✓ This file contains both the **SLIDES** and **HANDOUT**.
✓ Handout is very important

Spirometry

Objectives:

- ✓ Describe how a bell-type spirometer is used to measure lung volumes and capacities.
- ✓ List and define the different lung volumes and capacities.
- ✓ State the normal values of each lung volume and capacity.
- ✓ Discuss the physiological and pathological factors that may affect the different lung volumes and capacities.
- ✓ Perform a dynamic spirometry test on a fellow student.
- ✓ Describe the two graphs recorded by dynamic spirometry, namely: flow-volume loop (FVL) and the volume-time curve (forced expiratory curve "FEV1" curve forced expiratory curve (FEV1 curve).
- ✓ Analyze the components of each graph; FVL and FEV1 and describe their normal appearance.
- ✓ Calculate the forced expiratory volume in the first second (FEV1) and forced vital capacity (FVC) and the FEV1/FVC ratio from the FEV1 curve.
- ✓ Calculate the FVC, peak expiratory flow rate (PEFR), peak inspiratory flow rate (PIFR) and maximal expiratory flow rate at 50% of the forced vital capacity (MEF50).
- ✓ Analyze the components of each graph in both obstructive and restrictive lung diseases
- ✓ Differentiate between both obstructive and restrictive lung diseases

What is spirometry ?

It's a pulmonary function test that measures lung volumes and capacities.

Equipments

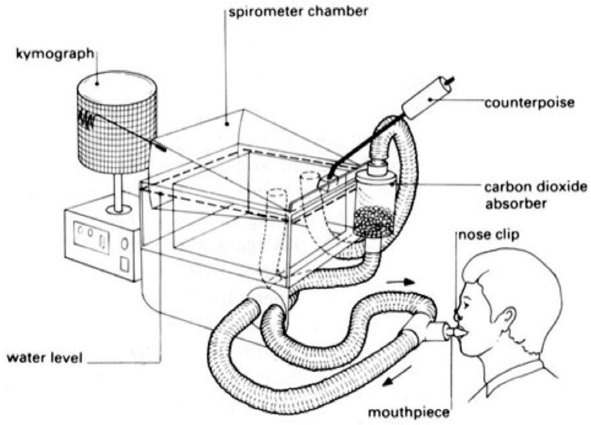
- Simple spirometer (many types are available, Bell-type spirometer or water-gauge spirometer)
- Disposable mouthpiece.
- Nose clip.

★ The subject breaths through a mouthpiece while a nose clip is placed on the nose to <u>avoid air escaping through the nose.</u>

★ While breathing, air moves in and out of the spirometer chamber causing displacement in the pen attached to it surface.

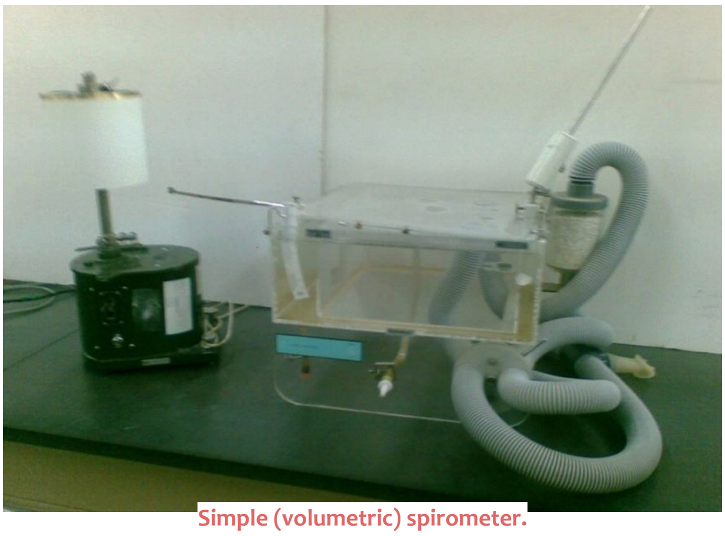
★ The moving pen draws the spirometry graph on the <u>kymograph</u>.

★ The degree of displacement is proportional to the volume of air moving in and out of the lungs. With proper calibration, the volume of air moving in and out of the lungs can be calculated.



Procedure

1. Insert the mouthpiece in the subject's mouth.
2. Place the nose clip on the subject's nose.
3. Ask the subject to take normal breaths through the mouthpiece for a short while.
4. After recording few normal breaths, ask the subject to take a deep forceful inspiration filling their lungs to their maximum ability, then exhale gently and follow it with few normal breaths.
5. Then ask the subject to expire quickly, forcibly and as completely as possible Followed by an inhalation and a period of normal breathing.
6. Finally, ask the subject to take a deep forceful inspiration and to follow it immediately with maximum quick and forceful expiration. Once this is complete,
   ask the subject to breath normally for a short time.
7. The spirogram is recorded on a moving drum.



Simple (volumetric) spirometer.

★ The air in the lungs can be subdivided on this diagram into **4** volumes and **4** capacities:

Lung Volumes

RESIDUAL VOLUME (RV)

The volume of air **remaining** in the lungs after the most forceful expiration.

= 1200ml or 1.2 L

EXPIRATORY RESERVE VOLUME (ERV)

The extra volume of air that can be **expired** by forceful expiration after the end of a normal tidal expiration.

= 1100 ml or 1.1 L

male=1000ml ,female=700 ml

INSPIRATORY RESERVE VOLUME (IRV)

The extra volume of air that can be **inspired** by a maximal inspiratory effort after normal inspiration.

= 3000 ml or 3 L

male=3.3 L ,female=1.9 L

TIDAL VOLUME (TV)

Volume of air inspired or expired during **normal** (quiet) breathing L

= 500 ml or 0.5 L

(male and female)

Lung Capacities

TOTAL LUNG CAPACITY (TLC)

Is the maximum volume to which the lungs can be expanded with the greatest possible effort

= 5800 ml or 5.8 L

=VC + RV

VITAL CAPACITY (VC)

The volume of air that can be maximally expired after maximum inspiration.

= 4600 ml or 4.6 L

male=4.8 L ,female=3.1 L

= TV + IRV + ERV

FUNCTIONAL RESIDUAL CAPACITY (FRC)

The amount of air that remains in the lungs at the end of normal expiration.

= 2300 ml or 2.3 L

ERV + RV

INSPIRATORY CAPACITY (IC)

Volume of air inspired by a maximal inspiratory effort after normal expiration.

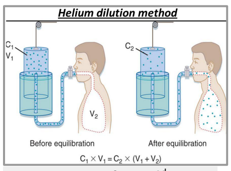
= 3500 ml or 3.5 L

male=3.8 L ,female=2.4 L

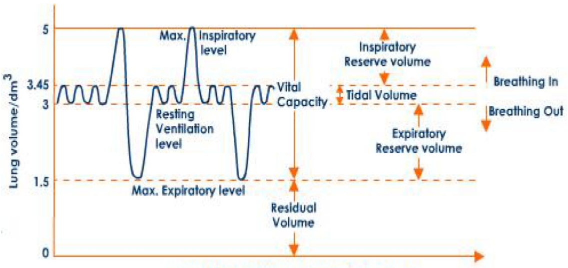
TV + IRV

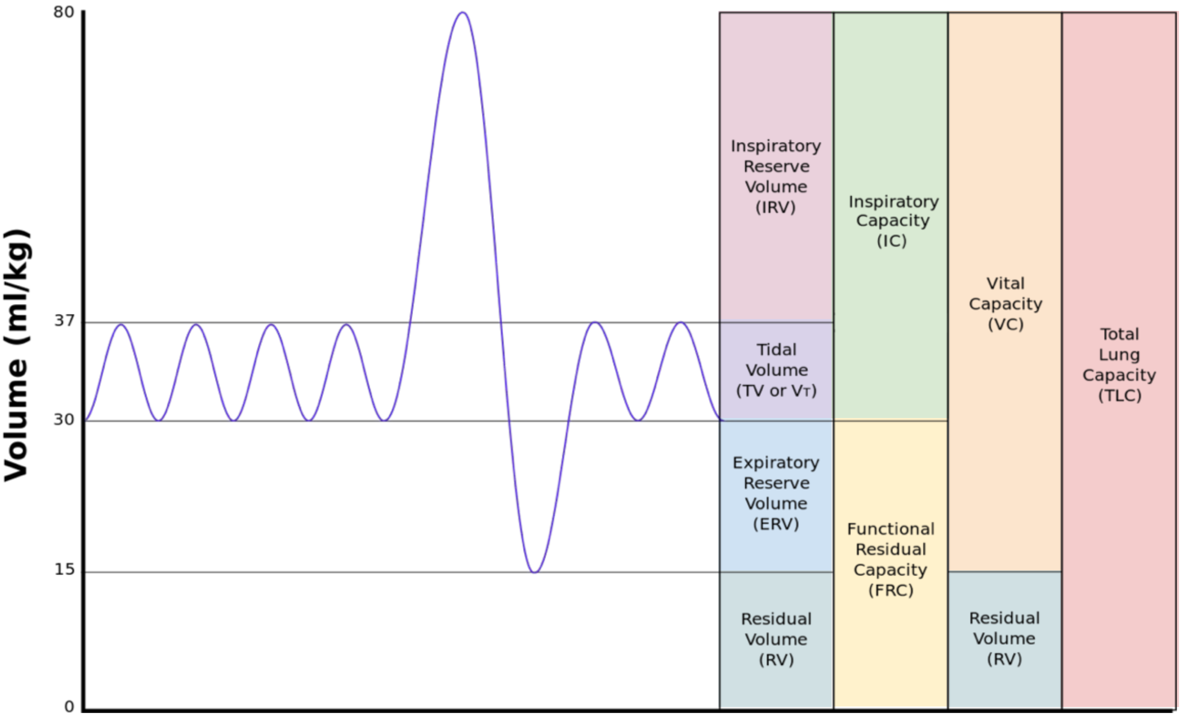
RV & FRC cannot be measured directly by Spirometry but measured by

Helium dilution method



→ Recall from 3ed lecture





factors affecting lung **volumes (V)** and **capacities (C)**	
Physiological factors	**Pathological factors**
• Age: -↑ RV, ↑ FRC with ↑ age -↓ VC with age • Sex: female 20-25% less VC than males. • Body size Obese : ↓ VC ↓ FRC because there's ↑ elastic recoil of the lungs • Athletes:↑ VC	**Restrictive Lung diseases** e.g. Alveolar Fibrosis - Reduce the compliance of the lungs compressed lung volumes ➔ ↓ VC, ↓ IRV, ↓ ERV, ↓ RV, ↓ TV ➔ ↑ breathing frequency **Obstructive Lung diseases** e.g. Emphysema - ↑ resistance to airflow ➔ ↑ TLC, ↑ FRC, ↑ RV, ↑ TV ➔ ↓ VC, ↓ ERV

Dynamic Spirometry

It's the most basic and frequently performed test of pulmonary (lung) function and concerned with the measurement of flow and volume of air entering and leaving the lungs.

- Performed at forcible and max effort against **time**
- Measures the **rate** at which the lung changes volume <u>during forced breathing.</u>

Equipments

- Dynamic spirometer
- Disposable mouthpiece.
- Nose clip.

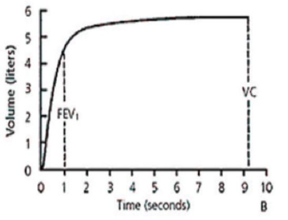
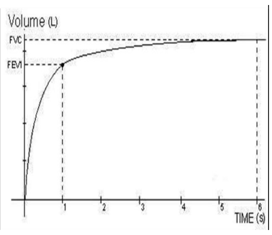
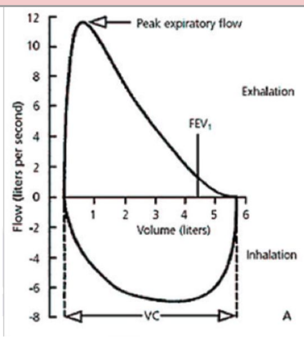
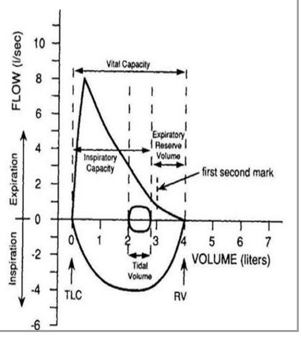
Procedure

1. Insert a new disposable mouthpiece into the flow sensor (SP-250).
2. Hold the sensor in an upright position.
3. Insert the mouthpiece in the oral cavity (mouth) and seal the lips tightly around the mouthpiece.
4. Place the nose clip on the subject's nose to avoid air escaping through nostrils.
5. While subject is standing, allow him/her to breathe normally through mouthpiece, approximately 3 normal breaths to record TV.
6. Then ask the subject to inhale as deep as possible and then follow it with a fast and forceful exhalation. The exhalation should be as fast and forceful as possible.
7. Two types of graphs may be recorded.

Dynamic Spirometer

★ Dynamic test

Two types of curves can be obtained:

Forced Expiratory Volume	Flow Volume Curve
 	 

Forced Expiratory Curve

- The subject takes a maximal inspiration and then exhales as rapidly, as forcibly as maximally as possible in short time approximately 3-5 seconds.
- A plot of volume against time.

Before you see the curve you should know some values:

- FEV1

Volume of air expelled in the 1st sec of forced expiration starting from full inspiration

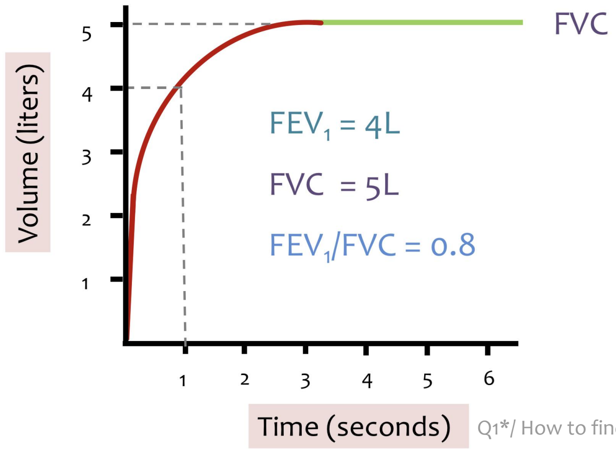
- Plateau: Forced Vital Capacity FVC

The max volume of air that can be forcibly and rapidly exhaled following a max inspiration.

- FEV1 % or ratio

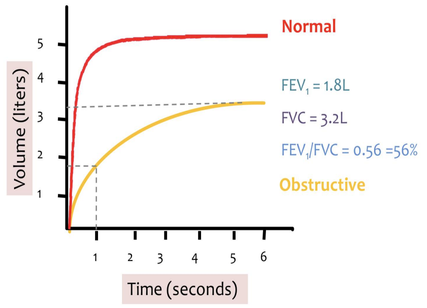
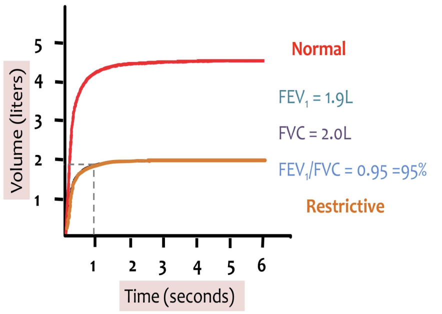
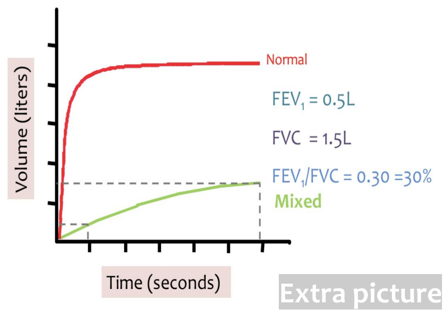
(FEV1/FVC) * 100 Fraction of the VC expired during the 1st sec of a forced expiration (NL 70%-80%) - FEV1 is a useful measure of how quickly the lungs can be emptied. -

➔ The ratio is a useful index of airflow limitation.



Q1*/ How to find the values based on the curve?

Parameter	Normal value (ATS "American Thoracic Society",/ERS "European Respiratory Society")
FEV1	≥ 70% (% predicted FEV1)
FVC	≥ 70% (% predicted FVC)
FEV1 % or ratio	≥ 70% (0.7)

<table>
<tr><th colspan="9">The curve helps (find the abnormalities or diagnose the diseases)</th></tr>
<tr><th colspan="3">Obstructive Lungs Disease</th><th colspan="3">Restrictive Lungs Disease</th><th colspan="3">Mixed</th></tr>
<tr><td colspan="3">
</td><td colspan="3">
</td><td colspan="3">
Extra picture</td></tr>
<tr><td>FEV1 = ↓↓↓</td><td>FVC = Normal or ↓</td><td>FEV1/FVC = < 0.7</td><td>FEV1 = Normal or ↓</td><td>FVC = ↓↓↓</td><td>FEV1/FVC = Normal or > 0.7</td><td>FEV1 = ↓↓</td><td>FVC = ↓↓↓</td><td>FEV1/FVC = variable</td></tr>
</table>

1* Mark the first second in X-axis and draw an imaginary vertical line from this mark till it reaches the curve. From there on, draw an imaginary horizontal line towards the vertical axis and see the value to which it ends. That will be your (FEV1) value.
Look where the curve becomes straight line at the top, then take that straight line left towards the vertical axis where it shows the units in liters and see what value it is leading to and that will be your forced vital capacity (FVC).

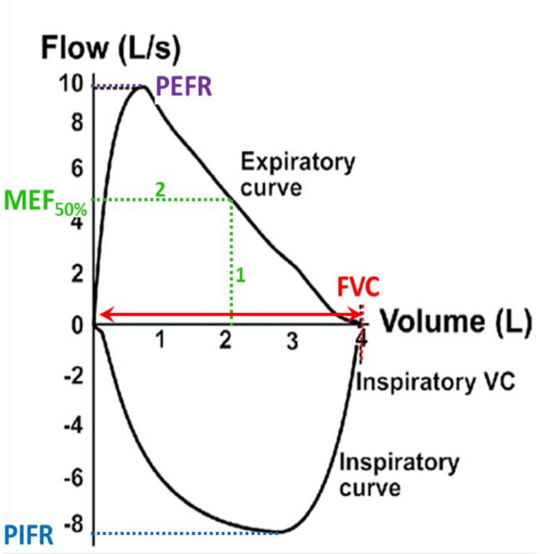
Flow Volume Loop

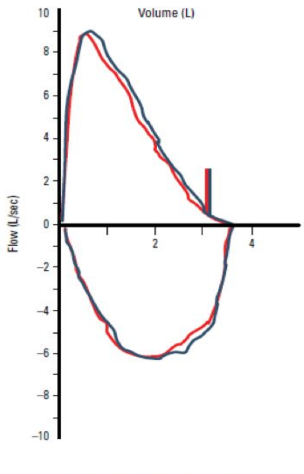
- This measures expiration & inspiration flow as a function of exhaled volume rather than against time.

Before you see the curve you should know some values:

Measurements on flow V loop:

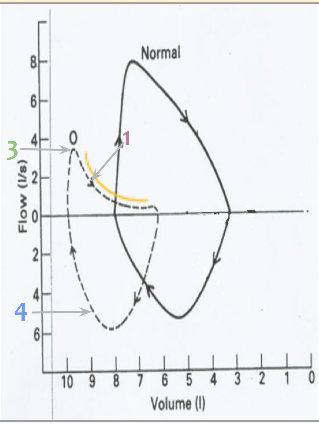
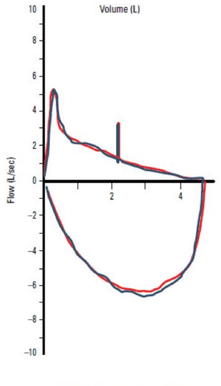
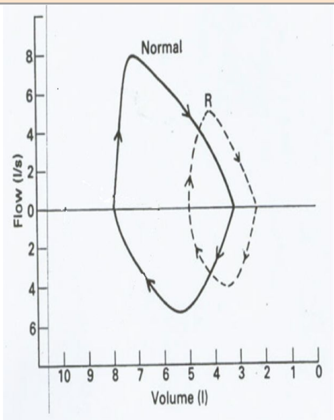
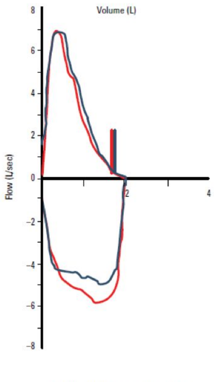
- PEFR "Peak Expiratory Flow Rate": Greatest flow achieved during forceful expiratory effort
  → =6- 12 L/sec
- PIFR "Peak Inspiratory Flow Rate": max flow speed achieved during forceful inspiratory effort
  → =6-12 L/sec
- MEF_{50}: max expiratory flow at 50% of FVC
- FVC = 4-6 L it can be measured over the **X-axis** **(not like Forced Expiratory Curve)**





Normal flow volume loop

Q1*/ How to find the values based on the curve?

The curve helps (find the abnormalities or diagnose the diseases)	
Obstructive Lungs Disease	Restrictive Lungs Disease
  Flow volume loop showing an obstructive ventilatory defect	  Flow volume loop showing a restrictive ventilatory defect
1- MEF50 ↓ 2- Effort independent part of curve: concave (Curvilinear) 3- PEFR normal or↓in severe cases 4- Inspiratory loop Normal	**1-** Miniature loop (elliptical) **2-** All flow parameters ↓

1* PEFR: It is measured over the Y-axis. Look at the Expiratory loop and draw an imaginary horizontal line towards Y-axis. The value at which this imaginary line crosses the Y-axis, that value will be your (PEFR).

PIFR: Same as PEFR but in the inspiratory loop

MEF50: First mark the 50% of the FVC on the X-axis. Then draw a vertical imaginary line till it meets the declining expiratory loop. From here on, draw a horizontal imaginary line towards left till it reaches the Y-axis. Look at the value of Y-axis, at which this line ends; that value will be your MEF50.

HANDOUT

1. **Define the following terms and state/calculate their values from the data collected in the lab:**

a. Tidal Volume(TV): Volume of air inspired or expired during normal (quiet) breathing

b. Expiratory reserve volume (ERV): The extra volume of air that can be **expired** by forceful expiration after the end of a normal tidal expiration.

c. Inspiratory Reserve Volume(IRV): The extra volume of air that can be **inspired** by a maximal inspiratory effort after normal inspiration.

d. Vital Capacity(VC): The volume of air that can be maximally expired after maximum inspiration.

e. Inspiratory Capacity(IC): Volume of air inspired by a maximal inspiratory effort after normal expiration.

2. **Name a few physiological factors that may influence lung volumes and capacities and how do they exert their effects?**
   - Age, Gender, Body size and Athletes

3. **Lung volumes and capacities are altered in a variety of pathological conditions. Name a few and explain how do these conditions bring about the changes are in lung volumes and capacities.**

I. Restrictive Lung diseases

- Reduce the compliance of the lungs and compressed the lung volumes
- ↓ VC, ↓ IRV, ↓ ERV, ↓ RV, ↓ TV

II. Obstructive Lung diseases

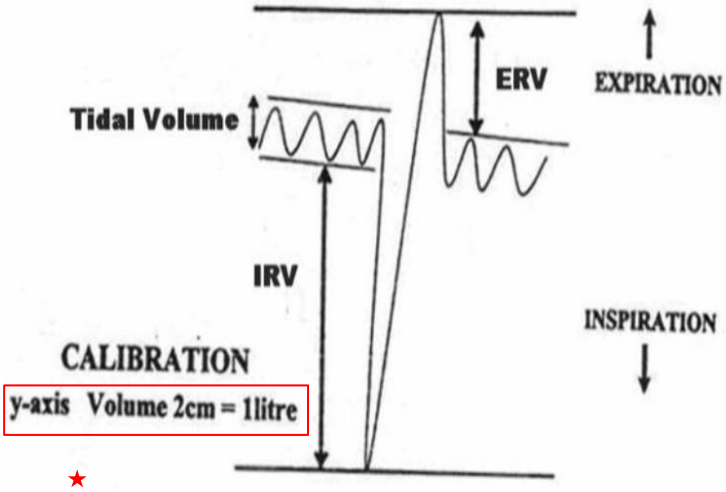
- Increases resistance to airflow
- ↑ TLC, ↑ FRC, ↑ RV, ↑ TV, ↓ VC, ↓ ERV

4. **What is the physiological significance of the residual volume and the functional residual capacity?**
   - They prevent the lungs from collapsing.
   - They maintain a continuous gas exchange between the breaths.
   - They make the work of breathing easier.

5. **Residual volume cannot be directly measured by spirometry. What is the technique that can be used to measure it?**
   - Helium dilution technique

6. **Using a simple ruler and the calibration provided in the graph, calculate the TV, IRV, ERV and VC from the graph below.**

Parameter	Volume in liters
TV	500 ml
IRV	3000 ml
ERV	1100 ml
VC	4600 ml

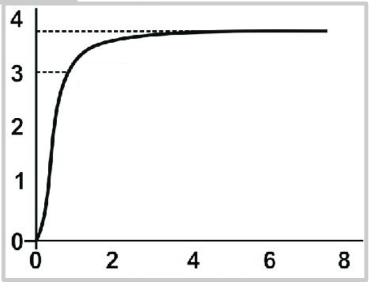


★ You have to see for two things when there is a curve:
1/The key of the curve calibration (ex: ..cm=..liters)
2/The direction of expiration and inspiration

1. **From the FEV1 curve produced in the lab, what is the value of the following:**

Parameter	Values	
	Liters	% predicted
FEV1	3L	≥ 70%
FVC	4L	≥ 70%
FEV1/FVC ratio	0.75	≥ 70%

Extra (for practicing)



2. **What is the expected normal value for FEV1 in a normal person?**
- 70-80%

3. **How long does it take for healthy subjects to expire approximately 70% of their vital capacity?**
- 1 second

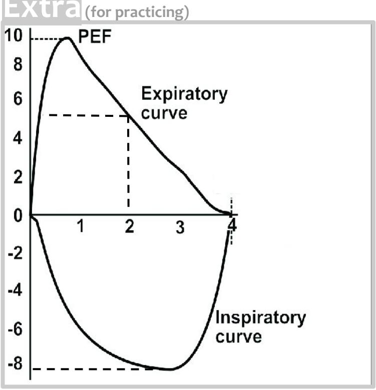
4. **Briefly explain what happens to FVC, FEV1 and FEV1 % measurements in patients with obstructive and restrictive lung diseases.**

Parameter	Normal	Obstructive	Restrictive
FEV1	≥ 70% predicted	↓ 3L	Normal or ↓
FVC	≥ 70% predicted	Normal or ↓2L	↓↓↓ 2L
FEV1 % or ratio	≥ 70% (0.7)	< 70%	> 80 %

5. **From the flow volume loop recorded, what is the value of the following parameters:**

Parameter	Values	
	Liters	% predicted
PEFR	10 L/sec	≥ 70%
PIFR	8.1 L/sec	≥ 70%
FVC	4 L	≥ 70%
$MEF_{50\%}$	5 L/sec	≥ 70%

Extra (for practicing)



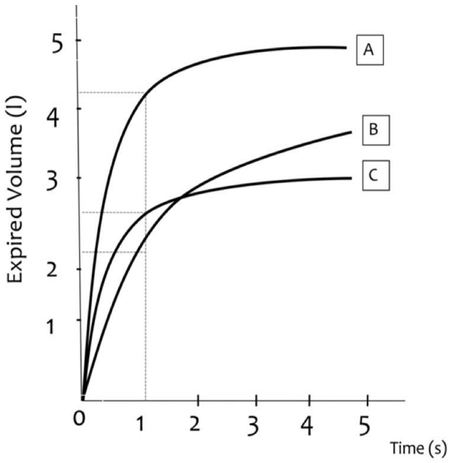
6. **Briefly describe the important characteristics of the flow-volume curve recorded in a normal healthy person.**
- It has an upward expiratory loop and a downward inspiratory loop. The expiratory loop has a rising phase and a falling phase. The rising phase is force-dependent, as the air comes out with force from the larger airways due to the contraction of expiratory muscles. The falling phase is force-independent as the air comes out from the smaller airways without any force due to the elastic recoil of the lungs.

7. **Why is the force-independent part of the expiratory loop curvilinear in obstructive lung disease?**
- Because the smaller airways are narrowed due to either spasm or accumulation of secretions, they provide resistance to the airflow during expiration; therefore, the airflow slows down and the force-independent part of the expiratory loop becomes curvilinear

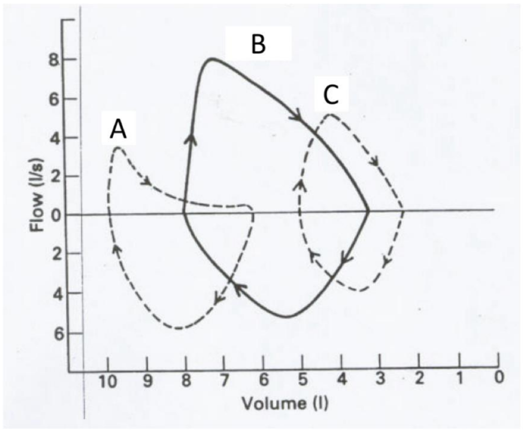
1. **What is the clinical significance of MEF50 measurements?**
- MEF50 becomes greatly reduced in obstructive lung diseases (less than 4 L/sec).

★ Dynamic Spirometry was done on 3 patients, the results were the following:
A. FEV1= 4L , FVC=5L FEV1/FVC=80%
B. FEV1=1.2L , FVC=3L FEV1/FVC=40%
C. FEV1= 2.7 L, FVC=3L FEV1/FVC= 90%

★ Answers
A. Normal
B. Obstructive lung diseases
C. Restrictive lung diseases



Answers:
A/ normal lung
B/ Obstructive lungs diseases
C/ Restrictive Lungs diseases



Answers:
A/ Obstructive lungs diseases
B/ normal lung
C/ Restrictive Lungs diseases

SUMMARY

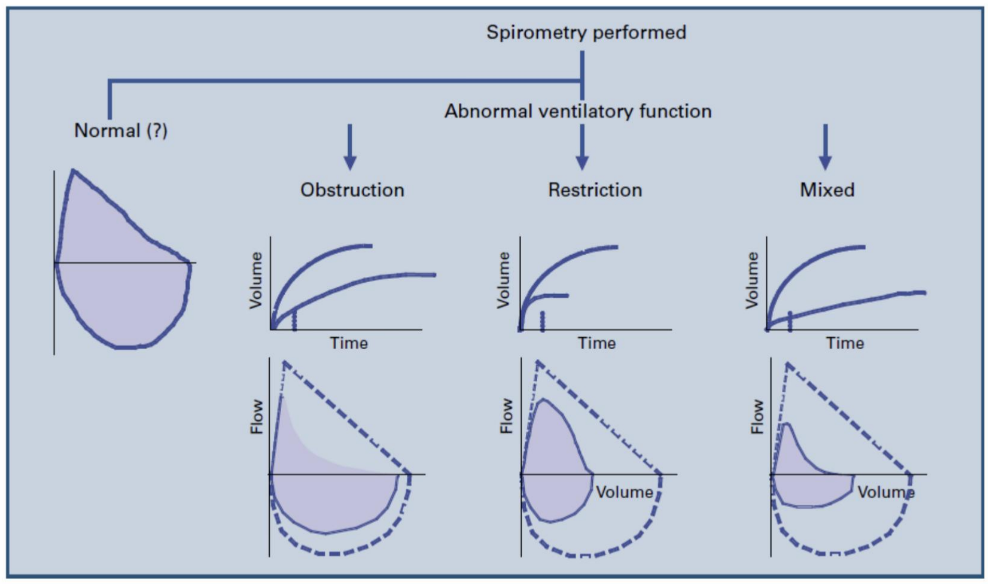


Figure 15. Typical spirograms and FVL in different ventilatory conditions (5).

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