RS MODULE
PHYSIOLOGY PRACTICAL

SPIROMETRY

BY

Associate Professor

Dr. Fatma Farrag Ali

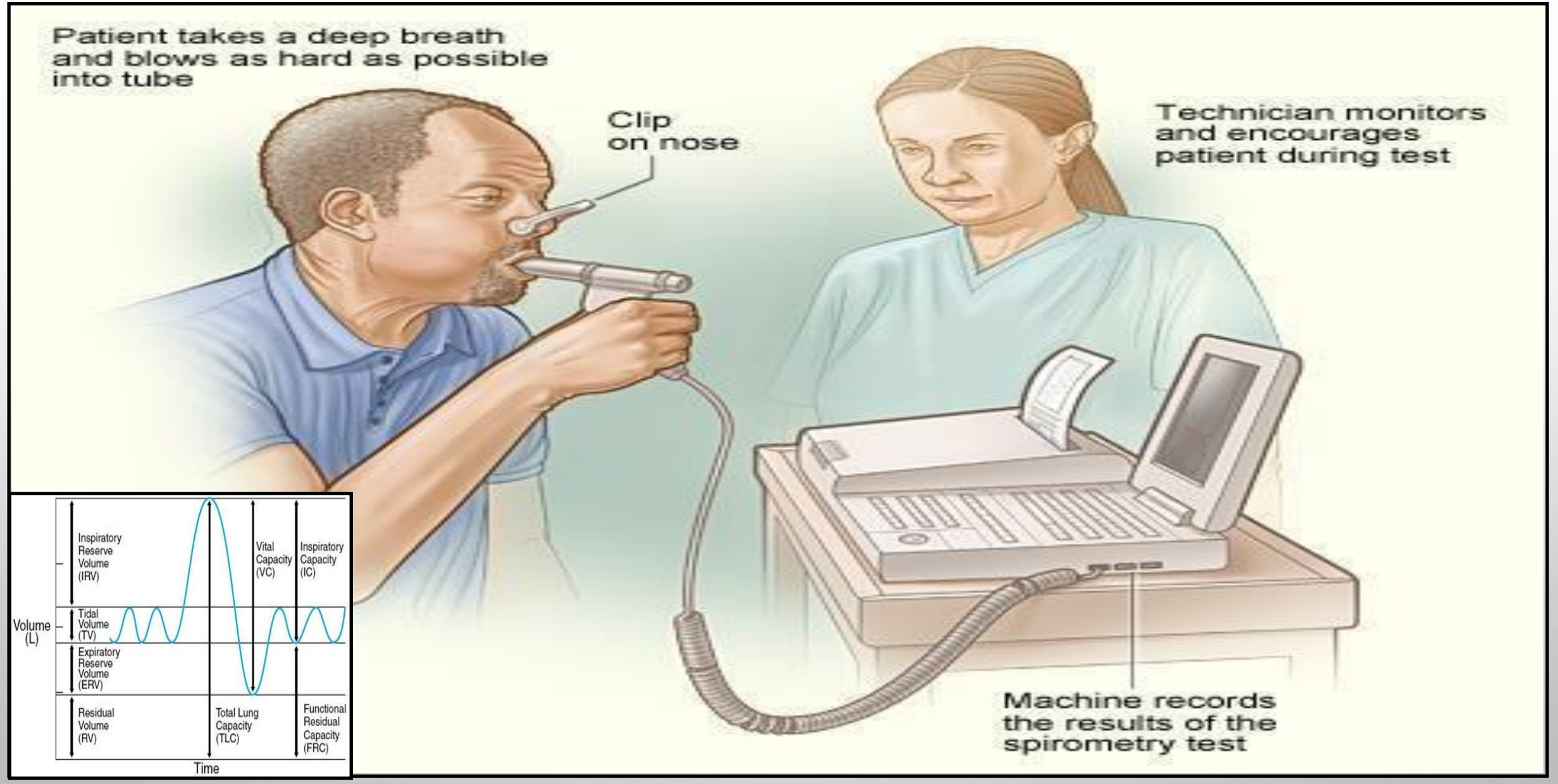
SPIROMETRY

- ✓ It is the first lung (pulmonary) function test done.
- ✓ It means measurements of lung volumes and capacities.

Indication:

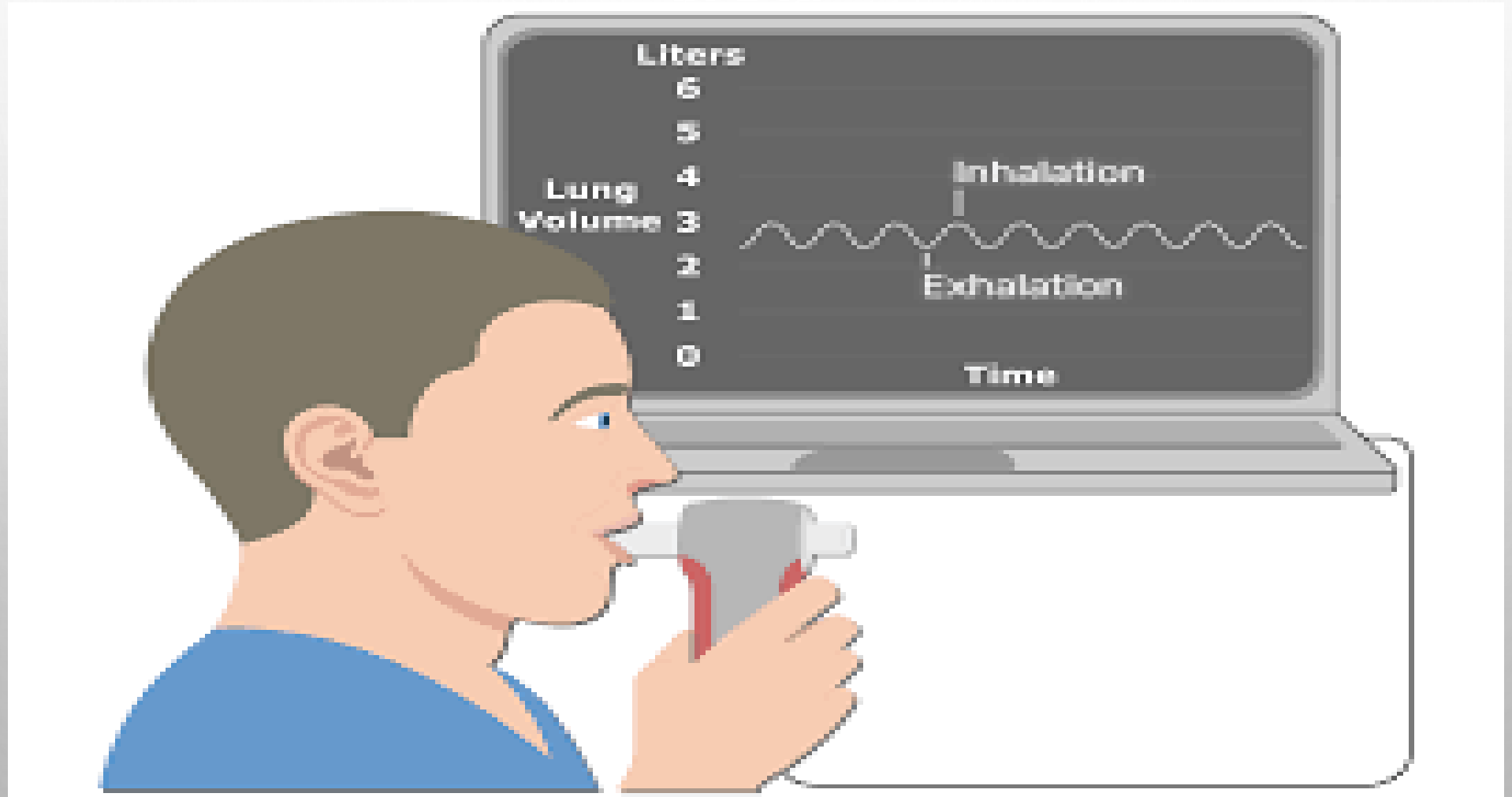
- ✓ Diagnosis of lung diseases.

For this test, the subject breathe into a mouth piece attached to a recording device called (**spirometer**).


Patient takes a deep breath and blows as hard as possible into tube
Clip on nose
Technician monitors and encourages patient during test
Machine records the results of the spirometry test
Volume (L)
Inspiratory Reserve Volume (IRV)
Tidal Volume (TV)
Expiratory Reserve Volume (ERV)
Residual Volume (RV)
Vital Capacity (VC)
Inspiratory Capacity (IC)
Total Lung Capacity (TLC)
Functional Residual Capacity (FRC)
Time

Spirometer

SPIROMETRY
SPIROMETER
SPIROGRAM



- Average healthy adult has 12-16 breaths/min.
- Respiratory volumes are **dependent** on a person's sex, age, size, physical build, and general health.
- **Spirometry** is used for **measuring both static and dynamic lung volumes and capacities**.
- Spirometry data may be **helpful** in the **diagnosis of respiratory disease**.

N.B.

Capacity is the **sum** of **two or more** lung volumes.

Static respiratory (lung) volumes

1. **Tidal volume (TV):**
   - It's the volume of air inspired or expired by **normal** inspiration or expiration.
   - It equals **500 ml.**
2. **Inspiratory reserve volume (IRV):**
   - It's the **maximum** volume of air inspired by maximum deep inspiration **after** normal inspiration (i.e. Tidal volume is excluded).
   - It equals **3000 ml.**
3. **Expiratory reserve volume (ERV):**
   - It's the **maximum** volume of air expired by maximum deep expiration **after** normal expiration (i.e. Tidal volume is excluded).
   - It equals **1000 ml.**

4. Residual volume (RV):

• It’s the volume of air remaining in the lung after maximum deep expiration.

• It equals **1200 ml**.

• RV can’t be measured by spirometry instead it’s measured by **Helium Dilution Method**.

Significance of residual volume (RV):

➢To ensure continuous gas exchange between alveoli and blood even during expiration.

Cause or mechanism:

• The negative intrapleural pressure (-ve IPP) prevents total collapse of the alveoli during maximum expiration maintaining the residual volume of air inside them.

• This volume of air is lost when the thoracic cavity is opened and the -ve IPP is no longer present.

5. Minimal air (or volume):

• It’s the volume of air present in **previously functioning alveoli** even after opening of the thoracic cavity.

• It has **a medico-legal significance**, the lungs of **a stillbirth child** will **sink** in water as it doesn’t contain any air but the lungs of **living-born child** will **float** due to the presence of minimal air.

Static respiratory (lung) capacities:

1. Inspiratory capacity (IC):

• It’s the maximum volume of air inspired by maximum deep inspiration **from midthoracic position** (i.e. Tidal volume is included).

• **It equals TV + IRV = 500 + 3000 = 3500 ml.**

2. Functional residual capacity (FRC) or alveolar air:

- **It's the volume of air present in the lungs after normal expiration.**
- **It equals ERV + RV = 1000 + 1200 = 2200 ml.**
- It **cannot be measured by the spirometer** as it cannot measure the residual volume.

Significance of FRC or alveolar air:

It maintains continuous exchange with pulmonary blood even during expiration → maintaining constant blood gas concentrations during different phases of respiratory cycle (i.e. Without alveolar air, blood O_2 will increase during inspiration and decrease during expiration).

3. Vital capacity (VC):

- **It’s the volume of air expired by maximum deep expiration after maximum deep inspiration.**
- **It equals TV + IRV + ERV = 500 + 3000 + 1000 = 4500 ml.**
- It normally varies with the size of the body. Accordingly, it’s often measured in relation to surface area.

(i.e. In males = 2500 ml/m^2 & in females = 2000 ml/m^2).

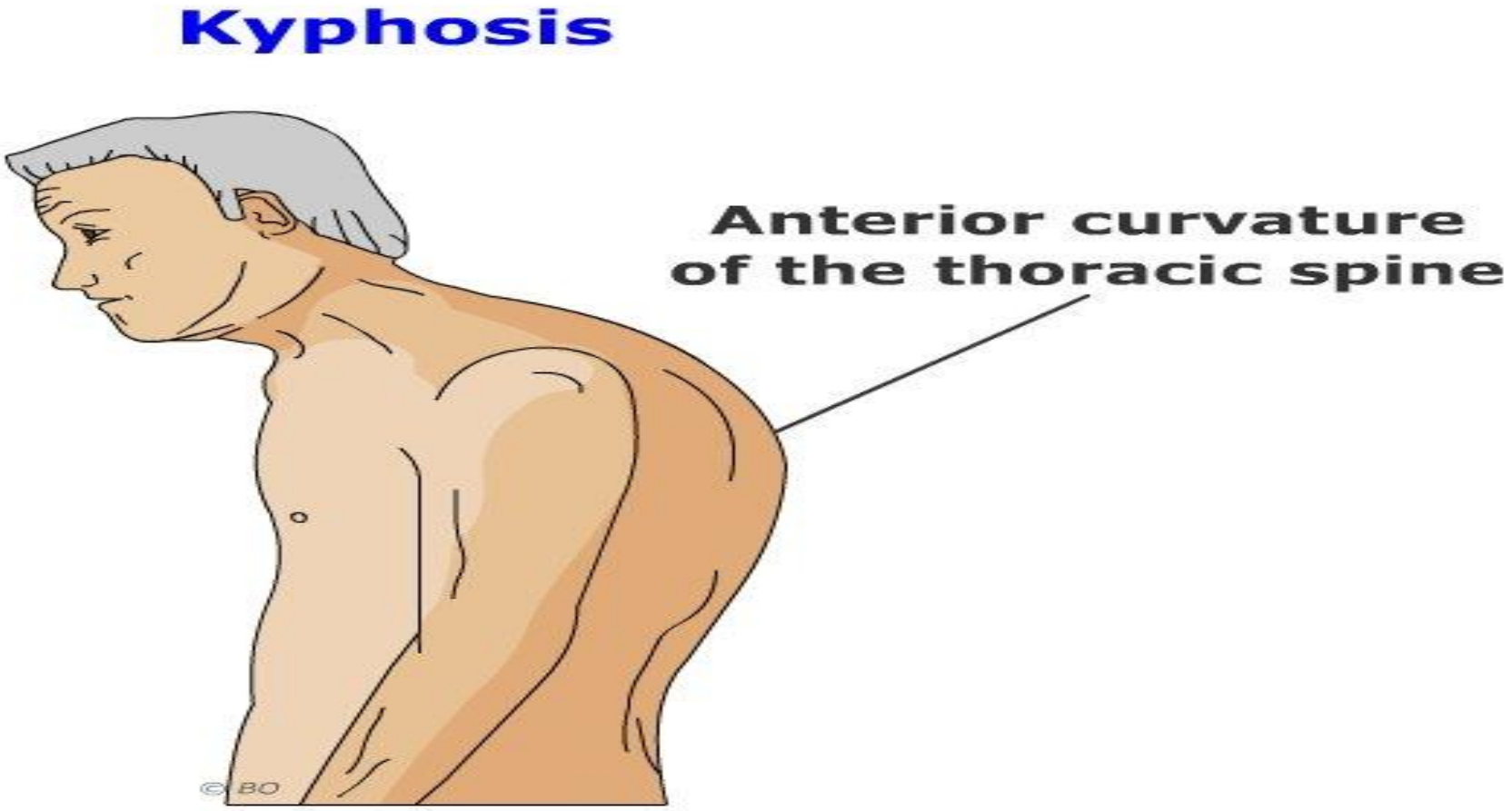
THE VITAL CAPACITY IS A **NON** SPECIFIC PULMONARY TEST !!

FACTORS AFFECTING VITAL CAPACITY (VC):

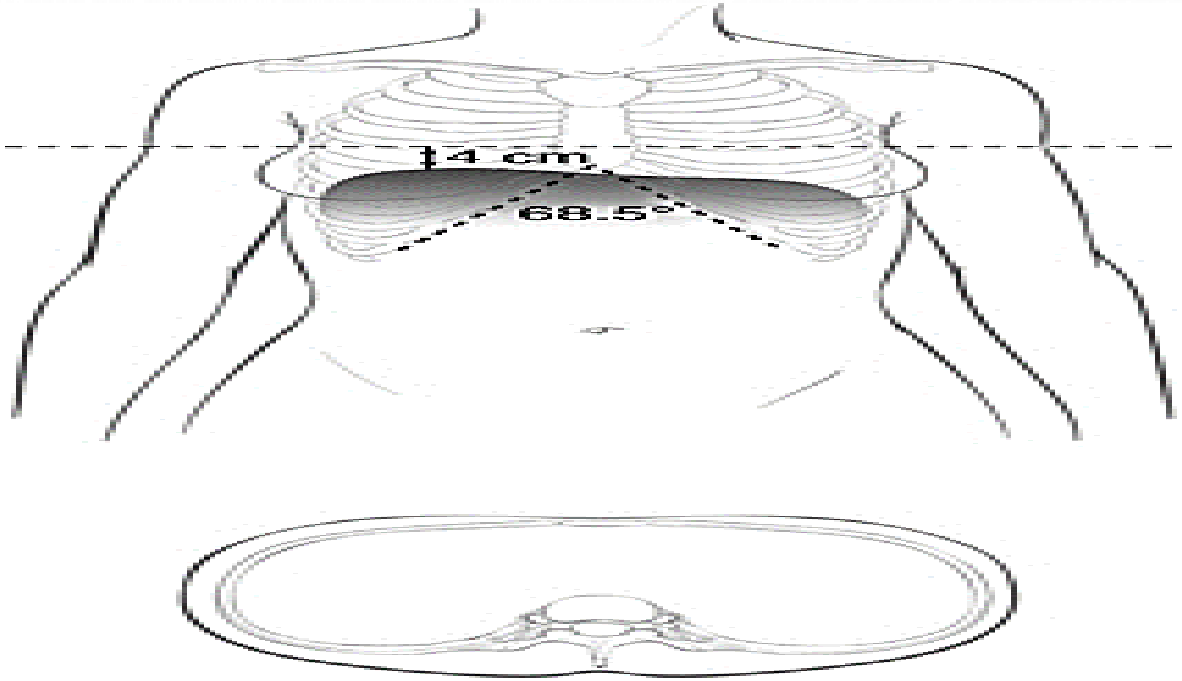
A. Muscle strength:

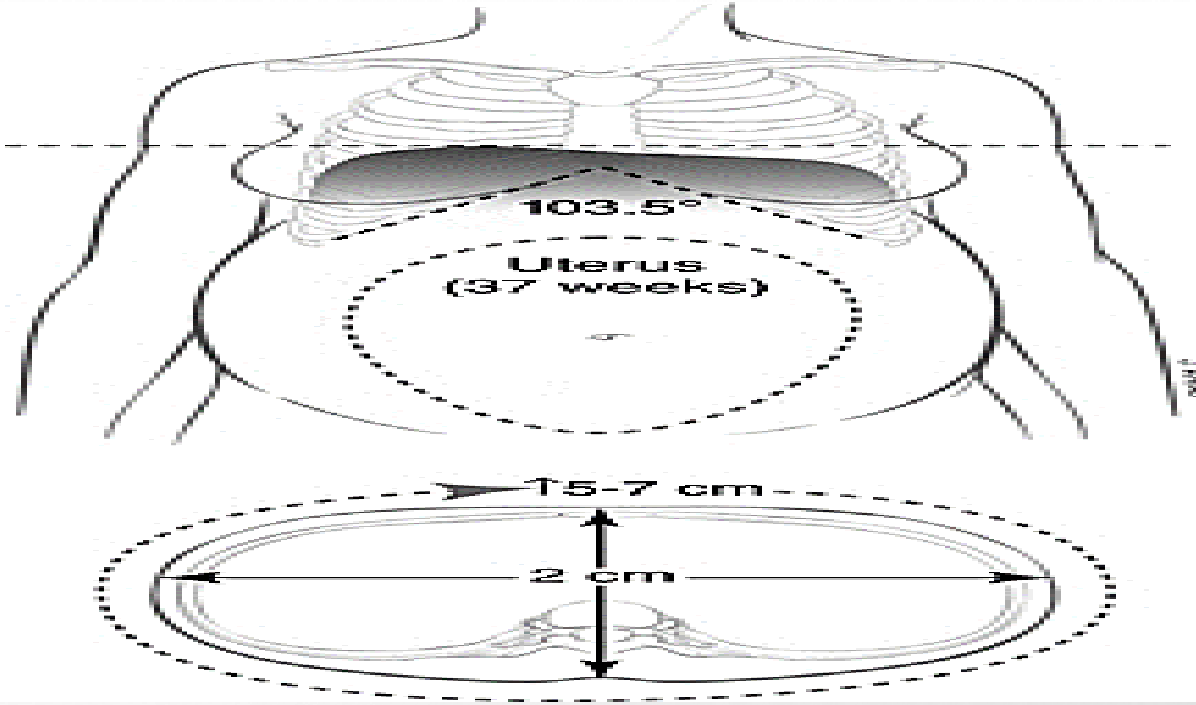
FACTORS AFFECTING VITAL CAPACITY (VC):

B- MOBILITY OF CHEST WALL:



Bloomsbury Osteopathy

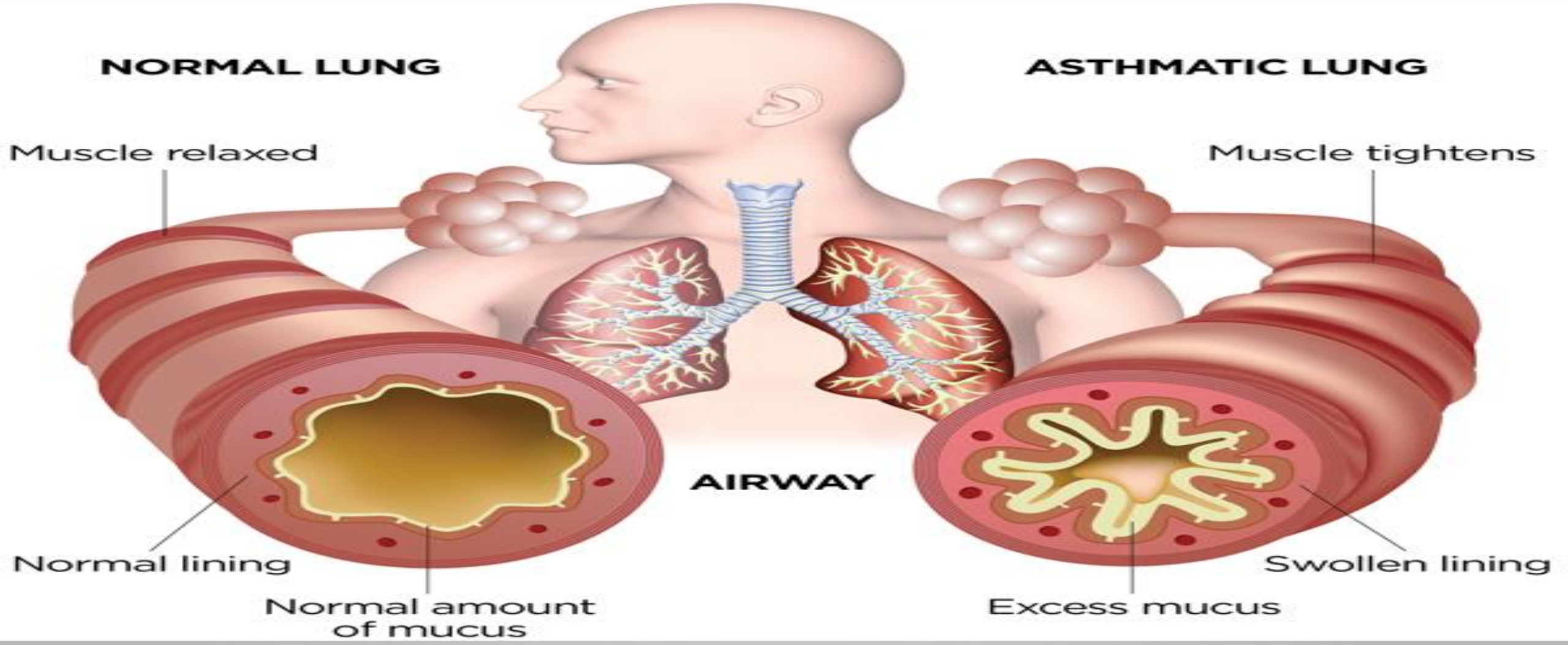




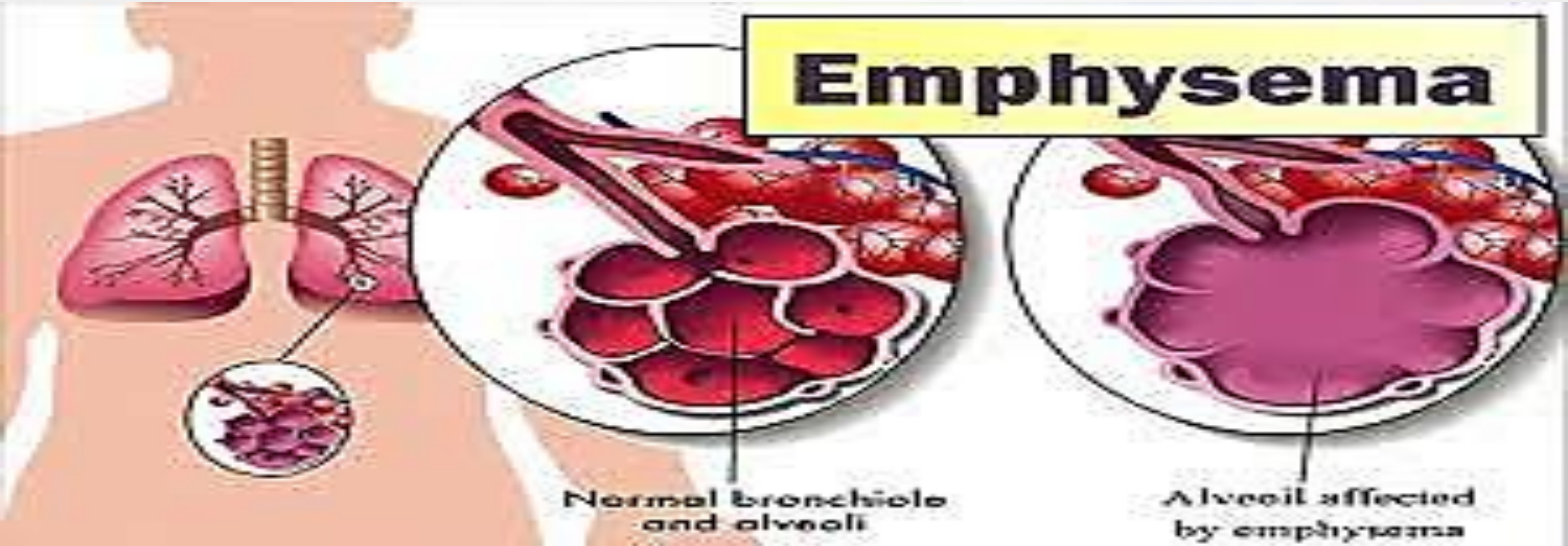
Enlarged spleen and liver
(hepatosplenomegaly)

FACTORS AFFECTING VITAL CAPACITY (VC):

C- PATENCY OF AIRWAYS:

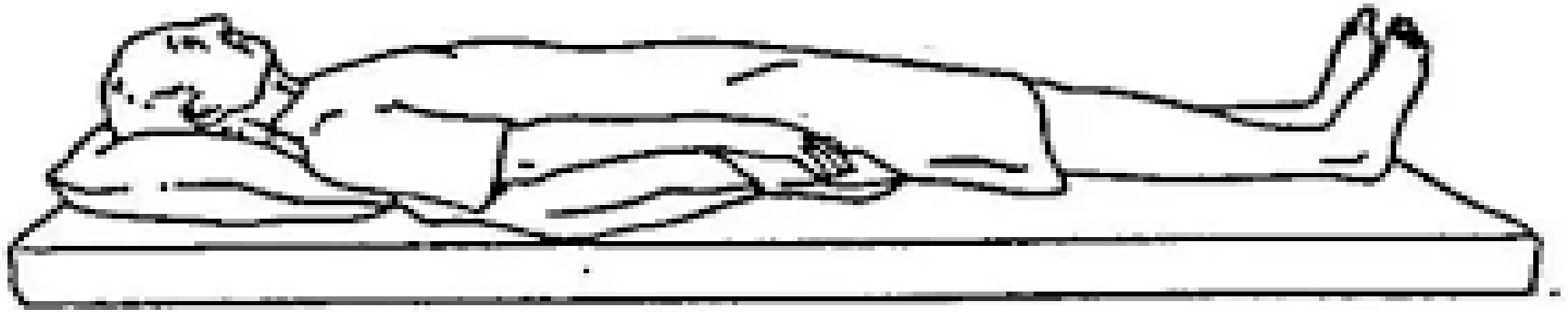


FACTORS AFFECTING VC:
D- ELASTICITY OF THE LUNGS:



FACTORS AFFECTING VC:

E- BODY POSTURE:

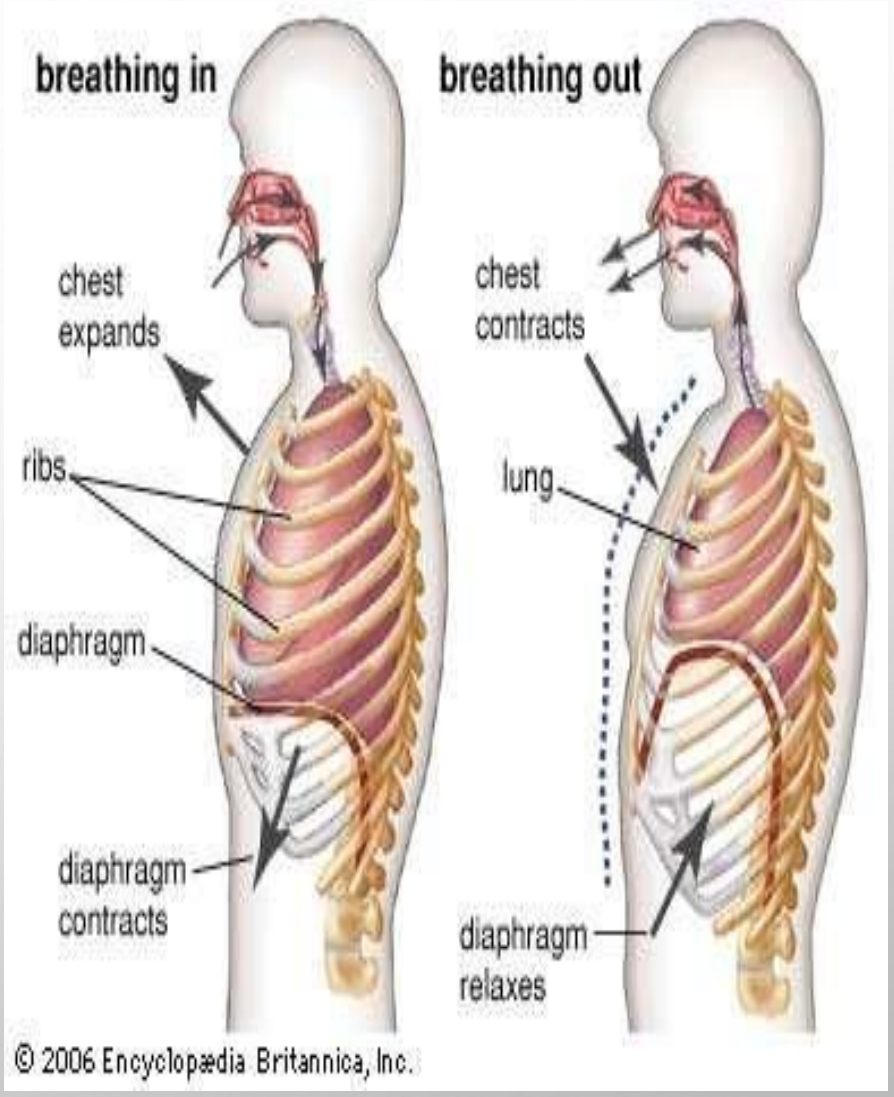


Factors affecting vital capacity (VC)

A) muscle strength: VC is higher in athletes with stronger muscles than in sedentary people.

B) mobility of chest wall: any deformity in the bones of the chest or any abdominal swellings as pregnancy decreasing its mobility lead to decrease in VC

C) patency of airways: decreasing the patency of airways lead to decrease in VC (as in bronchial asthma).



D) elasticity of the lungs: decrease elasticity also decrease VC (as in emphysema in smokers).

E) body posture: VC is higher in standing than in recumbent due to:

✓ In recumbent position ➡ abdominal viscera push the diaphragm upwards ➡ decreasing chest mobility ➡ decrease VC.

✓ In recumbent position ➡ increase venous return ➡ lung congestion with blood ➡ decrease air entering the alveoli ➡ decrease VC.

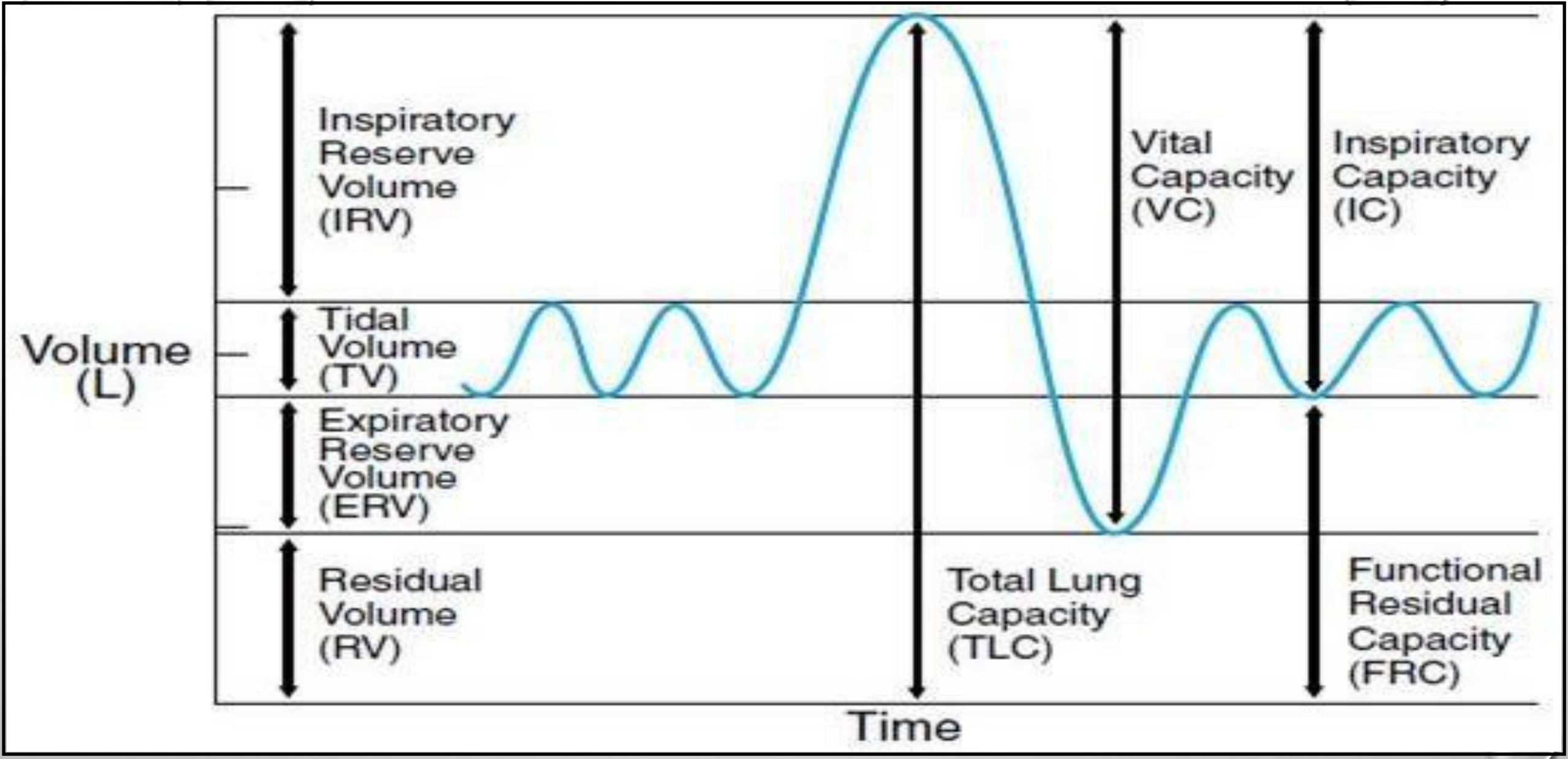
N.B. Orthopnea:

· It means **difficulty** of breathing on lying down which **improves** on **sitting or standing**. It is **marked**

In left sided heart failure**. Mechanism:** due to the **exaggerated** effect of posture on vital capacity.

4. Total lung capacity (TLC):

- **It’s the maximum volume of air present in the lungs after maximum deep inspiration,**
- **It includes all lung volumes (TV+IRV+ERV+RV) OR (VC + RV) = 4500 + 1200 = 5700 ml.**
- **It cannot be measured by the spirometer** (as it cannot measure the residual volume).


Volume (L)
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Spirogram.

Dynamic lung volumes & capacities:

- The term dynamic refers to lung volumes or capacities measured in relation to unit of time.
- **Includes:**

1) Timed Vital Capacity (TVC) or (Timed Forced Expiratory Volume or FEV).
2) Ratio of FEV1/FVC.
3) Minute; Total Ventilation or Minute Respiratory Volume (MRV).
4) True (effective; or alveolar) Ventilation (EV).
5) Maximum Breathing Capacity (MBC) or Maximum Voluntary Ventilation (MVV).
6) The Breathing Reserve (BR).

Dynamic lung volumes & capacities:

1. Timed vital capacity (TVC) or (timed forced expiratory volume or FEV):

- The vital capacity is **a nonspecific pulmonary function test** due to its affection by many factors.
- In bronchial obstruction, the vital capacity may be normal but the duration of expiration is

Prolonged.

- To take the expiration time into consideration, the timed vital capacity (TVC) is measured where the forced expiratory volume (**FEV is measured every second** during forced expiration till the end of expiration).

- Normally, the **FEV** (also called forced vital capacity; **FVC**) is completely expired in about **four seconds** as follows:

- **FEV1** = forced expiratory volume after the **first second** is about **83 %** of the total FVC. (Normal average 70-80% of FVC).

- **FEV2** = forced expiratory volume after the **second second** is about **94 %** of the total FVC.

- **FEV3** = forced expiratory volume after the **third second** is about **97%** of the total FVC.

- **FEV4** = forced expiratory volume after the **fourth second** is about **100%** of the total FVC.

N.B.

In obstructive airway diseases, (e.g. in bronchial asthma),

- ✓ **Although the forced vital capacity (i.e. FVC) may be normal.**
- ✓ **The timed vital capacity; FEV1 or 2, 3, 4 FVC is markedly reduced.**

2. Ratio of FEV1/FVC:

- It is calculated by dividing the volume of FVC expired in the 1st second (FEV1) by the total FVC.
- Normally = **0.7 – 0.8** (i.e. 70-80%)
- **Decreased** in **obstructive** lung diseases (e.g. **Asthma**) .

Example:

- **Calculate the FEV1/FVC ratio knowing that the total FVC is 5L and the person expired about 4L of his FVC in the 1st second.**

✓ **Solution:**

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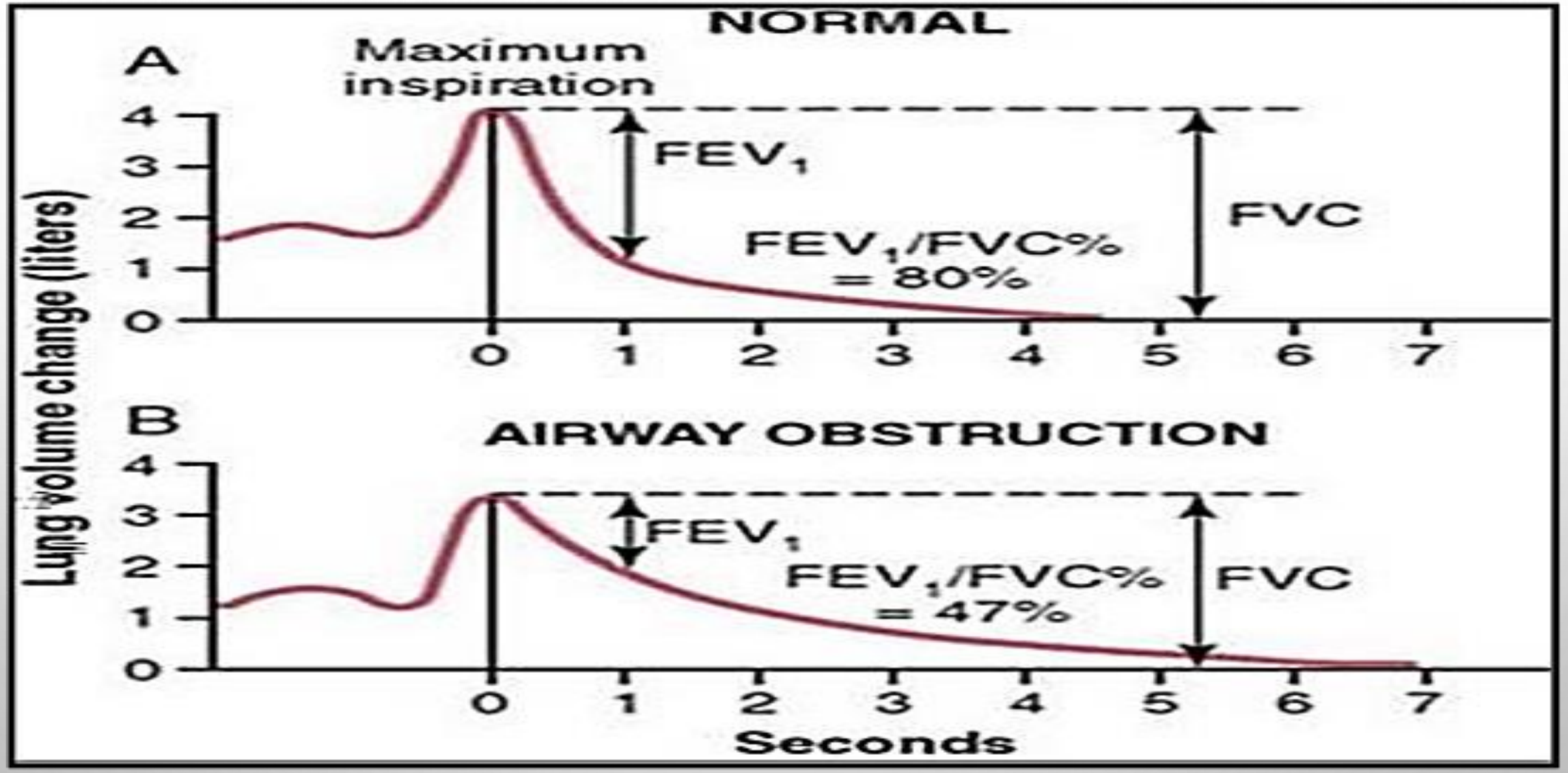
✓ **Solution:**

The FEV1/FVC ratio = 4/5 = 0.8 (i.e. 80%)



Forced vital capacity (FVC) and FEV1 in normal versus asthmatic patient

3. Minute; total ventilaation or minute respiratory volume (MRV):

- **It is the volume of air breathed/minute.**
- It equals = **tidal volume x respiratory rate** = 500 x 12 = **6000 ml (6L) /minute**.

4. True (effective; or alveolar) ventilation (EV):

- It is **the volume of air that enters the alveoli and undergoes gas exchange with blood/ minute.**
- EV = **(tidal volume - dead space) x respiratory rate**.

= (500-150) x 12 = 350 x 12 = **4200 ml (4.2L) /minute**.

Significance:

- **The EV is more significant than MRV.**

In shallow rapid breathing (Tachypnea), the **rate of respiration may be doubled 24 cycle/minute**, the **tidal volume is decreased, may be 250 ml**, accordingly,

- The minute ventilation will be 24 X 250= 6000ml/minute (i.e. Normal), while true ventilation will be; (250-150) x 24 = 2400ml/minute, which is very much reduced as compared to normal values.

5. Maximum breathing capacity (MBC) or maximum voluntary ventilation (MVV):

- It is **the maximal volume of air breathed/ minute** when respiration is as **fast** and as **deep** as the person can.
- Or it is **the maximal volume of air breathed/ minute** when the **subject repeats his vital capacity as rapid as he can**.

Measurement:

We ask the person to breathe as rapid and as deep as he can (i.e. Maximal effort) for **1/4 of a minute**.

Then, the volume of air breathed during this time is multiplied by 4 to calculate the volume of air during a whole minute.

N.B.

- We cannot allow the subject to do the maximal effort for a whole minute. WHY?

As this hyperventilation leads to → excessive wash of CO_2 (i.e. Hypocapnia and alkalosis and may be tetany) → inhibition of respiratory centers.

Normal values of MBC:

- In **adult males**, it is about **80-160 L /minute**.
- In **adult females**, it is about **60- 120 L/minute**.

N.B. MBC is the best test to assess the strength of respiratory muscles.

6. The breathing reserve (BR):

BR = maximum breathing capacity (MBC) - minute ventilation (MRV).

Significance:

- **Used for calculation of dyspneic index (DI).**
- **The dyspneic index (DI) =**

$$\frac{\text{Maximum breathing capacity - minute ventilation (BR)}}{\text{Maximum breathing capacity (MBC)}}$$

- Normally, **DI** is about **90 %**.
- when D.I. < 70 %, dyspnea occurs on slight effort.

RECALL INFORMATION

IMPORTANT REMARKS:

Obstructive lung diseases:

- Also, they are referred to as chronic obstructive pulmonary diseases or COPD (e.g. Emphysema, chronic bronchitis, asthma, and bronchiectasis).
- These diseases are characterized by **air outflow obstruction (with/without inflow obstruction)** and Subsequent **air trapping within the lungs**.
- Diagnosed by dynamic testes of spirometry.
- Pulmonary function testing (PFTs) shows;

1. A markedly decreased FEV1 and decreased FVC (although possibly normal).
2. **The hallmark of obstructive lung disease is a decreased FEV1/FVC ratio (i.e. < 0.7 or 70%)**
3. **RV, FRC and TLC are increased because of air trapping.**

Restrictive lung diseases:

- Restrictive lung diseases may be caused by either **pulmonary causes (i.e. Lung fibrosis as TB) or extrapulmonary causes (e.g. Chest deformity as kyphosis)**.
- They are characterized by **reduced lung expansion (i.e. Decreased lung volume)**.
- TLC and RV are reduced. In turn, FEV1 and FVC are also decreased.
- **FEV1 and FVC decrease proportionately, resulting in a normal FEV1/FVC, or sometimes FVC is decreased to a greater degree than FEV1, resulting in an increased FEV1/FVC (i.e. ≥ 0.7 or 70%)**

Lung Volumes in Restrictive Versus Obstructive Disease

	RV	FRC	TLC	FVC	FEV1	FEV1/FVC
Obstructive	↑↑	↑	↑	↓	↓↓	↓
Restrictive	↓	↓	↓	↓↓	↓	↑ or normal

Where, FEV1, forced expiratory volume in 1 second; FRC, functional residual capacity; FVC, forced vital capacity; RV, residual volume; TLC, total lung capacity.


THANK YOU