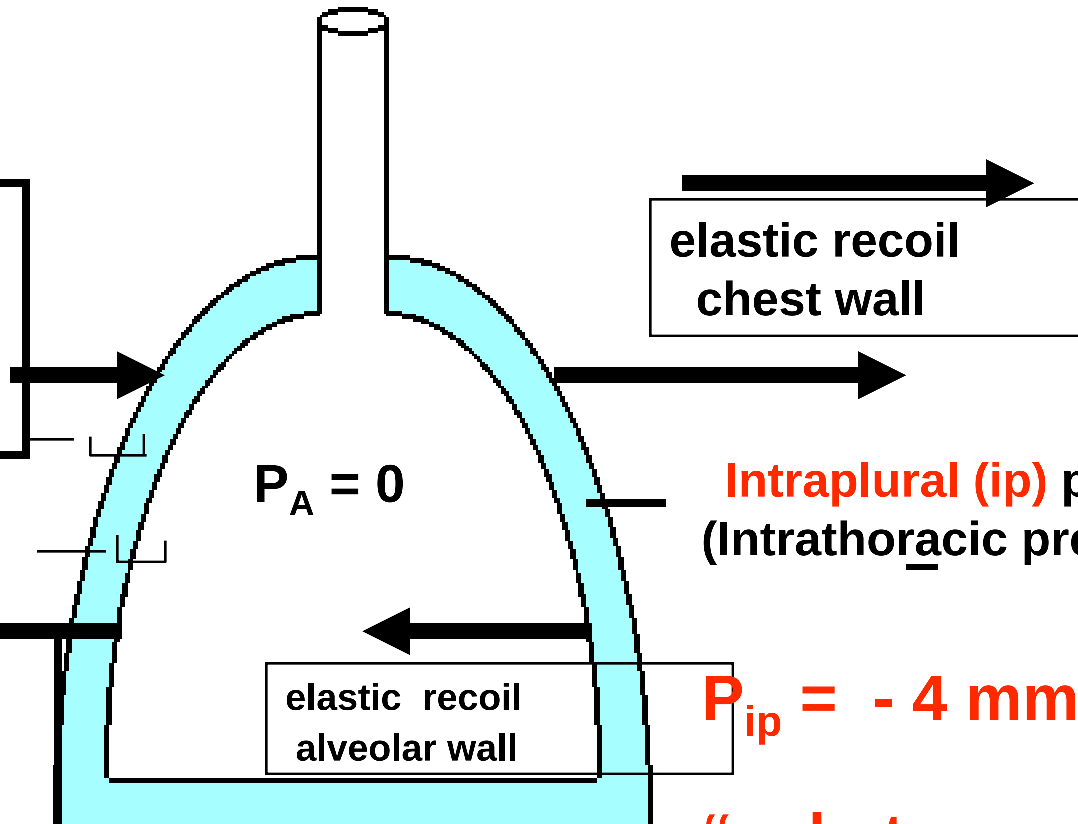
$P_o = 0$

transmural pressures

Across chest wall

$P_{ip} - P_o = -4$

$-4 - 0 = -4$



Intraplural (ip) pressure
(Intrathoracic pressure)

Across lung wall

$P_A - P_{ip} = 4$

$0 - (-4) = 4$

$P_{ip} = -4$ **mm Hg**

"subatmospheric"

Transmural or alveolar distending pressure

Chest At Rest

Lung "without chest" is much smaller

Chest "without lungs" is much bigger

When together (pulling in opposite directions)

Intraplural pressure is sub-atmospheric (- 4 mmHg)

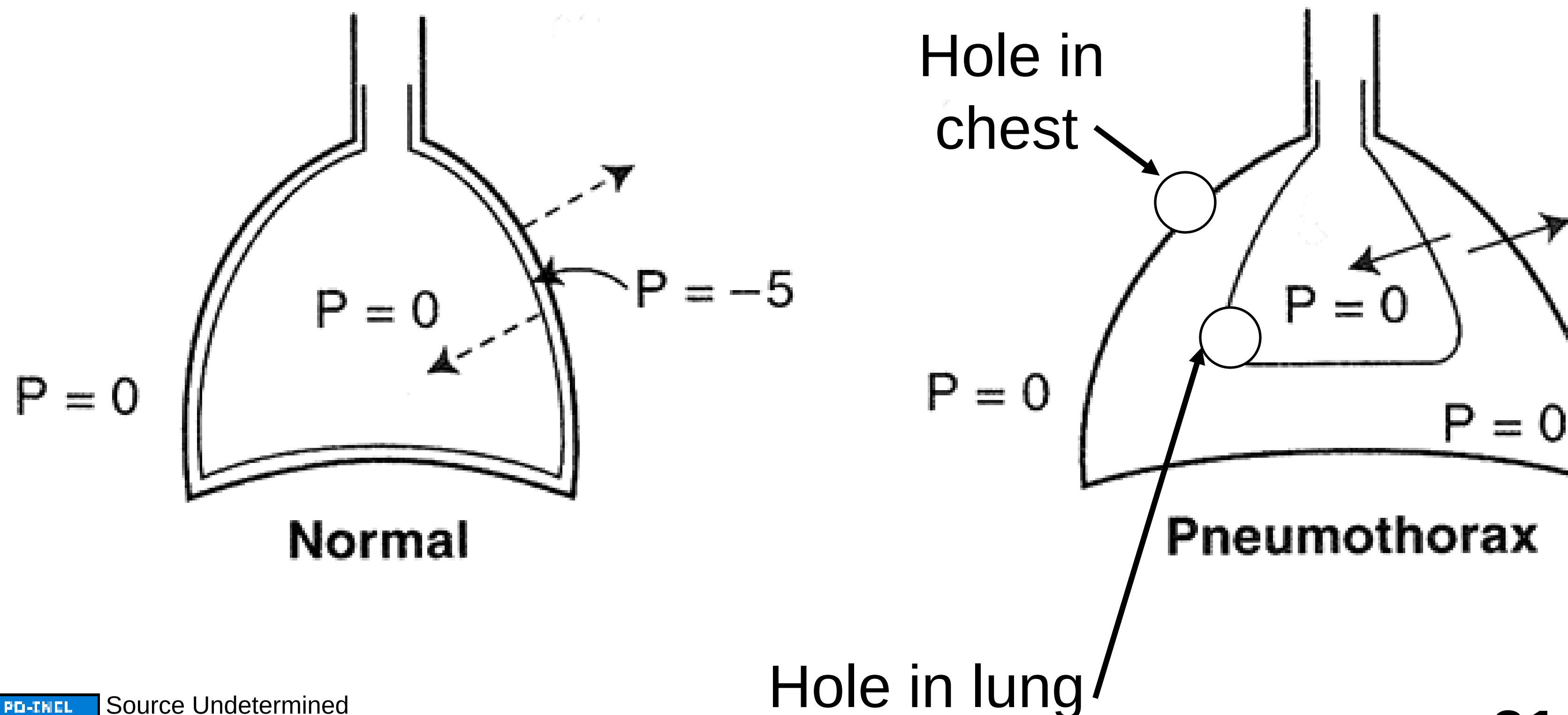
Therefore if you make a hole in either the

chest wall or the lung

the chest gets bigger

and the lungs get smaller (collapses) as

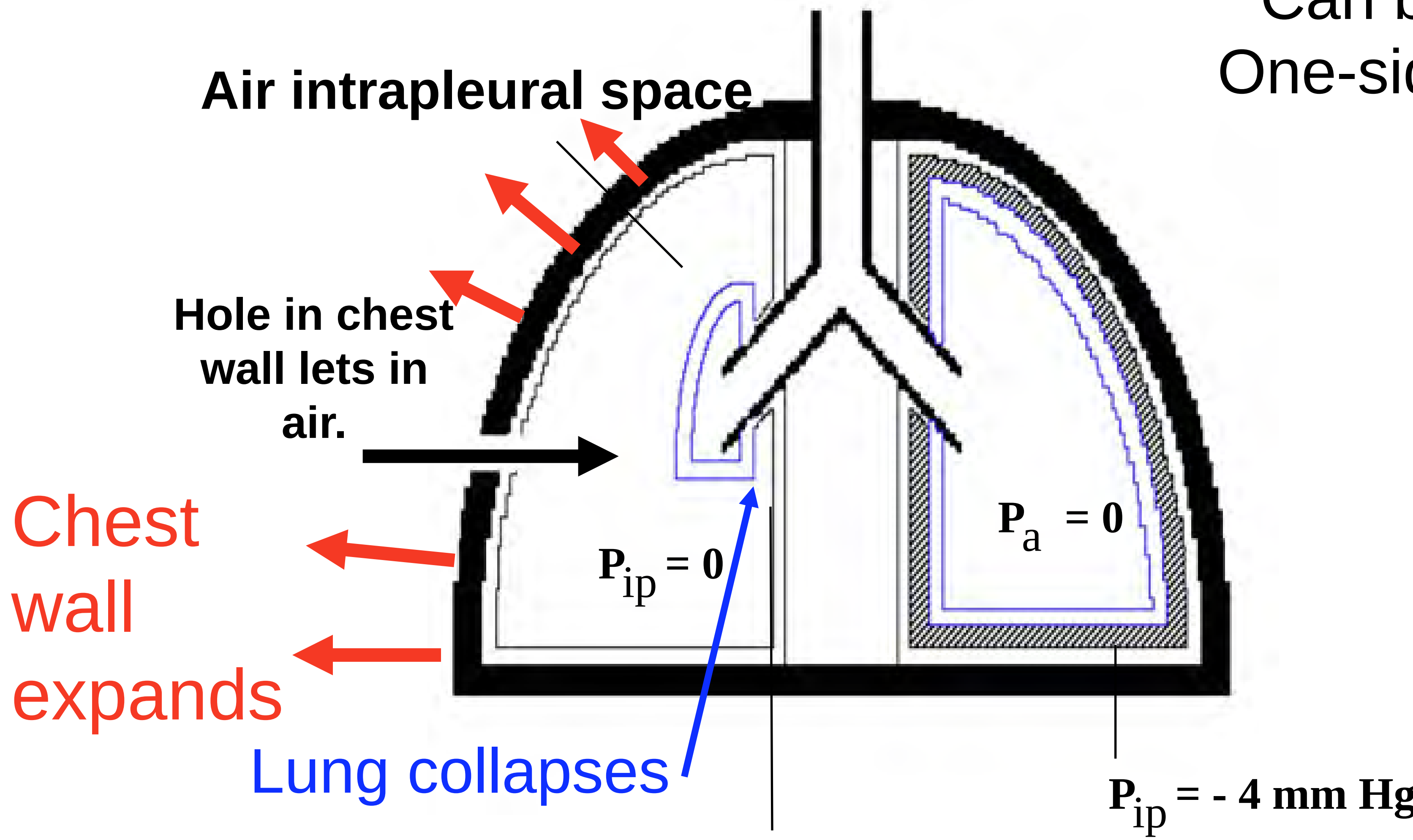
P_{ip} goes to zero or atmospheric.



PD-INEL Source Undetermined

PNEUMOTHORAX (air in thorax)

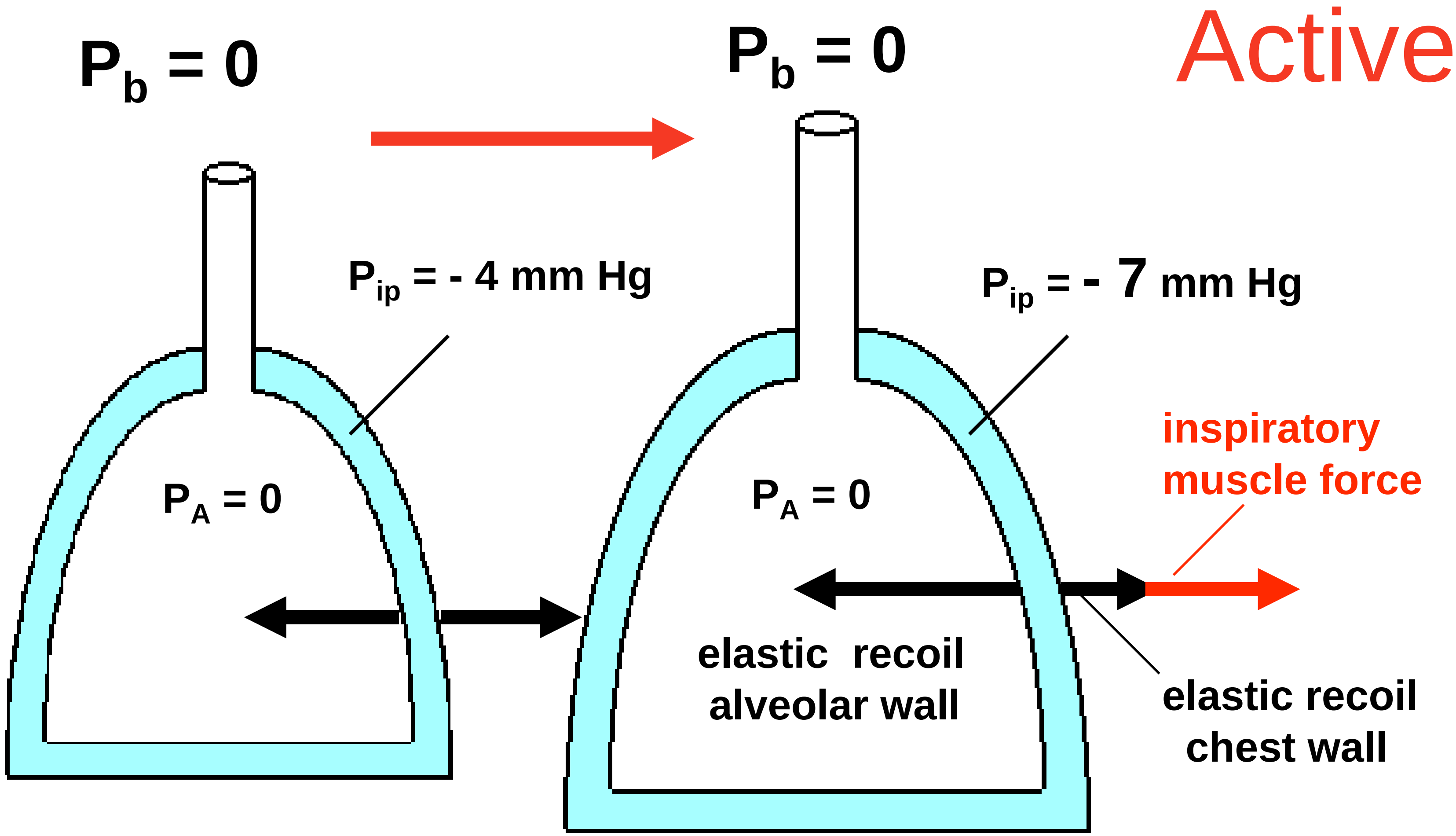
Can be One-sided



atelectasis - collapse of (alveoli) lung

(atel -Gk - incomplete, ectasis -Gk -stretching out)

<u>Inspiration</u> = chest (including lungs) made bigger



End of normal inspiration****

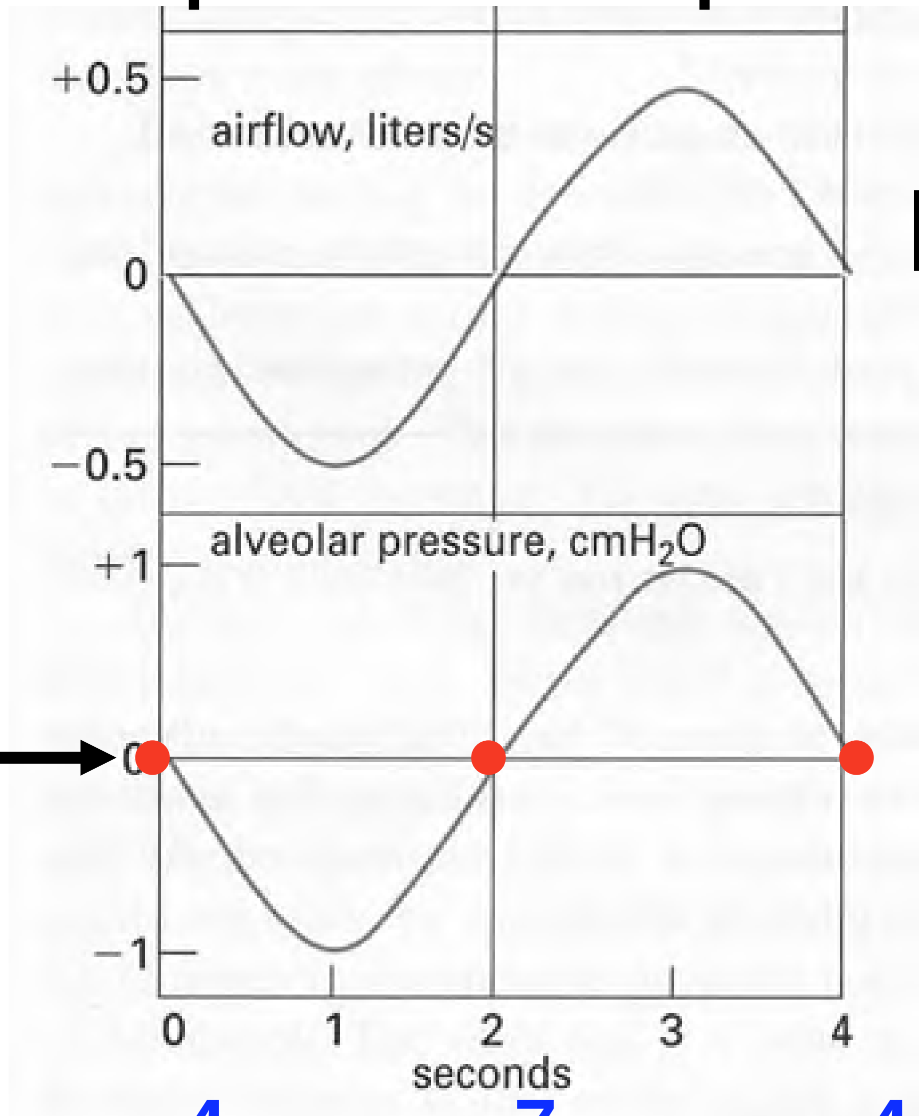
Inspiration (rest & end)

$P_A = P_{ip} +$ Alveolar recoil

0	=	-4	+	4	at rest
0	=	-7	+	7	at end of inspiration

Respiratory Air Flow = ΔP

Inspiration **Expiration**



Flow

P_A

P_b = 0 and so does

P_{ip} is **-4** **-7** **-4**

Source Undetermined

For Inspiration:

You make the chest (volume) bigger

and lower the P_A

By_active contraction of skeletal muscle.

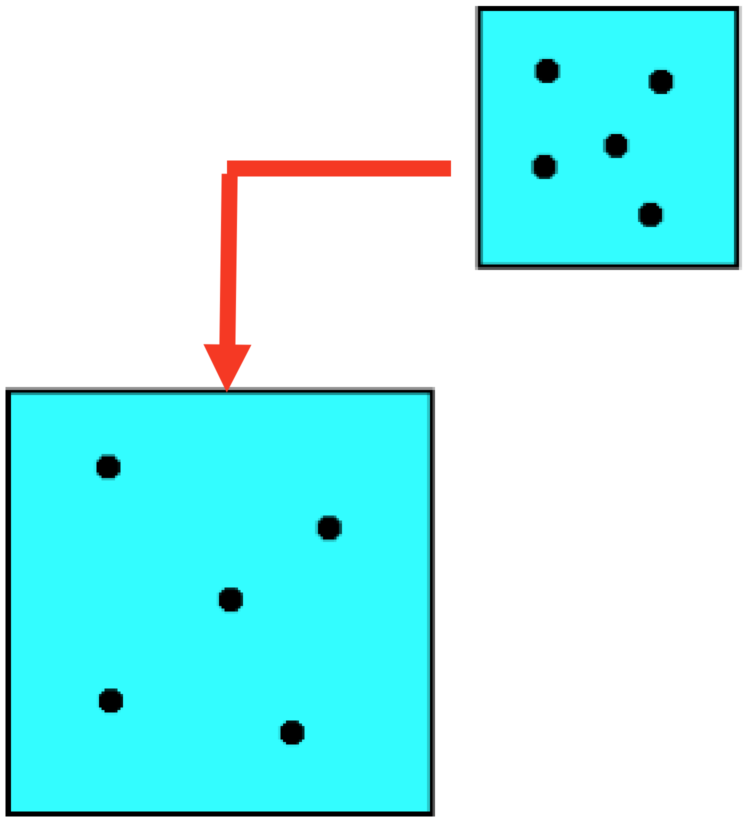
1. **Diaphragm Contraction**

2. **External intercostal Contraction**

3. **Accessory Muscles of Inspiration Contraction**

<u>BOYLE'S LAW:</u>

At constant temperature, the pressure of a gas is inversely proportional to its volume.



At Rest

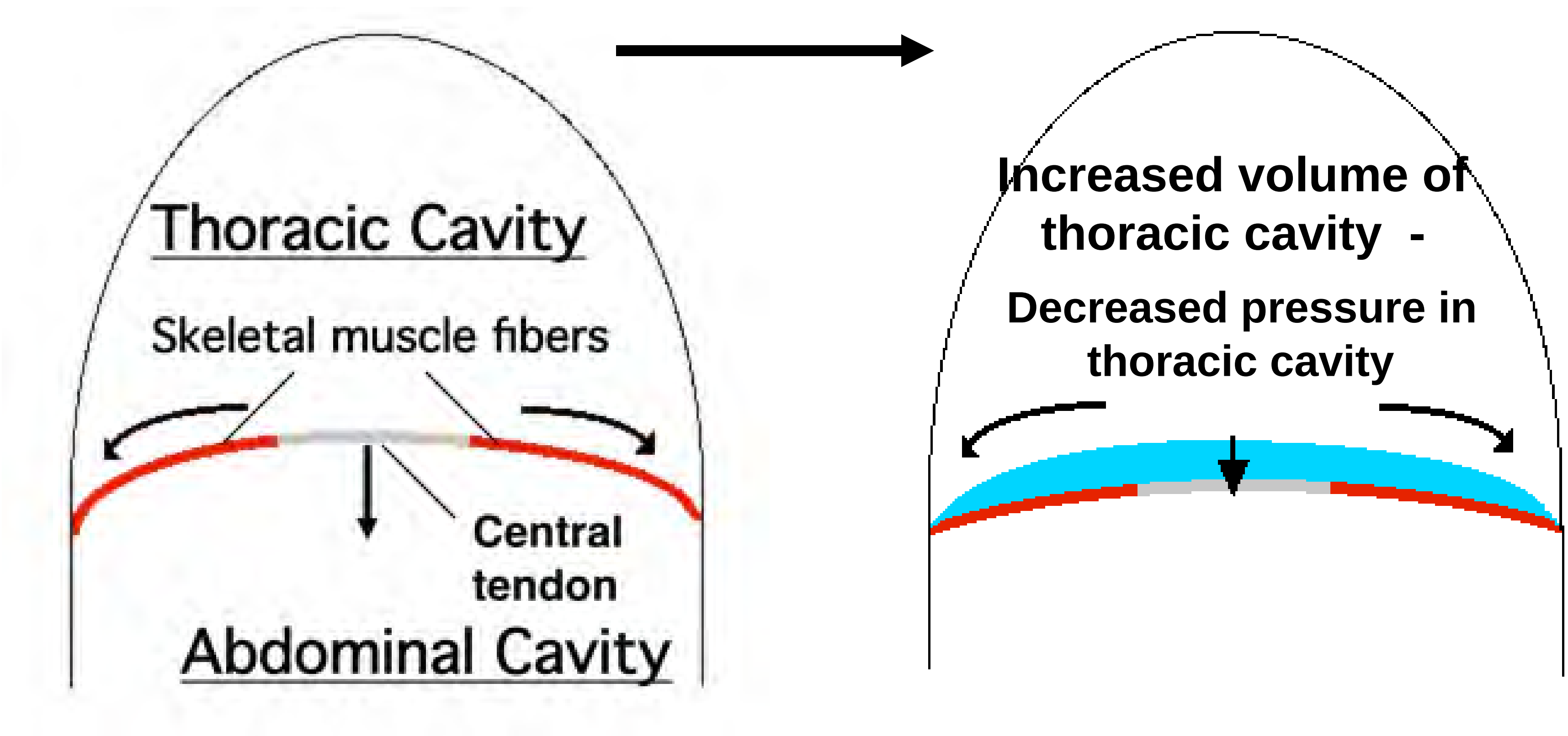
At End Inspiration

Thus

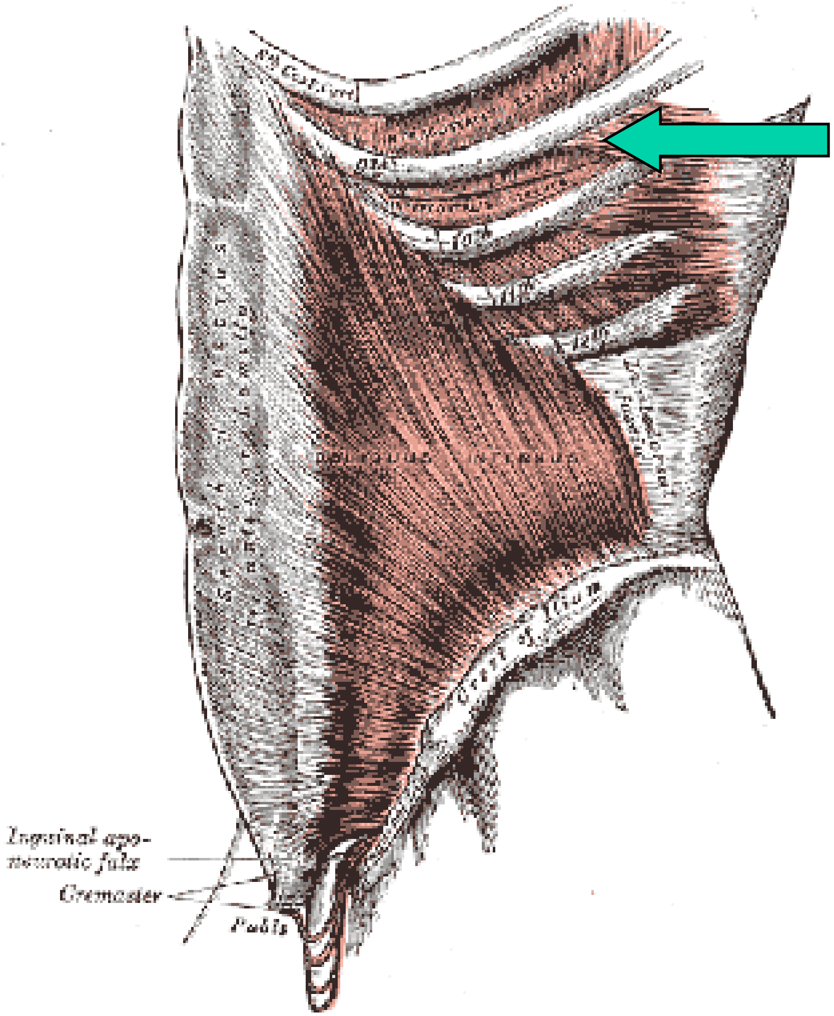
If you ↑volume → ↓pressure

DIAPHRGAM CONTRACTION

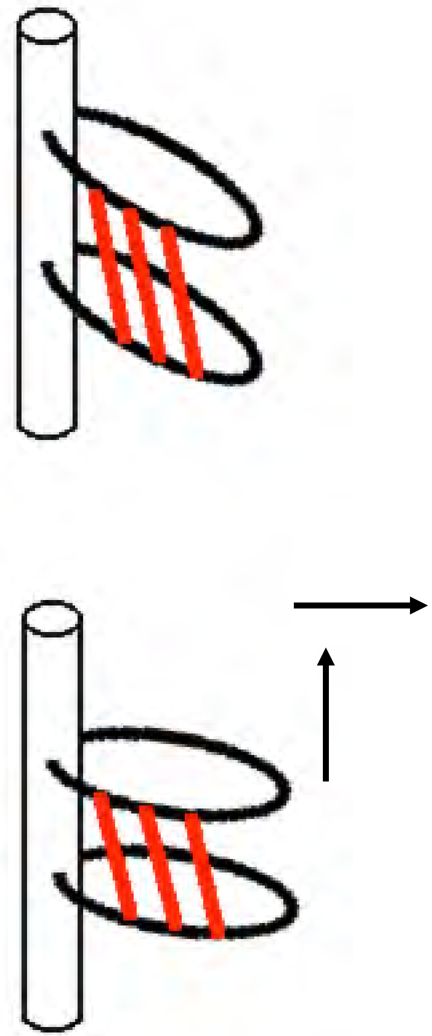
Inspiration



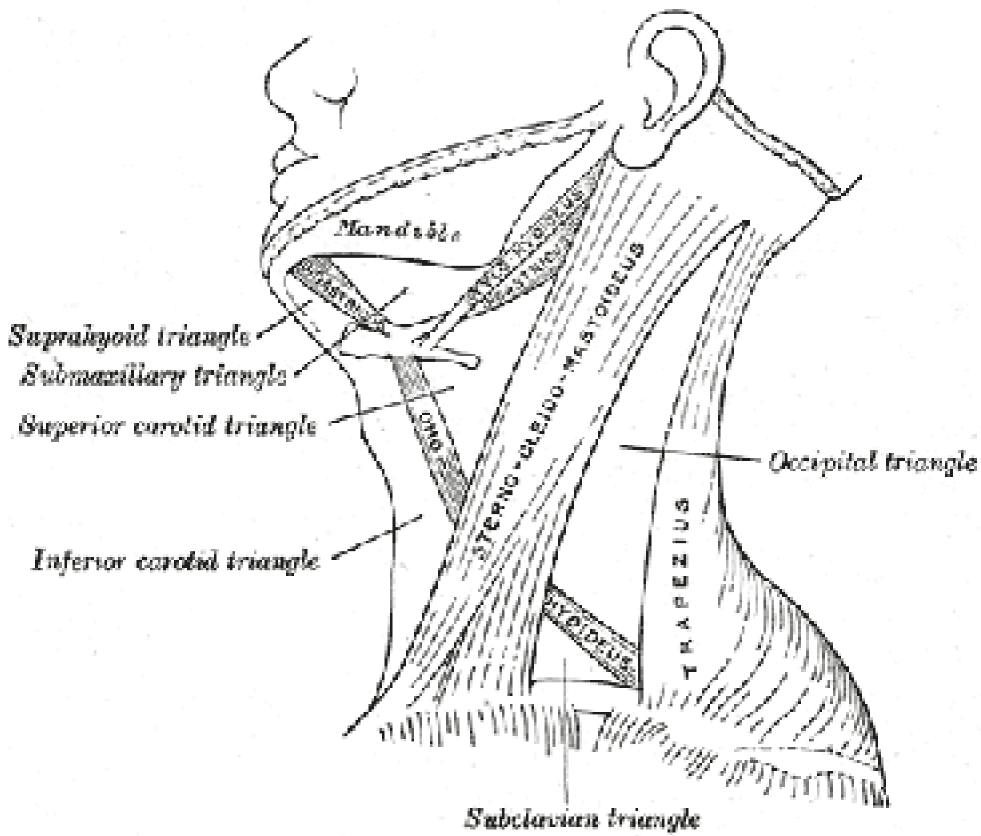
External Intercostals



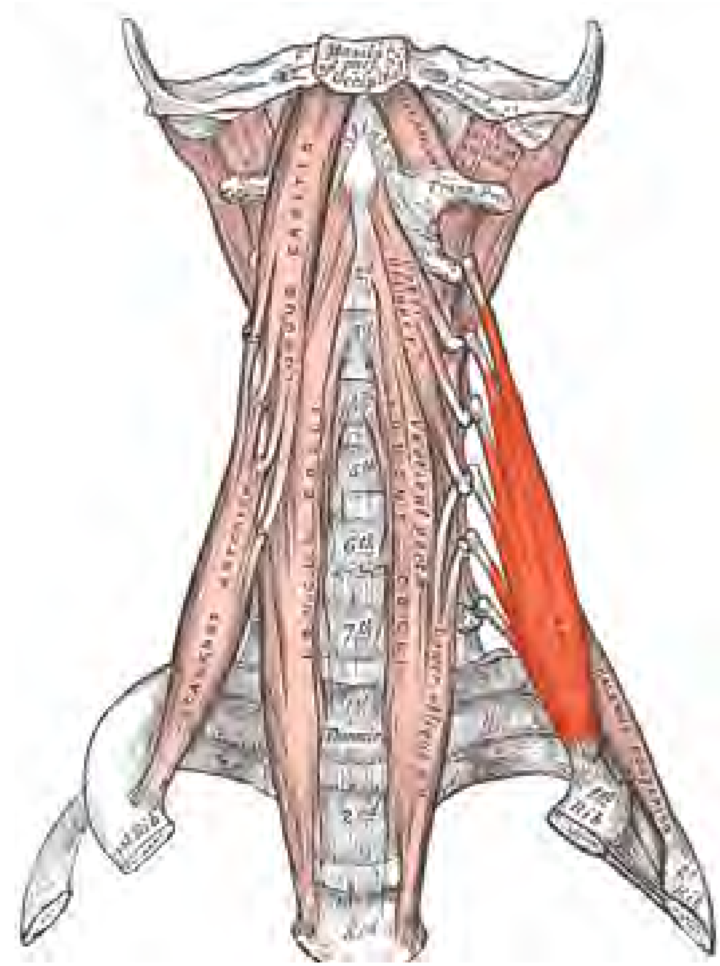
PD-INEL Gray's Anatomy



Sternocleidomastoideus



Scalenus medius



Expiration (Passive)

Inspiratory muscles relax.

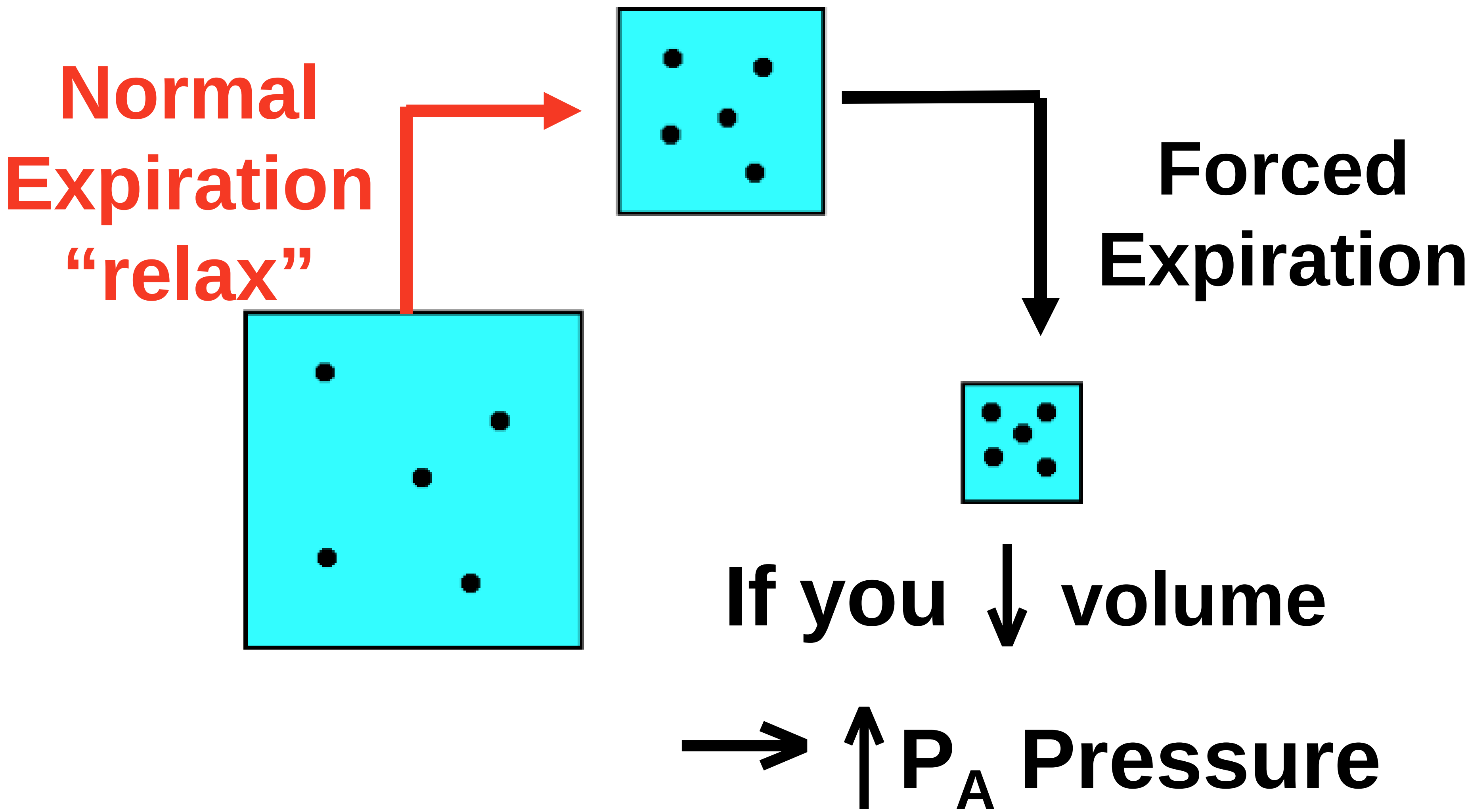
Thoracic volume decreases.

P_A increases (Boyle's Law).

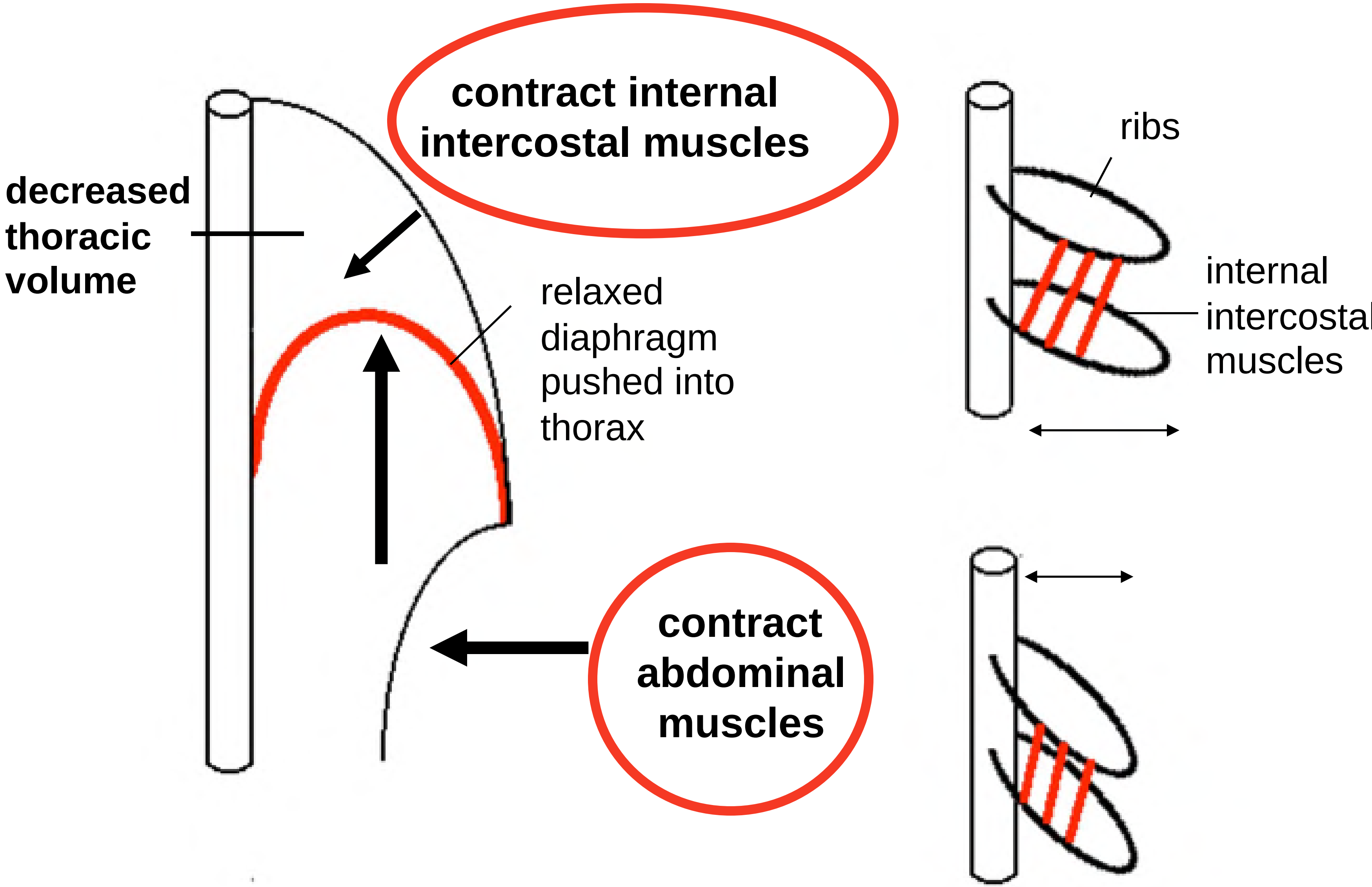
Air flows out by ΔP .

Normal Expiration:

Elastic recoil of lung returns volume to rest.



FORCED EXPIRATION



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Slide 18: Please see: http://www.kscience.co.uk/as/module1/pictures/alveolus.jpg
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Slide 22: Source Undetermined
Slide 23: Source Undetermined
Slide 28: D'Alecy
Slide 29: D'Alecy
Slide 31: Source Undetermined
Slide 32: D'Alecy
Slide 33: D'Alecy
Slide 35: Source Undetermined
Slide 38: D'Alecy
Slide 39: Gray's Anatomy
Slide 40: Gray's Anatomy; Gray's Anatomy
Slide 43: D'Alecy