Respiratory module

Session 3: **Mechanics of Breathing**

Lecture 2: **Lung Function testing**

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Objectives

- explain common tests of lung function including simple spirometry
- describe the measurement of forced vital capacity (FVC) and forced expiratory volume in one second (FEV1.0)
- explain obstructive and restrictive patterns of spirometry
- explain expiratory and inspiratory flow volume loops and how they are affected by upper and lower airway obstruction
- describe in principle the measurement of residual volume and transfer factor
- explain the nitrogen washout curve

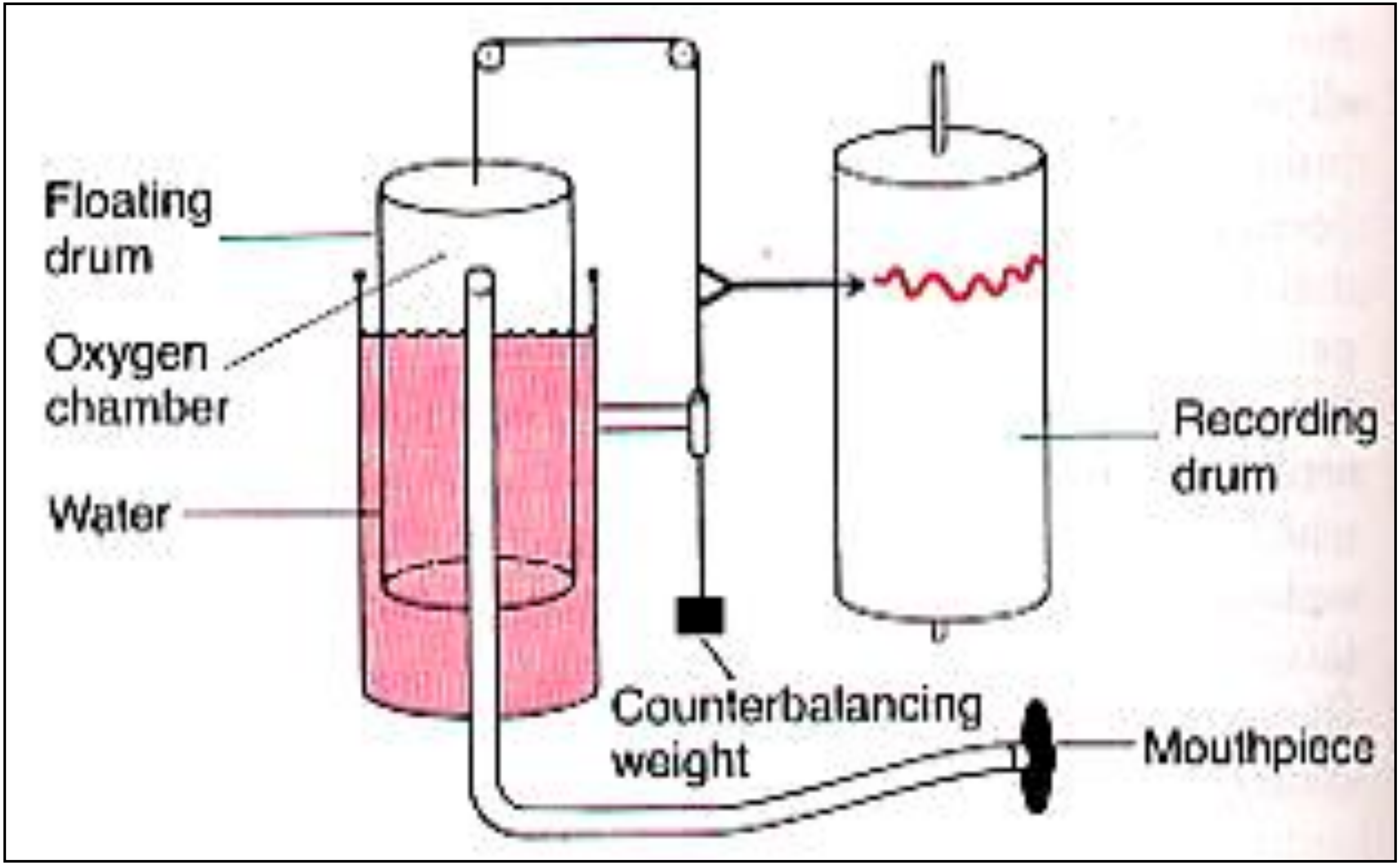
Objective 1

explain common tests of lung function including simple spirometry

Lung Volumes

Simple spirometry

Vital capacity is particularly significant. Tables can be used to predict the vital capacity of an individual of known age, height and sex.



Old spirometer

Recent spirometer

GOALS of spirometry

- To predict the presence of pulmonary dysfunction
- To know the functional nature of disease (obstructive or restrictive.)
- To assess the severity of disease
- To assess the progression of disease
- To assess the response to treatment
- To identify patients at increased risk of morbidity and mortality, undergoing pulmonary resection.

	Measurement	Adult male average value	Adult female average value	Description
Respiratory volumes	Tidal volume (TV)	500 ml	500 ml	Amount of air inhaled or exhaled with each breath under resting conditions
	Inspiratory reserve volume (IRV)	3100 ml	1900 ml	Amount of air that can be forcefully inhaled after a normal tidal volume inhalation
	Expiratory reserve volume (ERV)	1200 ml	700 ml	Amount of air that can be forcefully exhaled after a normal tidal volume exhalation
	Residual volume (RV)	1200 ml	1100 ml	Amount of air remaining in the lungs after a forced exhalation
Respiratory capacities	Total lung capacity (TLC)	6000 ml	4200 ml	Maximum amount of air contained in lungs after a maximum inspiratory effort: TLC = TV + IRV + ERV + RV
	Vital capacity (VC)	4800 ml	3100 ml	Maximum amount of air that can be expired after a maximum inspiratory effort: VC = TV + IRV + ERV (should be 80% TLC)
	Inspiratory capacity (IC)	3600 ml	2400 ml	Maximum amount of air that can be inspired after a normal expiration: IC = TV + IRV
	Functional residual capacity (FRC)	2400 ml	1800 ml	Volume of air remaining in the lungs after a normal tidal volume expiration: FRC = ERV + RV

(b) Summary of respiratory volumes and capacities for males and females

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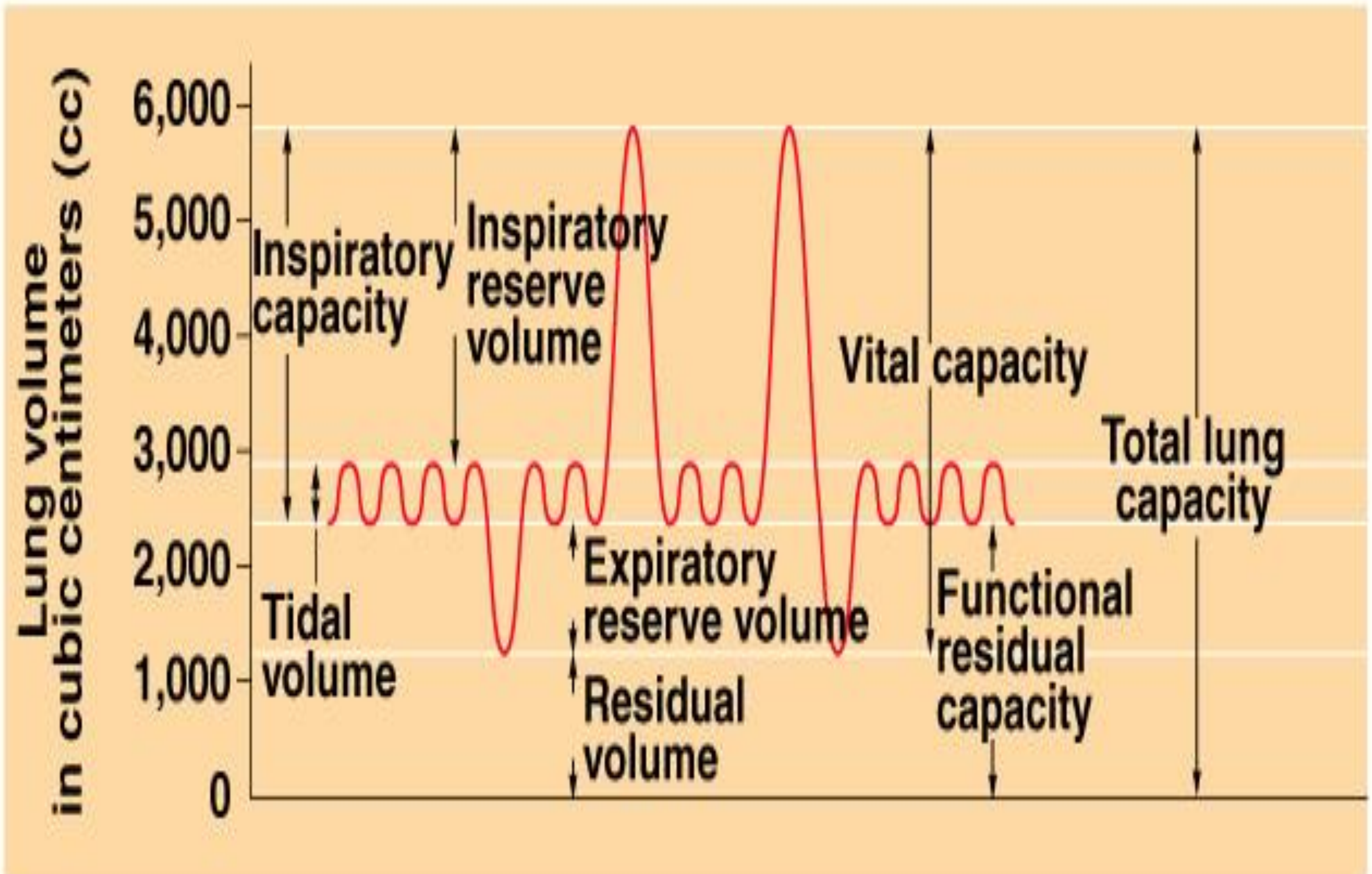

Lung volume
in cubic centimeters (cc)
6,000
5,000
4,000
3,000
2,000
1,000
0
Inspiratory capacity
Inspiratory reserve volume
Vital capacity
Total lung capacity
Tidal volume
Expiratory reserve volume
Residual volume
Functional residual capacity

- **Objective 2**
- describe the measurement of forced vital capacity (FVC) and forced expiratory volume in one second (FEV1.0)

Measurements Obtained from the FVC Curve

- FEV_1---the volume exhaled during the first second of the FVC maneuver

- FEF 25-75%---the mean expiratory flow during the middle half of the FVC maneuver; reflects flow through the small (<2 mm in diameter) airways

- FEV_1/FVC---the ratio of FEV1 to FVC X 100 (expressed as a percent); an important value because a reduction of this ratio from expected values is specific for obstructive rather than restrictive diseases

Objective 3

- explain obstructive and restrictive patterns of spirometry

Maximal filling of the lungs is determined by the balance

between the maximum inspiratory effort and the force of recoil

of the lungs.

a ***'restrictive' deficit*** :

If lungs are unusually stiff,

or inspiratory effort is compromised by muscle weakness,

injury or deformity, then

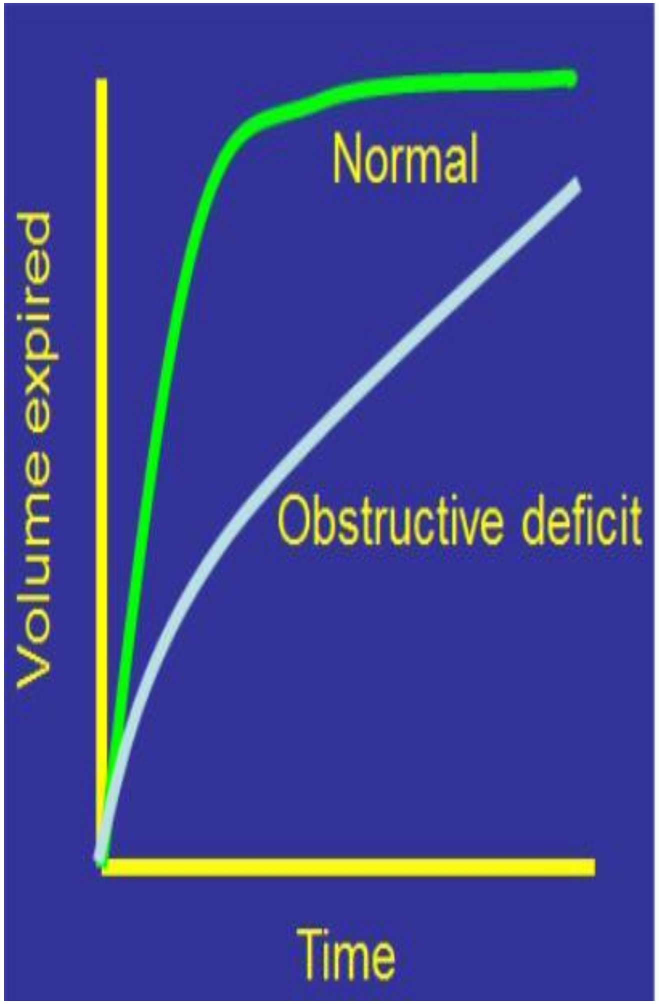
During expiration, particularly when forced, the small airways are compressed, increasing flow resistance, eventually to the point where no more air can be driven out of the alveoli. If airways are narrowed, then expiratory flow is compromised much earlier in expiration - producing an **'obstructive'** deficit

- **Objective 4**
- explain expiratory and inspiratory flow volume loops and how they are affected by upper and lower airway obstruction

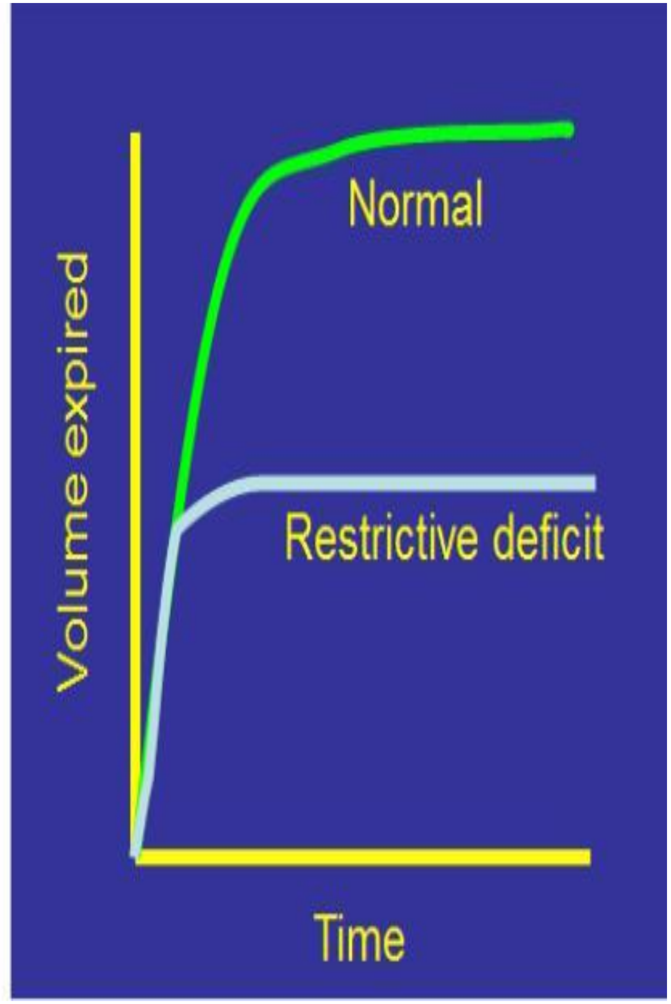
Spirometry

Restrictive and obstructive deficits may be separated by asking patients to breathe out rapidly from maximal inspiration through a single breath spirometer which plots volume expired against time (a 'vitalograph').

A time-volume plot (graph) generated during spirometry is often referred to as a ‘vitalograph’ tracing. This is because the first portable spirometers to become widely used were the ‘Vitalograph’ machines by the company of the same name (in much the same way as vacuum cleaning became synonymous with the ‘Hoover’ vacuum cleaner).



(i) A time-volume graph (vitalograph) showing a normal tracing and the obstructive pattern



(ii) A time volume graph (vitalograph) showing normal, and restrictive patterns

Obstructive and restrictive deficits are distinguished by measuring the Forced Expiratory Volume in one second (FEV1.0). In normal individuals this is greater than 70% of the Forced Vital Capacity (FVC) - i.e. the FEV1/FVC ratio is <70%

In an Obstructive defect

FVC is nearly normal

FEV1 is reduced markedly

FEV1/FVC ratio is <70%

Note the typical shape of the tracing in obstructive patter

In a Restrictive defect

FVC is reduced

FEV1 is reduced proportionately

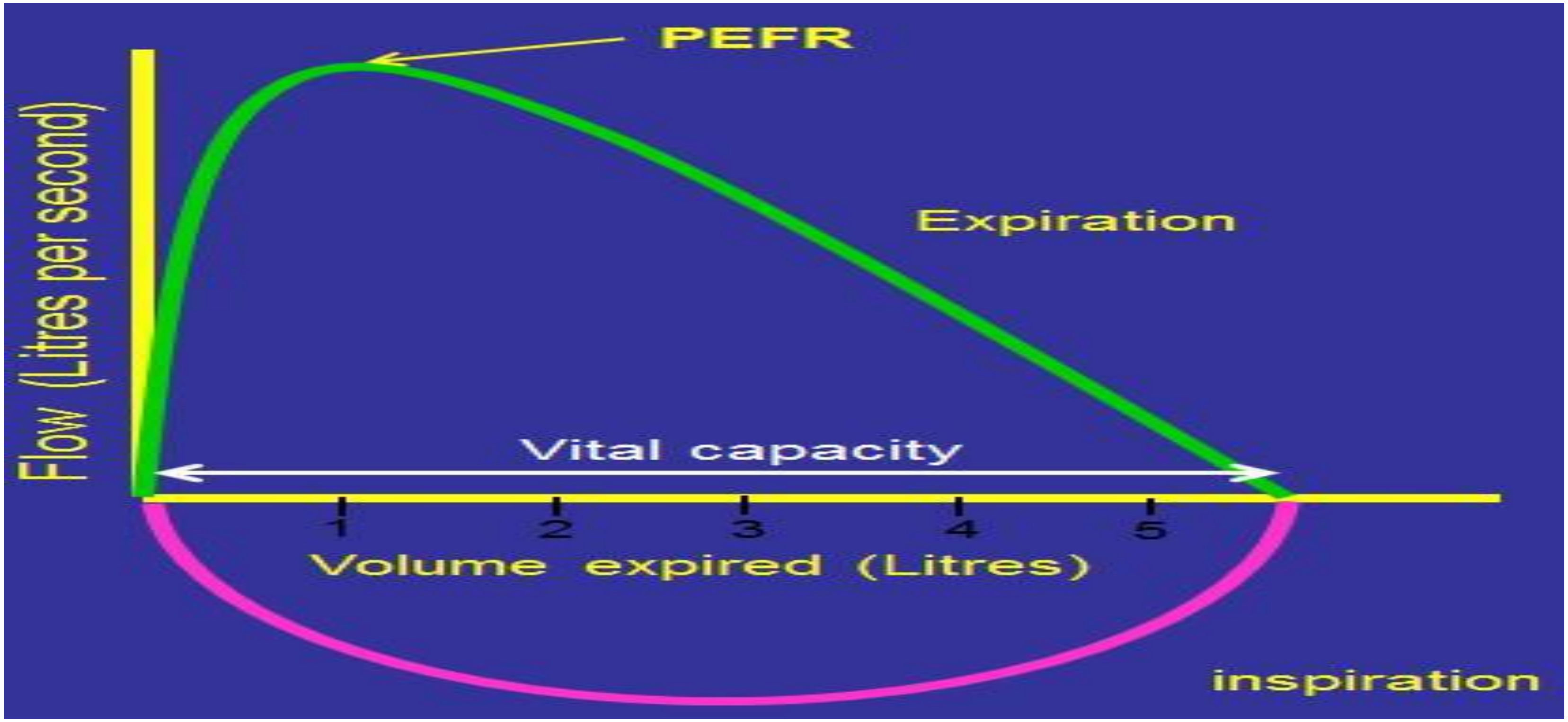
FEV1/FVC ratio is normal (or even higher than normal) – i.e. ≥ 70%

Note the typical shape of the tracing in restrictive pattern

Flow Volume Curves

Obstructive deficits in particular may be more sensitively revealed by deriving an expiratory flow volume loop. Here **expiratory flow rate** is plotted against **lung volume.**

The peak expiratory flow occurs early in expiration. As expiration continues the small airways are narrowed by compression of the lungs, and where there is small airway obstruction this narrowing produces a characteristic, early fall in expiratory flow rate.



The flow volume curve

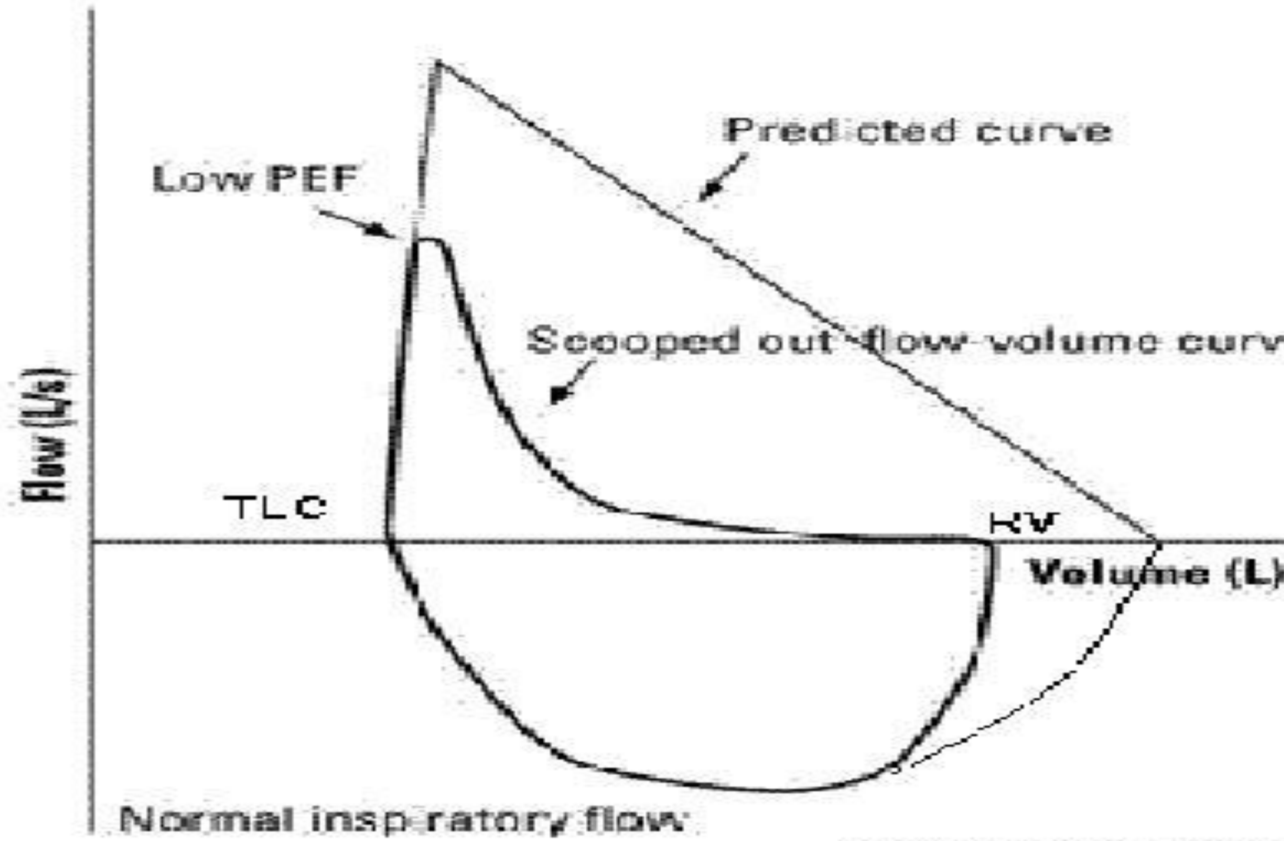
Peak Expiratory Flow Rate (PEFR).??

Peak Flow Meter??.

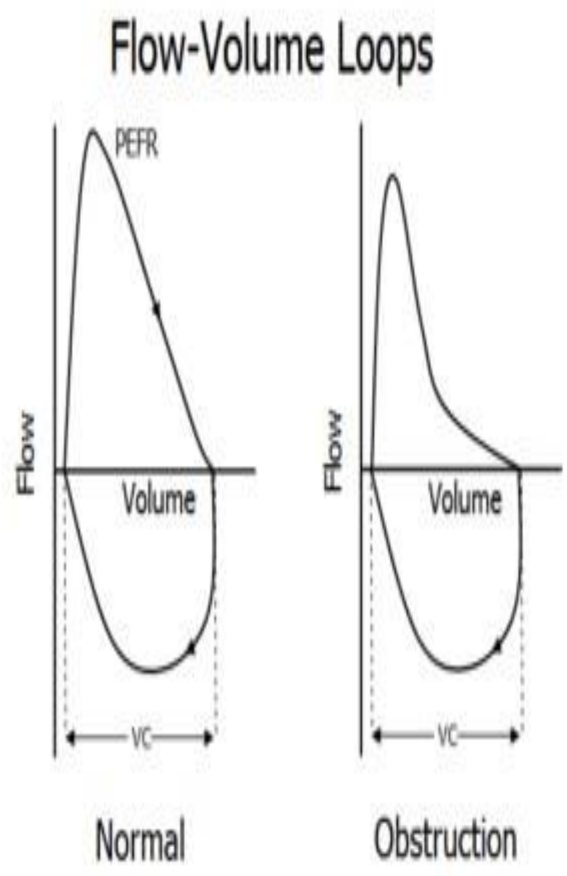
Peak Flow Meter

In normal individuals peak flow is affected most by the resistance of the large airways, but with severe obstruction of the smaller airways, as happens in exacerbations of asthma the peak expiratory flow rate will be affected.

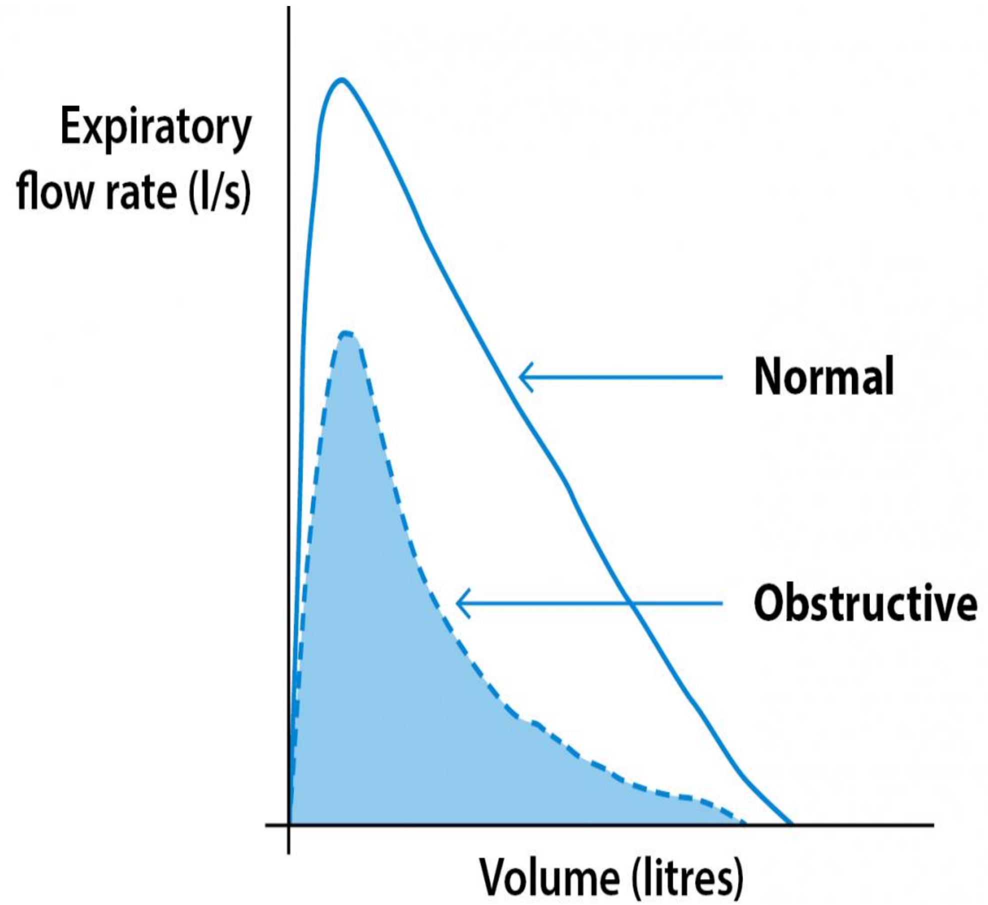
Mild obstruction of the small airways produces 'scalloping' of the flow volume curve. More severe obstruction also reduces PEFR.



severe obstructive airways diseaes



Flow-Volume Loops
PEFR
Flow
Volume
VC
Normal
Flow
Volume
VC
Obstruction



Expiratory flow rate (l/s)
Normal
Obstructive
Volume (litres)

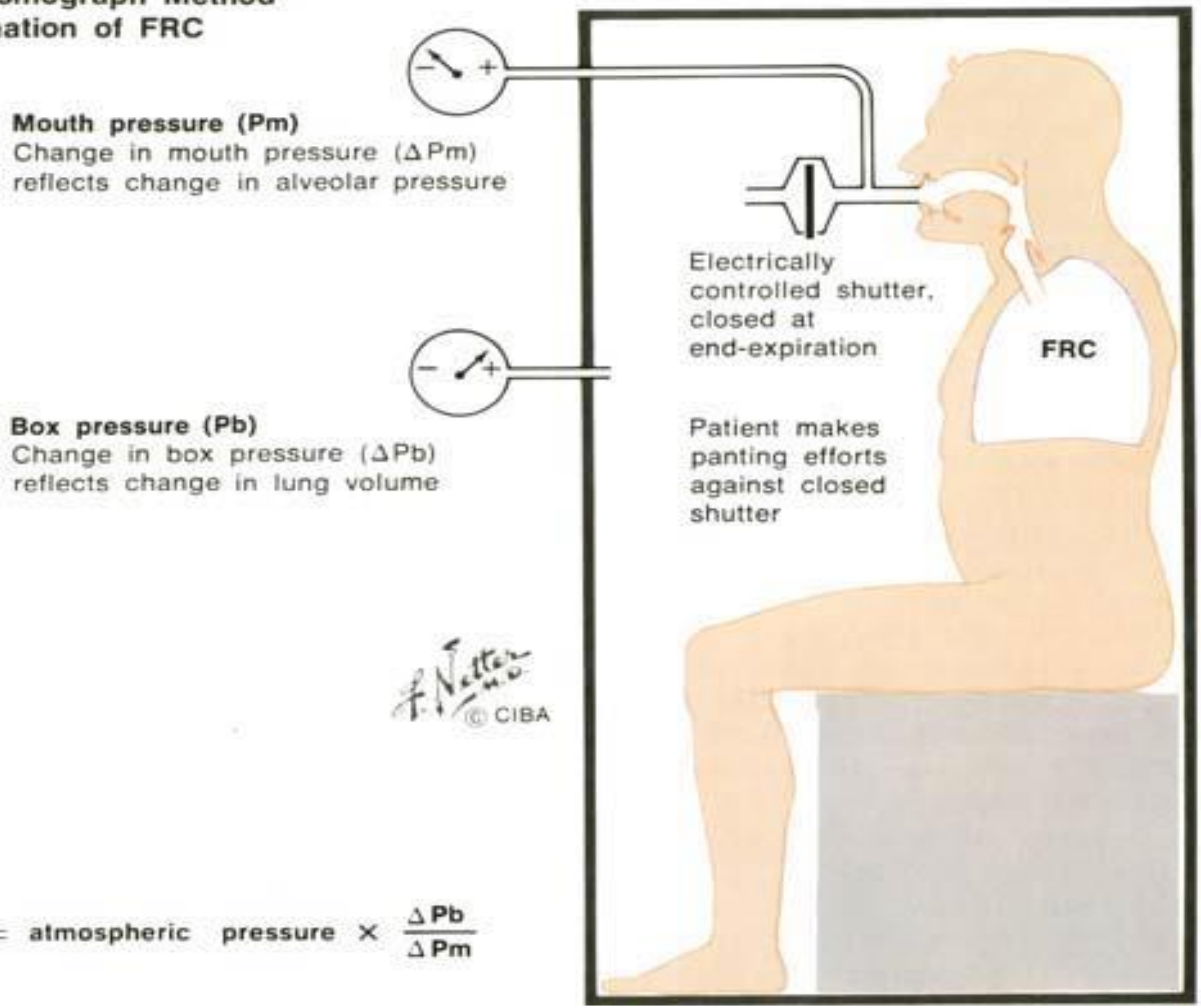
- **Objective 5**
- describe in principle the measurement of residual volume and transfer factor
- explain the nitrogen washout curve

Under some circumstances the compliance of a patient's lungs is measured directly using a **whole body plethysmograph**, which may also be used to estimate the resistance of the airways more directly.

Measuring Residual volume: The volumes of air remaining in the lungs after expiration may be measured by the **Helium dilution test**.

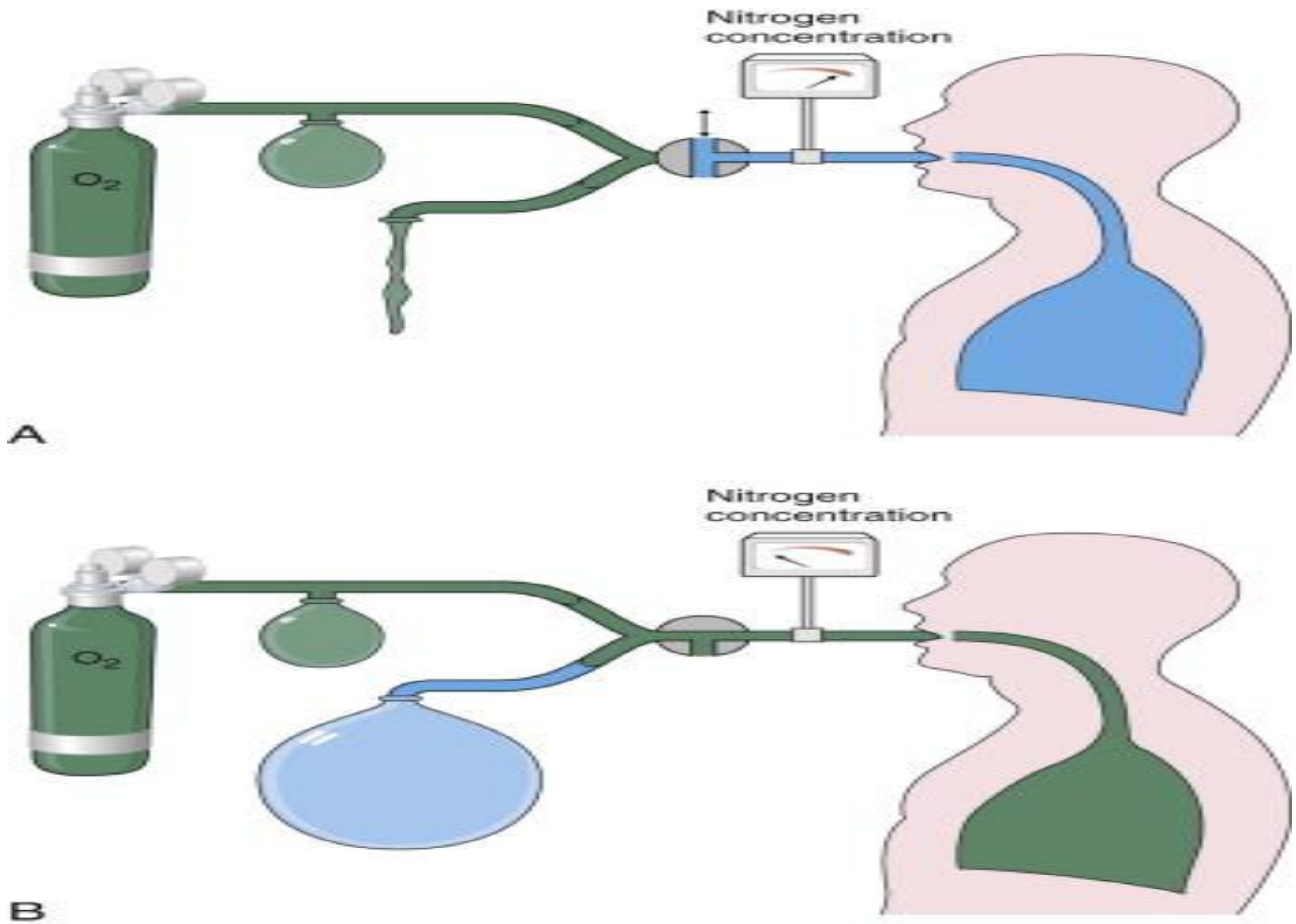
Measuring Dead space: Dead space may be measured by the nitrogen washout method.

Body Plethysmograph Method for Determination of FRC



$$\text{FRC} = \text{atmospheric pressure} \times \frac{\Delta \text{Pb}}{\Delta \text{Pm}}$$

Nitrogen washout is a test for measuring anatomic dead space in the lung during a respiratory cycle, as well as some parameters related to the closure of airways.



Lung volume measurement by nitrogen washout