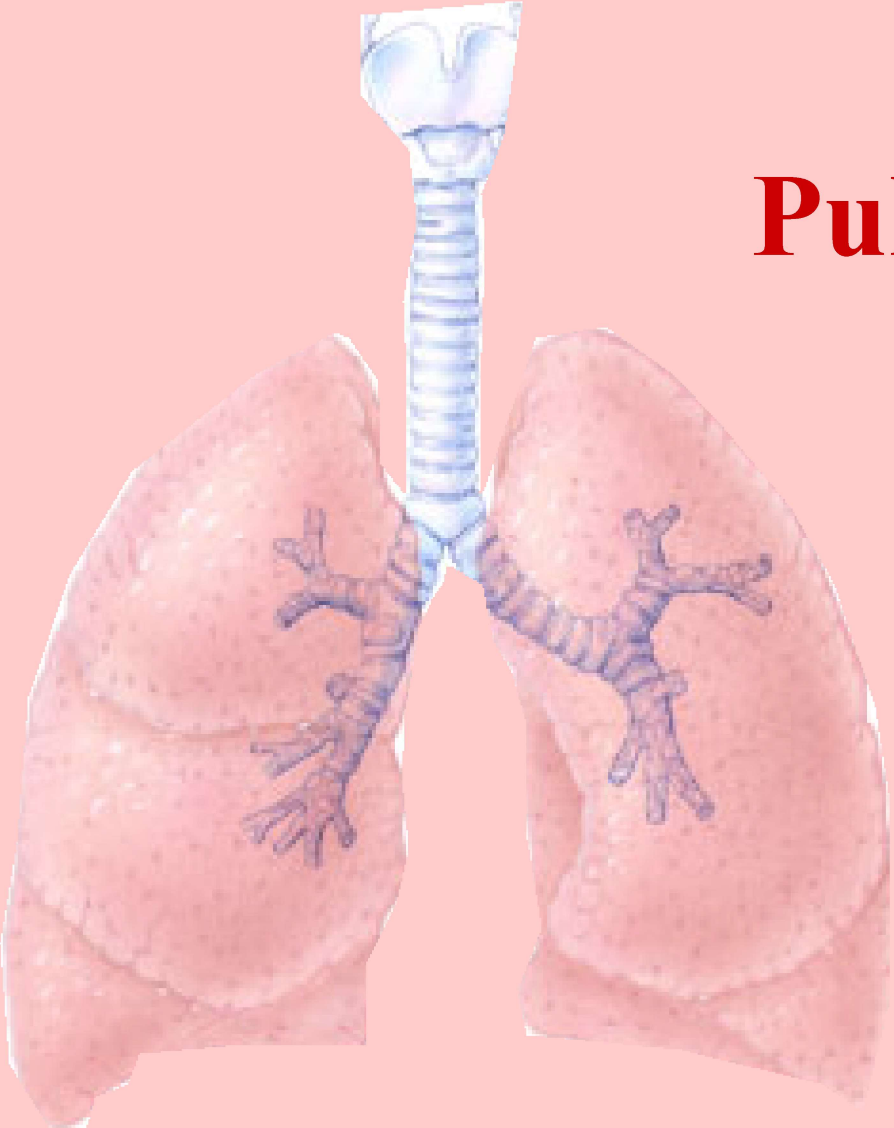


Pulmonary Function

Linda Paumer
August 2022

We are living beings, composed of living cells…

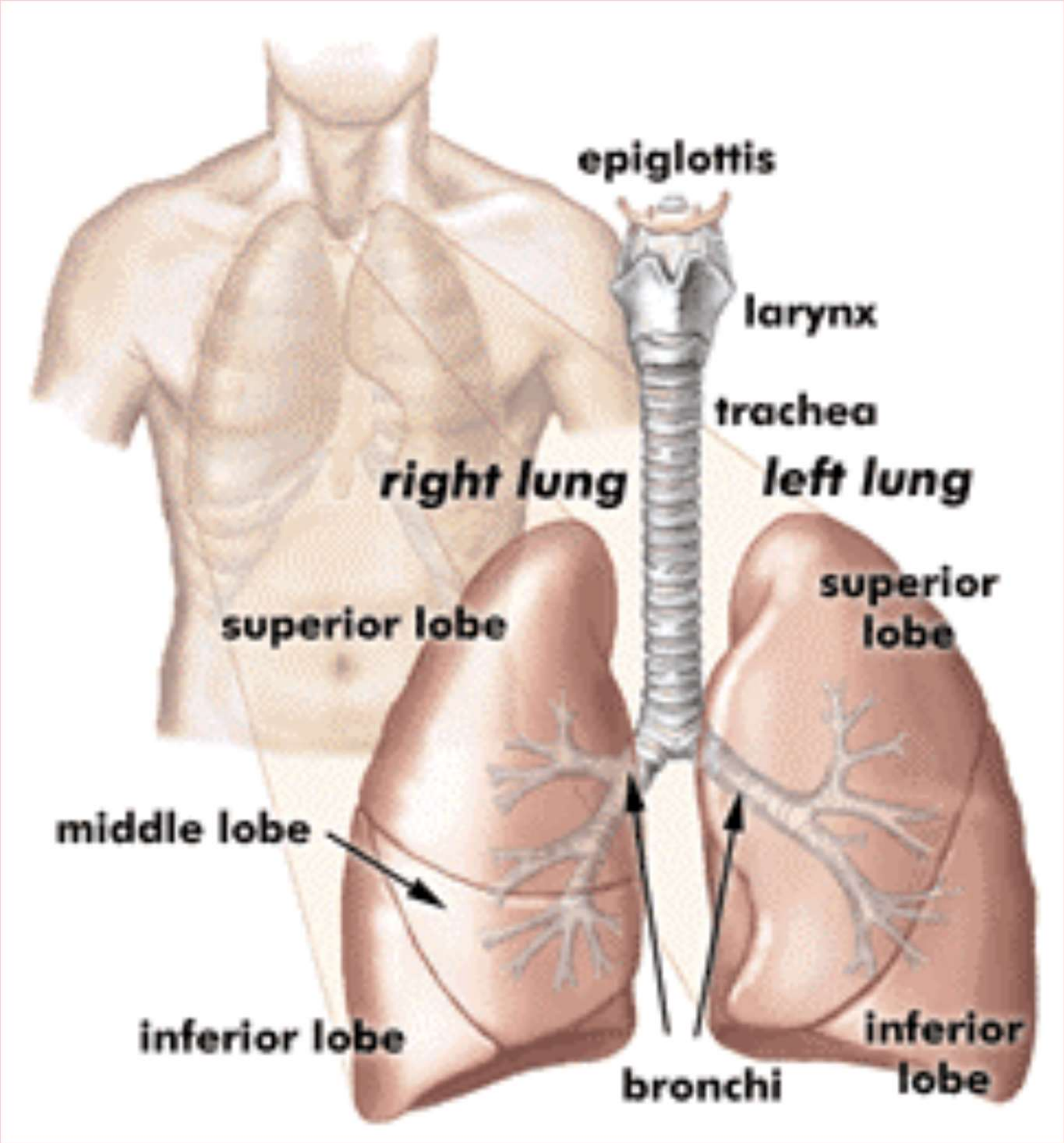
The living cell uses oxygen for metabolism and produces carbon dioxide as an end product. It requires a large surface area to exchange oxygen (O_2) and carbon dioxide (CO_2).

The human body uses the alveoli in the lungs for gas exchange. Two transport systems are used because the lungs are far from the muscles that need O_2.

Respiratory system – uses the lungs to supply O_2 to the body & return CO_2 to the environment

Circulatory system – uses blood to circulate O_2 and other substances throughout the body

Lung Anatomy

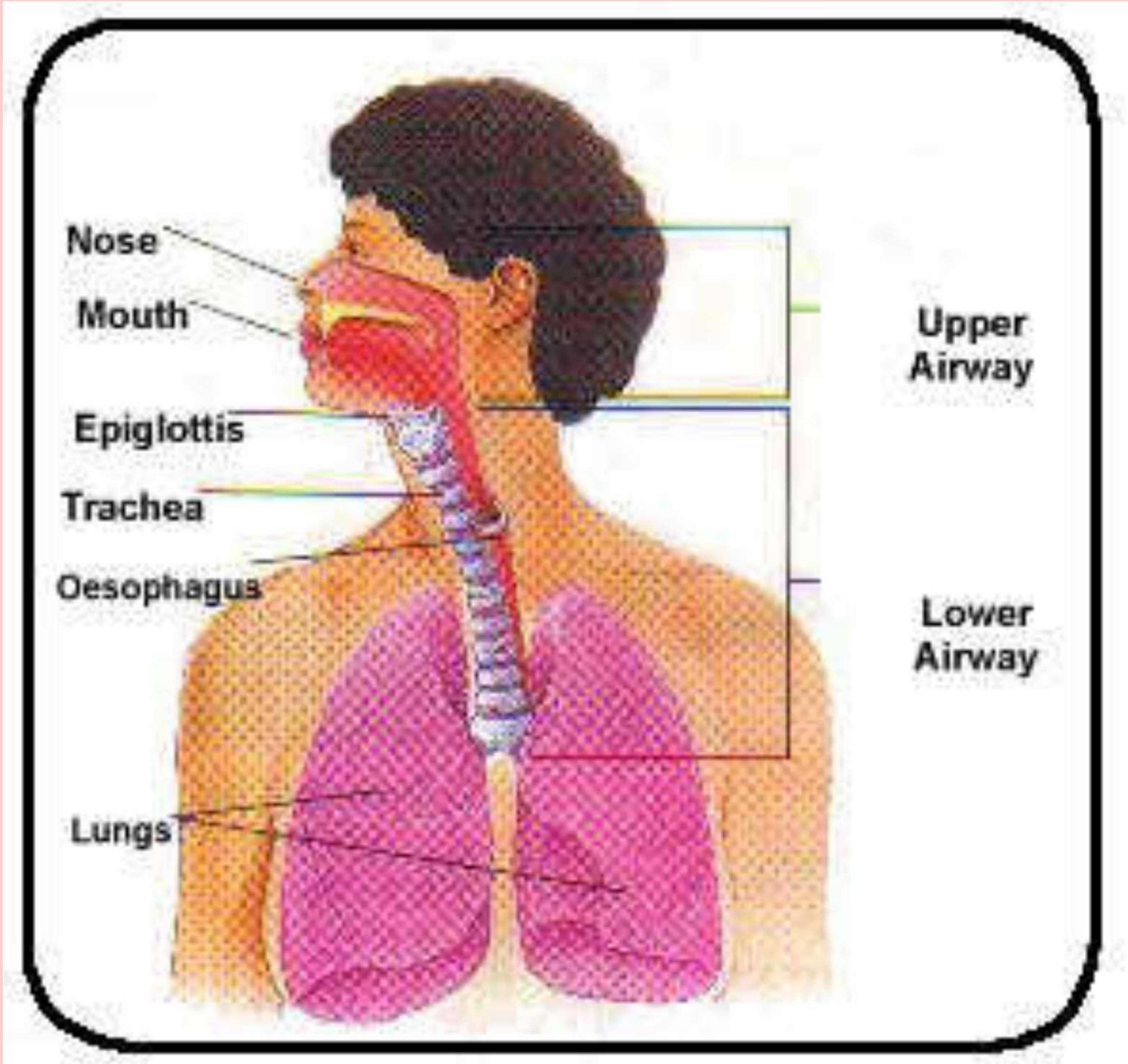


Healthy Lungs

Elements of healthy gas exchange:

- Large surface area of the membrane between lungs and bloodstream for optimal oxygen and carbon dioxide exchange (ie many alveoli with few obstructions)
- The membrane must be kept moist and at a certain temperature to maintain gas exchange. The mouth, nose, and lungs provide heat and moisture for oxygen intake.
- Oxygen uptake and carbon dioxide production must be proportional. Unequal amounts can affect blood pH levels. Excess carbon dioxide causes hyperventilation (increases oxygen intake to cancel out excess carbon dioxide)

Airways

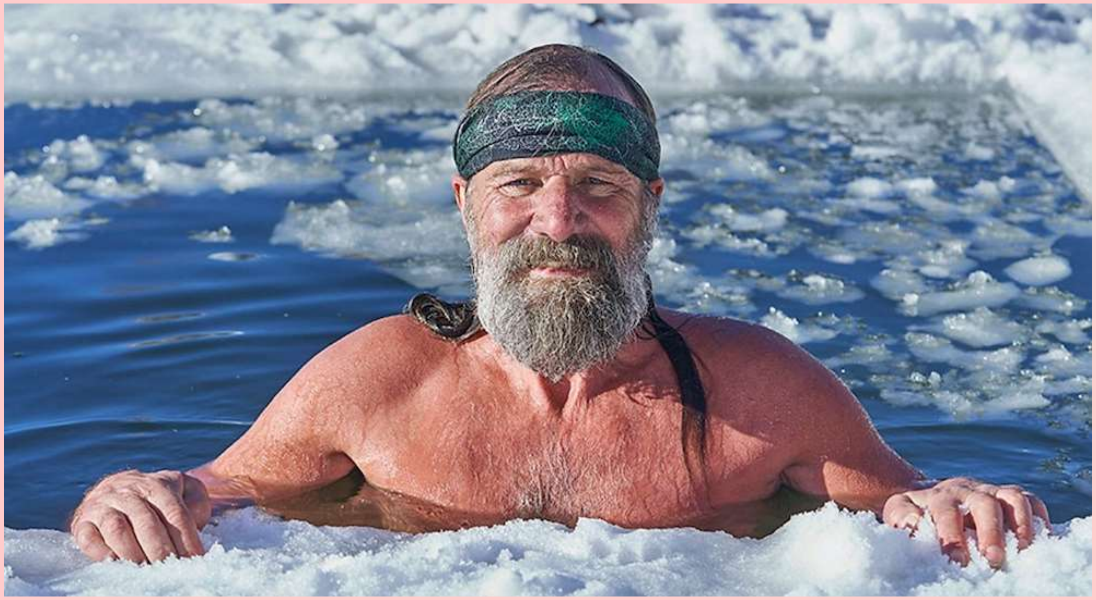

Nose
Mouth
Epiglottis
Trachea
Oesophagus
Lungs
Upper Airway
Lower Airway

Airways

- Air enters through the nose and mouth and passes through the trachea into the bronchial tree. The airways branch and keep branching.
- An adult man has about 23 generations of branches.
- First 16 generations are the "conductive zone" in the "bronchial tree." No gas exchange occurs between the blood and the air in this zone.
- Generations 17 through 19 are called bronchioles in the "transitory zone".
- The branches in the last generations are alveolar ducts (~1,000,000) in the "respiratory zone" This is where gas exchange occurs.

Air Conditioning

- Inspired air may be cold or hot, dry or moist, but due to the rich blood supply of the mucous membranes in the nose, mouth, and pharynx, the air temperature becomes adjusted to body temperature and also moistened as it passes through the conductive zone.



Even when exposed to the cold air in the Artic or the hot air in the Tropics, the inspired air is about 37 degrees C (body temperature) when it reaches the pharynx.

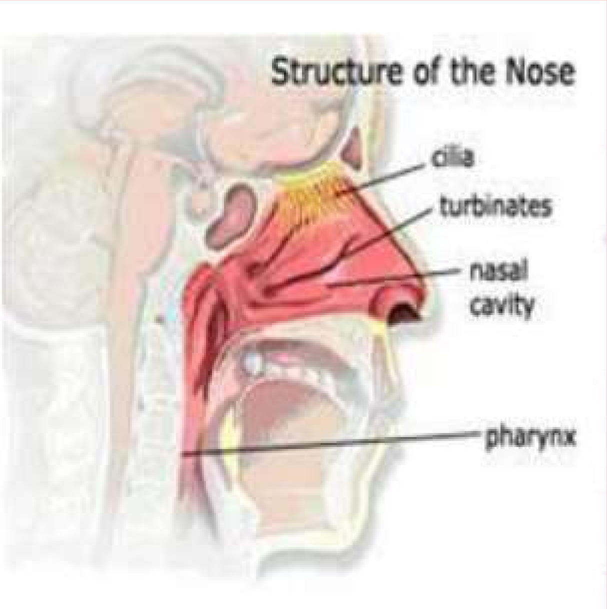
Air Filtering

- If we live in a city , we may inhale billions of particles of foreign matter every day. Particles larger than about 10 microns are effectively removed from the inspired air in the nose, where they are trapped by the hair or the moist mucous membranes. Only a few and very small particles are likely to reach the alveoli, and this part of the lung is most sterile.

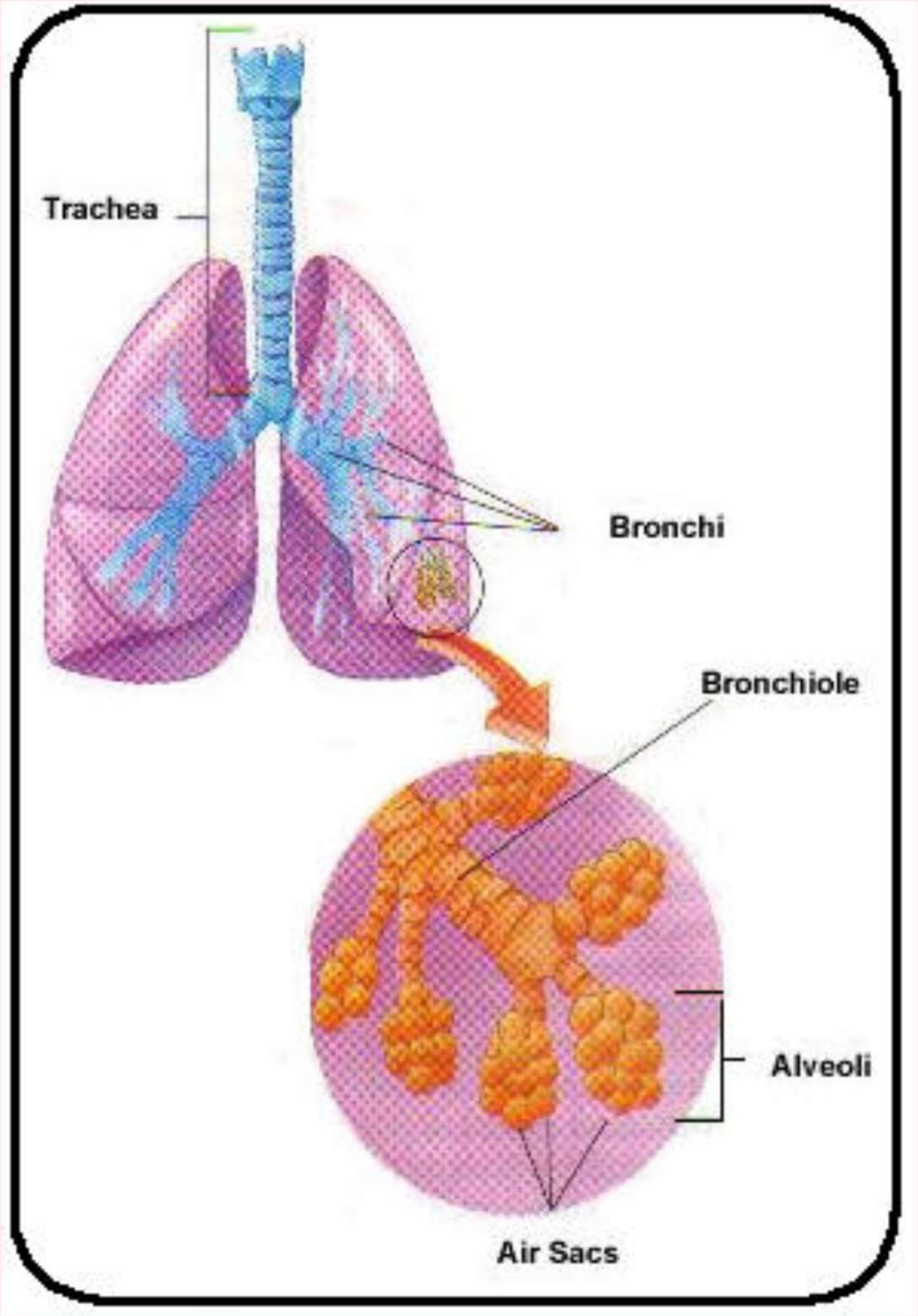
Air Filtering – Ciliar Function

- The cilia (little hairs) throughout the conductive zone beat in an organized whiplike fashion in strokes. They are covered by a continuous surface of watery mucous. This fluid carpet with all the trapped particles moves toward the larynx at a speed of well over 1 cm/min. This mucous is also expectorated (spit out) or swallowed.

- Be mindful—cigarette smoke has a deleterious effect on this ciliar function. They slow or stop their beating when exposed to the smoke.

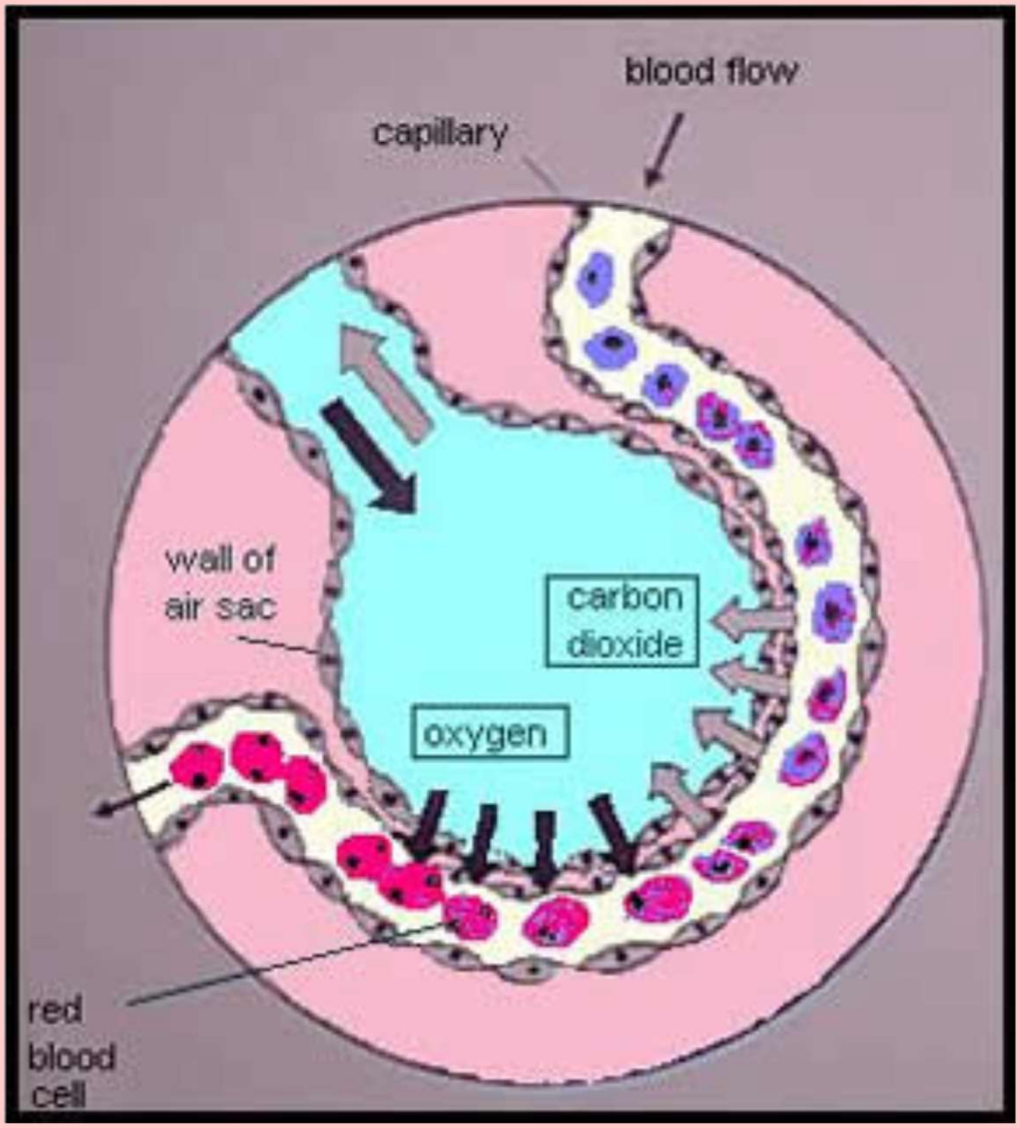


Respiratory Zone



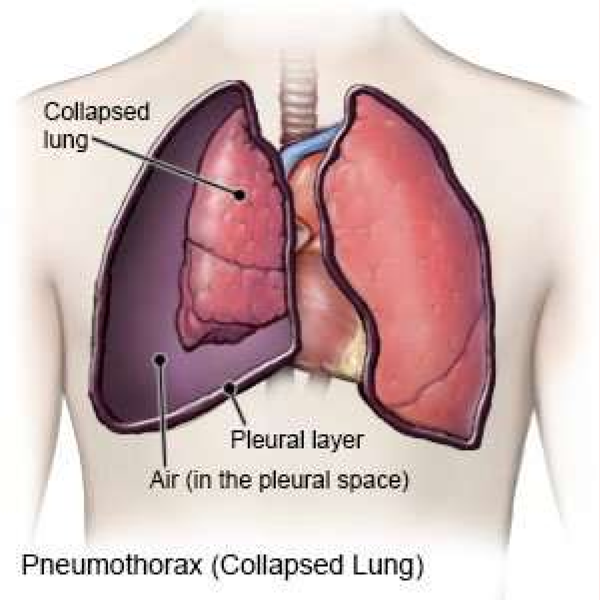
Alveoli

Gas Exchange

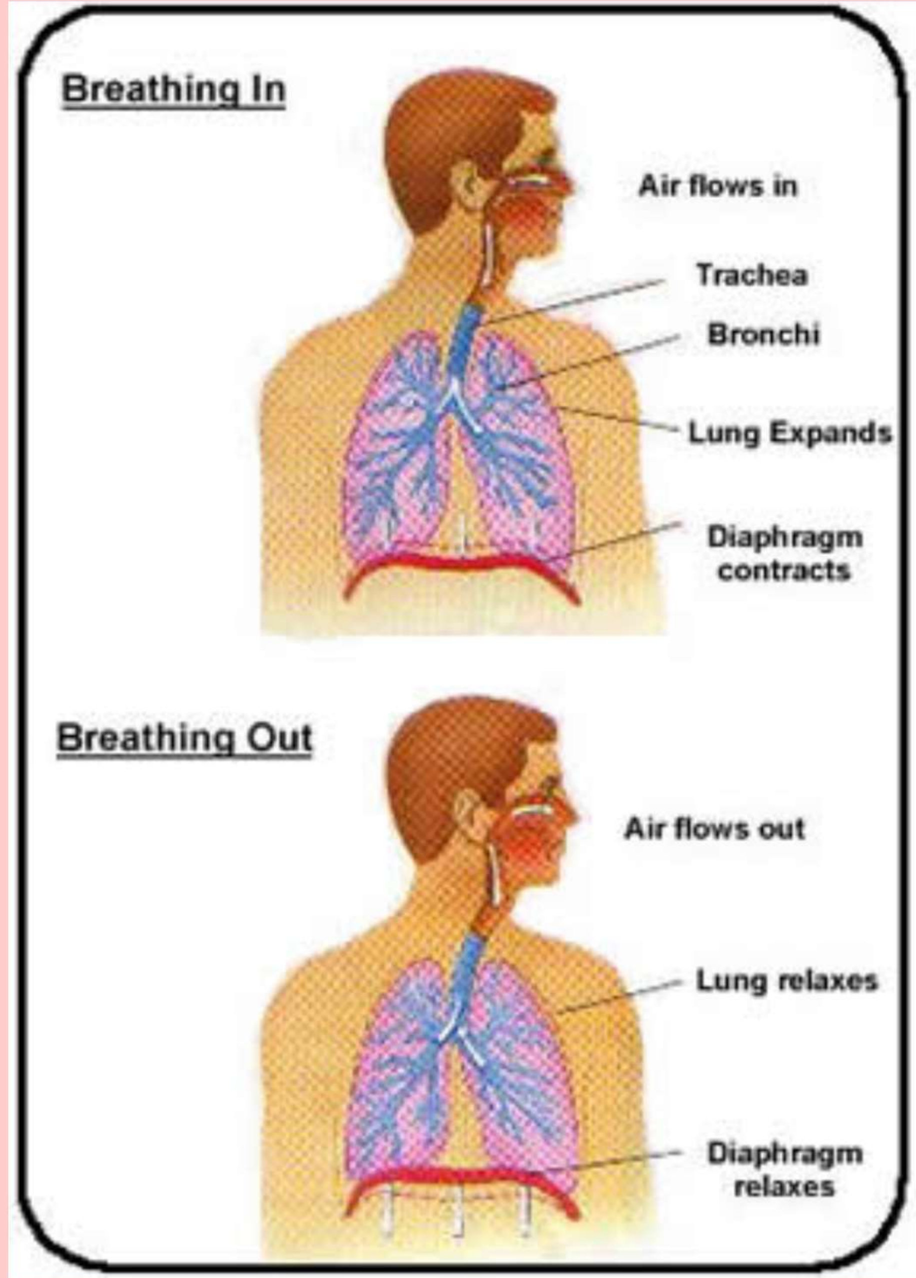


The Pleurae

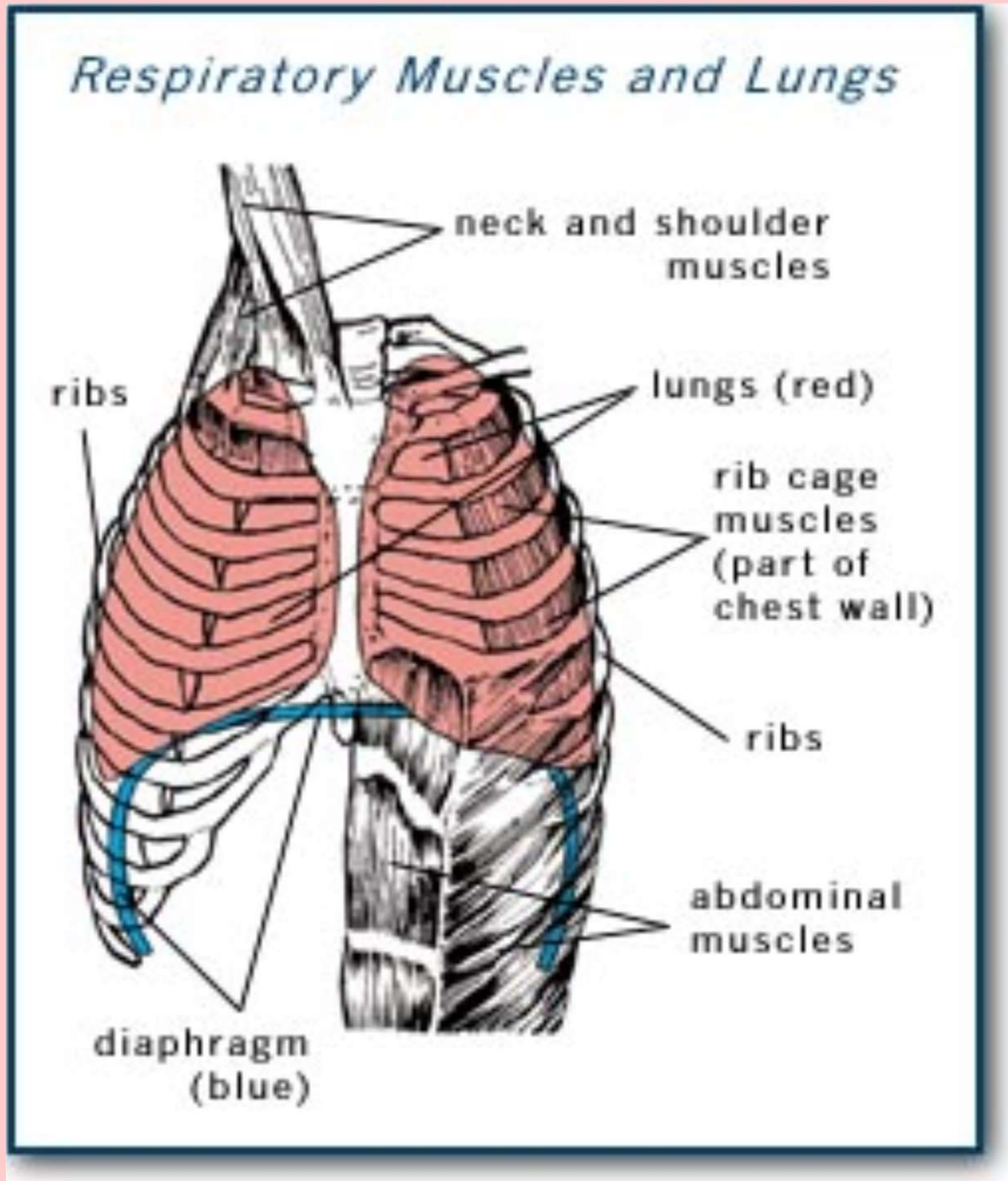
- The lungs increase their volume with the reciprocating movement of the thorax. The thoracic cavity is covered by a thin membrane or pleura, and the lungs are covered by the pulmonary pleura. The two pleural surfaces are held close together with a thin fluid film in between, providing smooth lubricated surfaces.
- If the thorax is opened and air enters the interpleural space, the elastic recoil of the lungs causes them to collapse. Such an injury (pneumothorax) of course makes the lung incapable of its normal respiratory function.



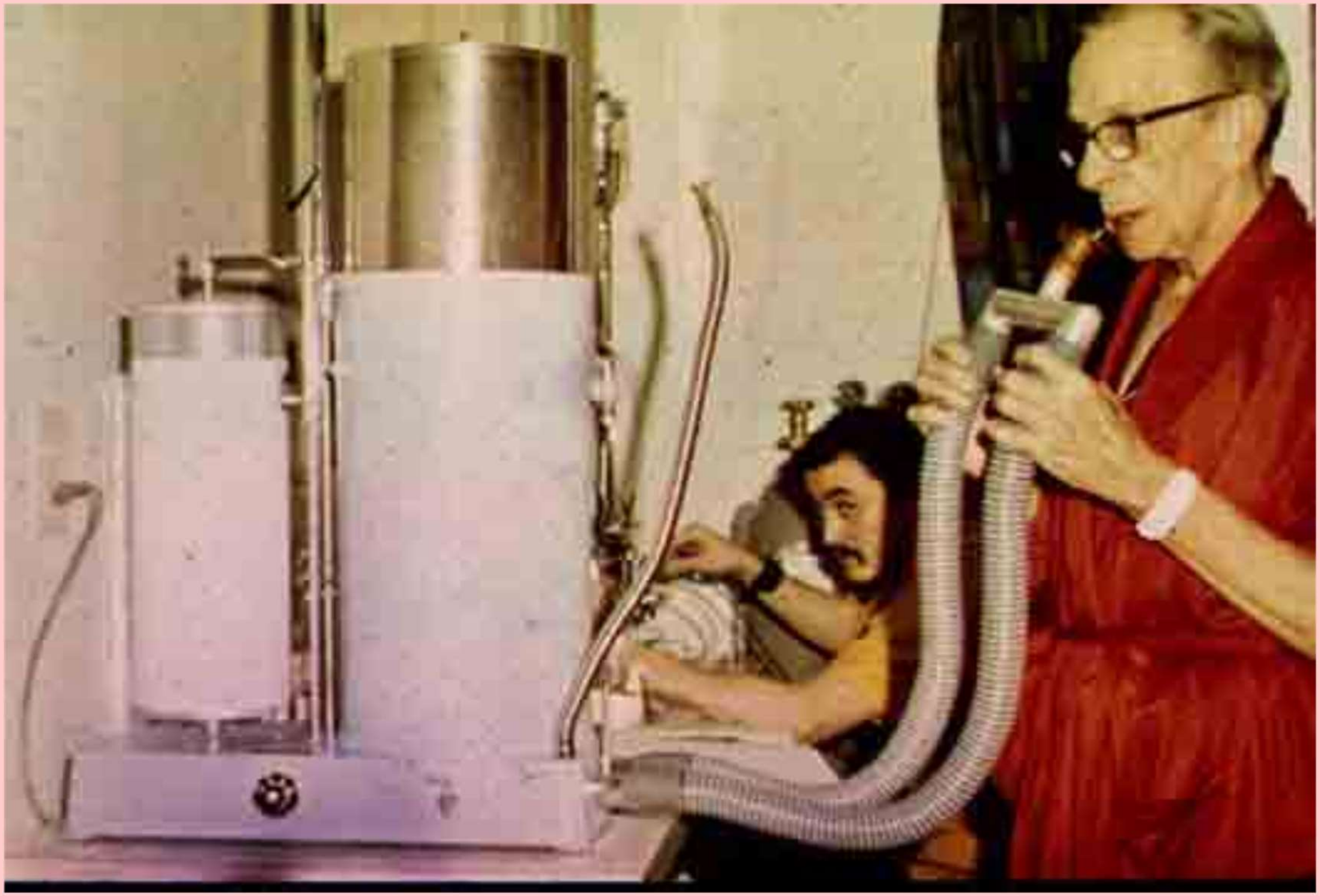
Mechanics of Breathing



Respiratory Muscles

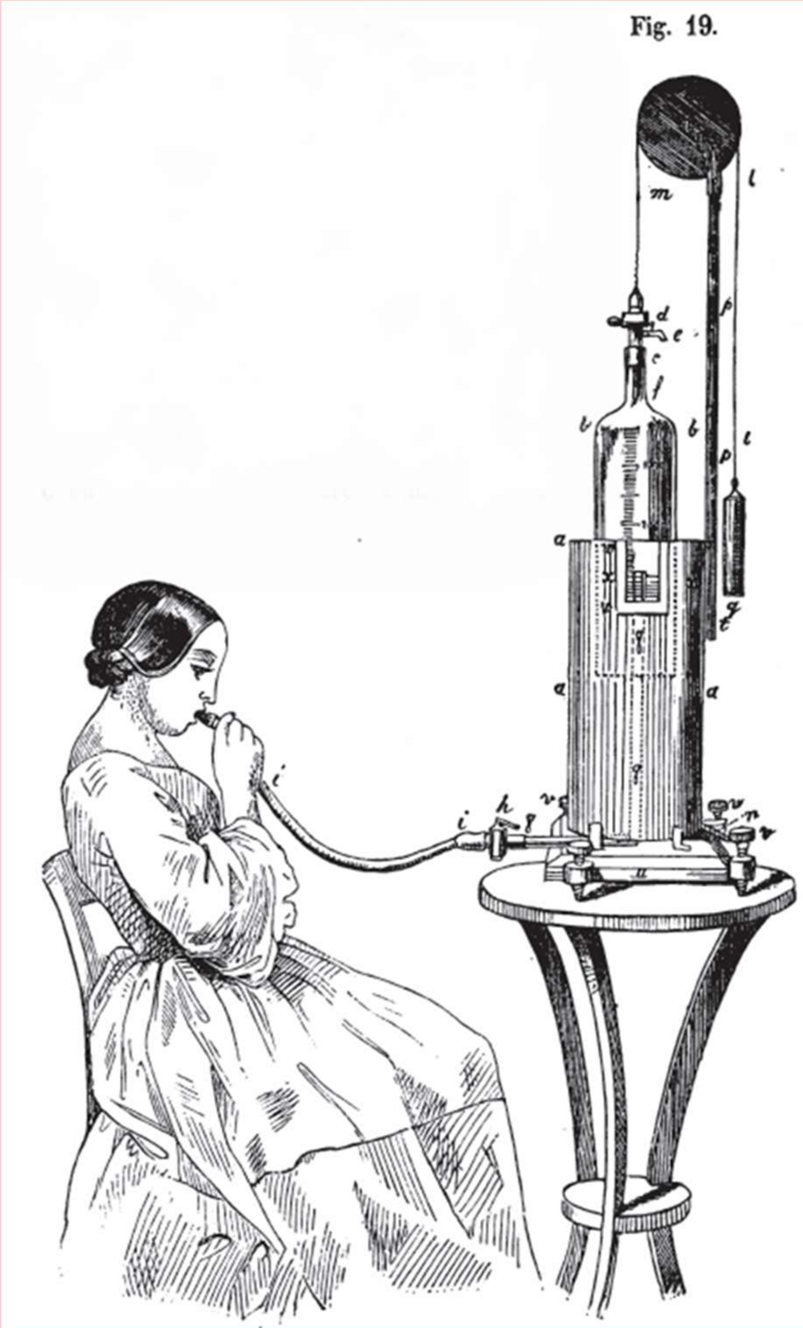


Static Volume Measurements



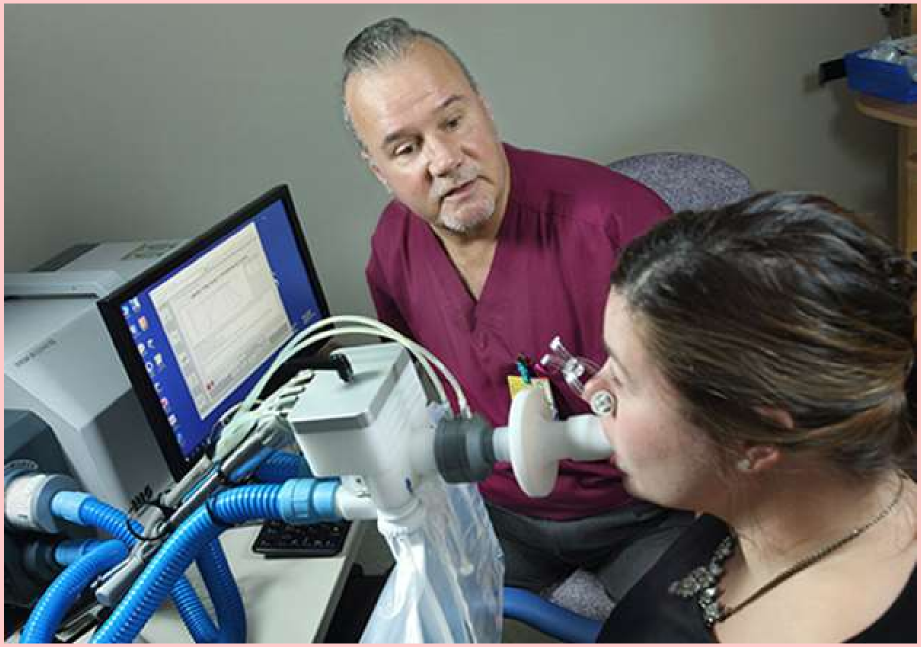
Spirometry

- Spirometry, derived from the Latin words SPIRO (to breathe) and METER (to measure), is a medical test which provides diagnostic information to assess a patient's lung function. The spirometer was originally invented in the 1840's by John Hutchinson, an English surgeon.

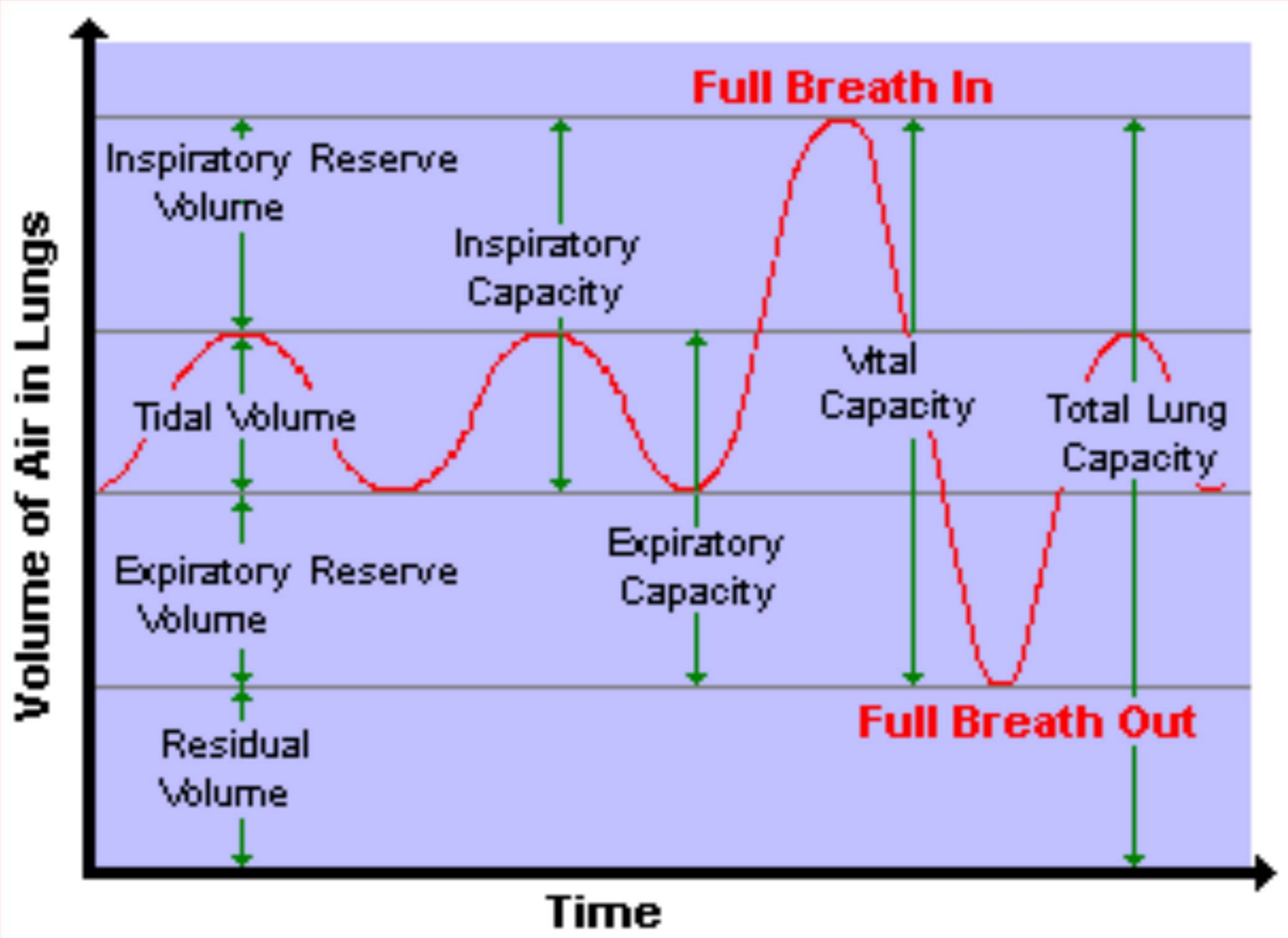


- Of course, testing equipment is more sophisticated now than 180 years ago.

- Spirometry is recommended in the practice guidelines for the diagnosis and management of both asthma and COPD.



Spirometry can identify airflow obstruction before COPD symptoms present and 5-10 years before signs appear on an X-ray.


Full Breath In
Inspiratory Reserve Volume
Inspiratory Capacity
Tidal Volume
Vital Capacity
Total Lung Capacity
Expiratory Reserve Volume
Expiratory Capacity
Residual Volume
Full Breath Out
Volume of Air in Lungs
Time

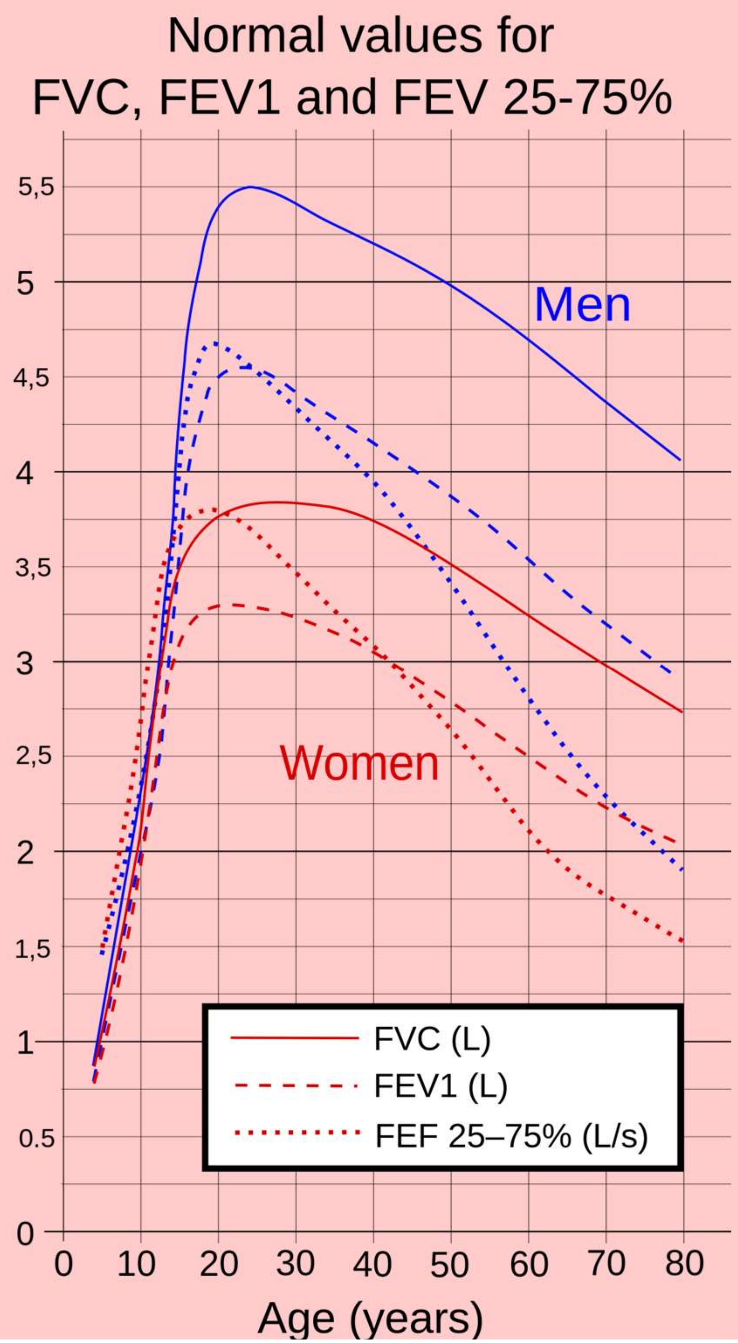
Dynamic Measurements

Forced Expiratory Volume

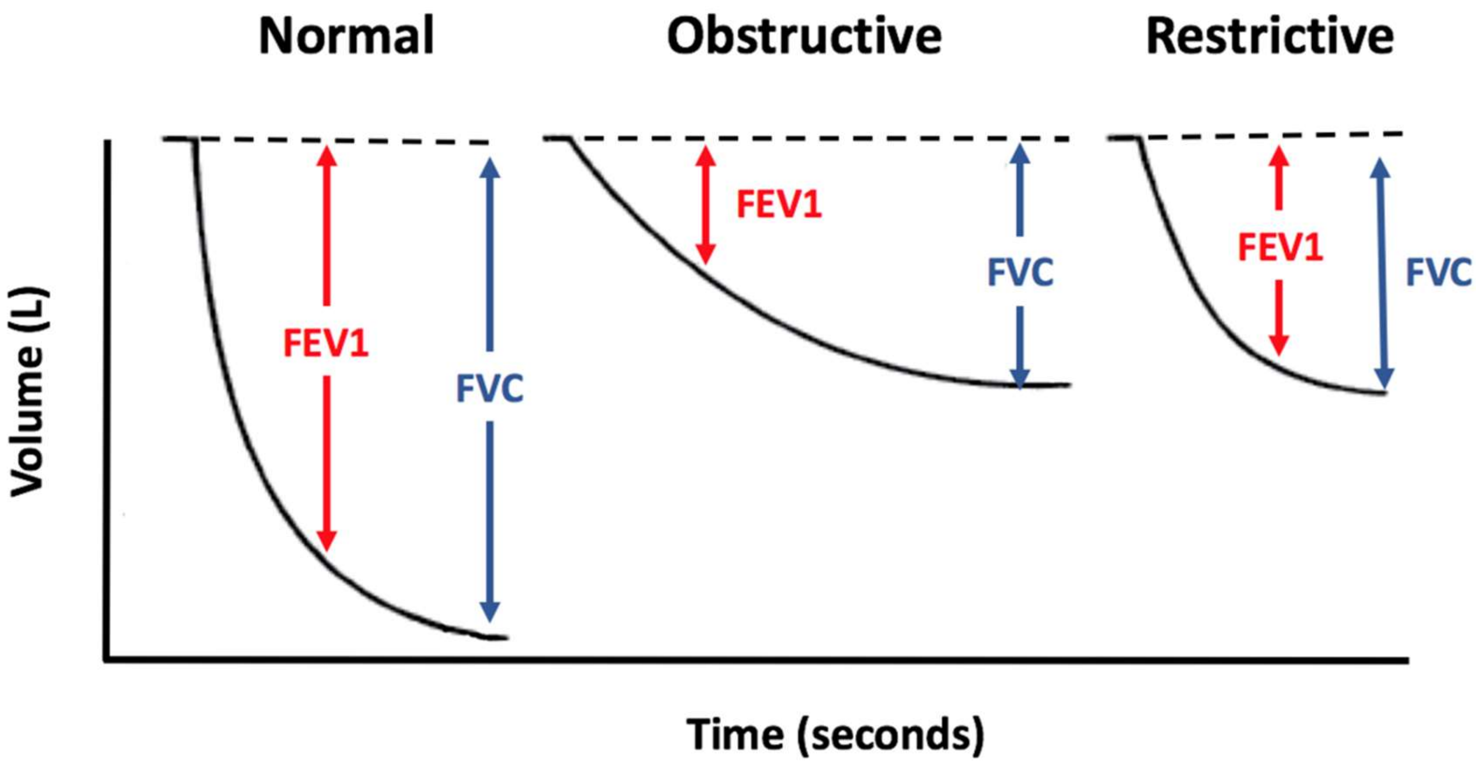
- ~1950 it was determined that 90% of the predominant respiratory disorders (asthma and COPD) were obstructive (limited flow rate). In 1950 Dr. Tiffeneau of France introduced the forced measurement of air volume during a given time frame, i.e., forced expiratory volume in 1 second, FEV1.

FEV1

The FEV1 measurement is so important that it is the primary end point in clinical trials for nearly every respiratory drug approved today. Spirometry is also now required for Social Security/Disability evaluations, OSHA occupational respiratory surveillance and DOT physicals.



Comparisons of FEV1's



FEV1 = 3.3
FVC = 4.0
FEV1/FVC = 83%

FEV1 = 1.0
FVC = 2.0
FEV1/FVC = 50%

FEV1 = 1.8
FVC = 2.0
FEV1/FVC = 90%

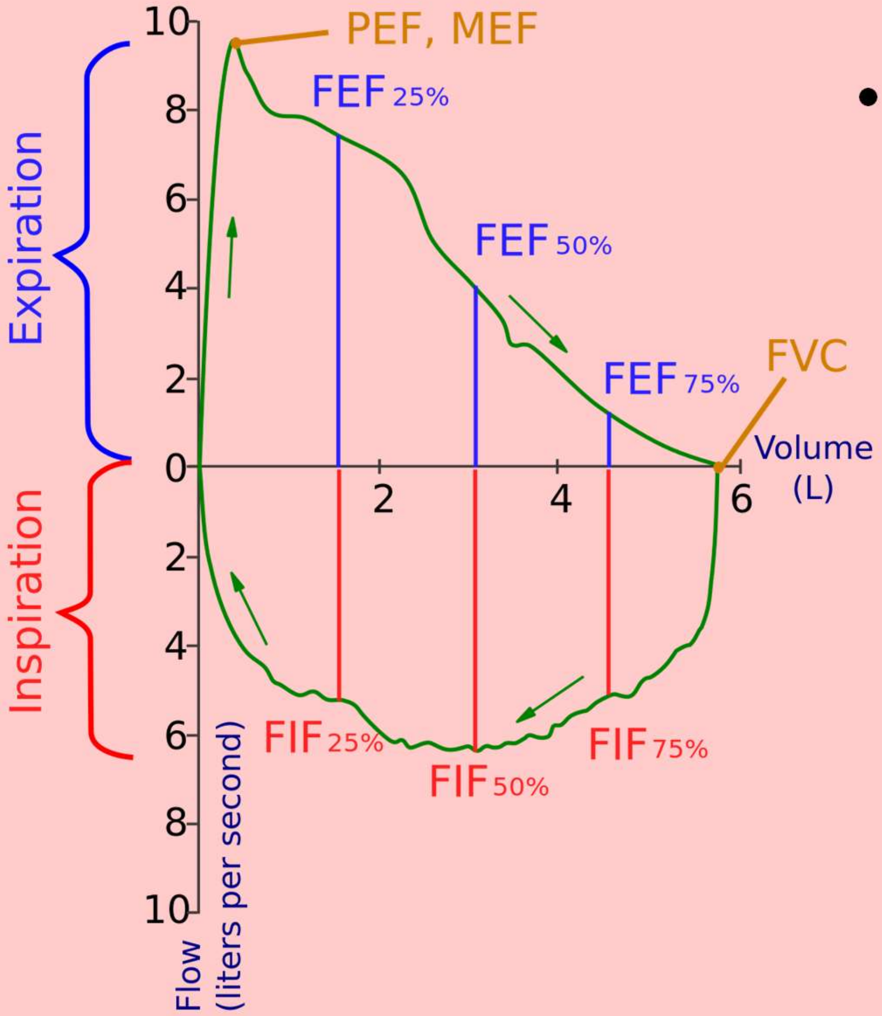
Pulmonary Function Tests (PFTs)

Vital Capacity (VC)

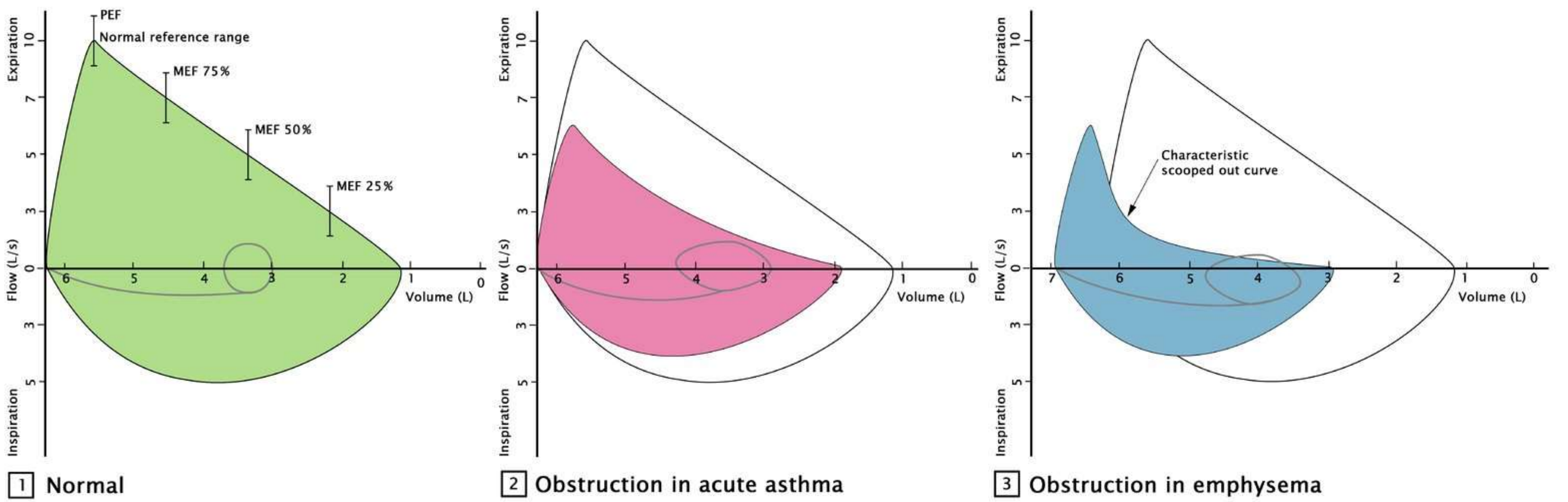
Forced Expiratory Volume (FEV)

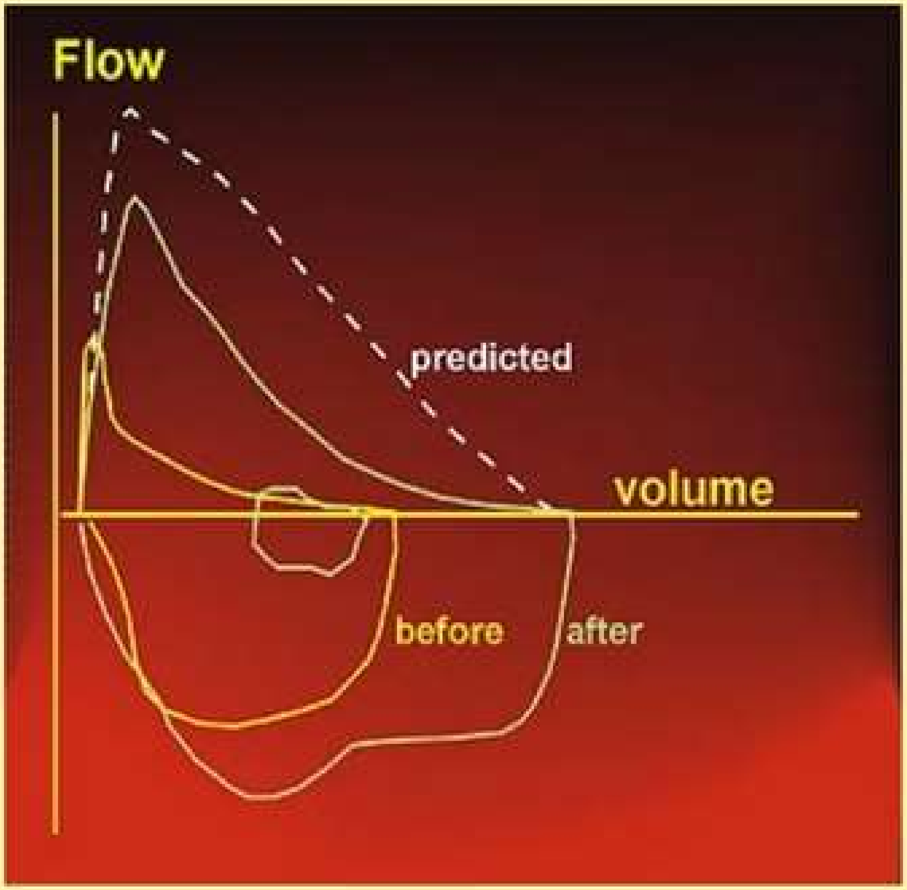
FEV/VC ratio—used to determine if breathing pattern is obstructive, restrictive, or normal.

Flow Volume Loops



- Flow-volume loops are produced by asking the patient to breath out then in as forcefully as possible, and may reveal a characteristic pattern suggestive of restrictive, obstructive or other pulmonary disease.


PEF
Normal reference range
MEF 75%
MEF 50%
MEF 25%
Expiration
Flow (L/s)
Inspiration
Volume (L)
Characteristic scooped out curve
1 Normal
2 Obstruction in acute asthma
3 Obstruction in emphysema

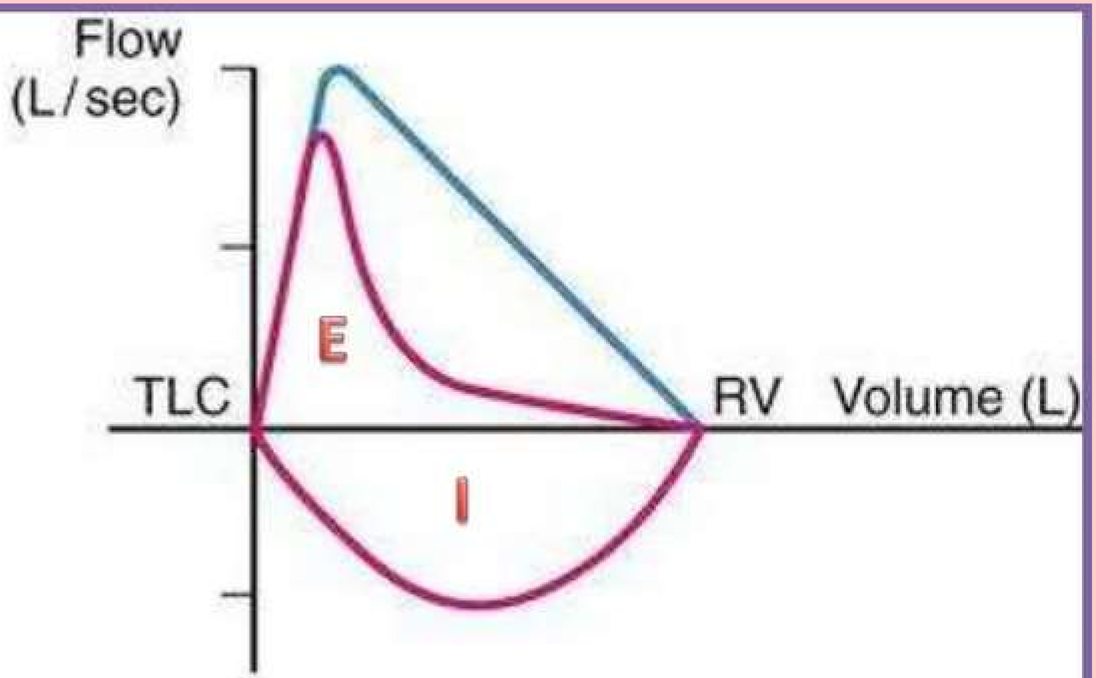


- FEV_1 improvement by
- 12% and ≥ 200mL

with

- 200-400mcg Salbutamol by inhaler
- or
- 40-80mcg Ipratropium Bromide by inhaler

Reversible airway disease diagnostic of asthma



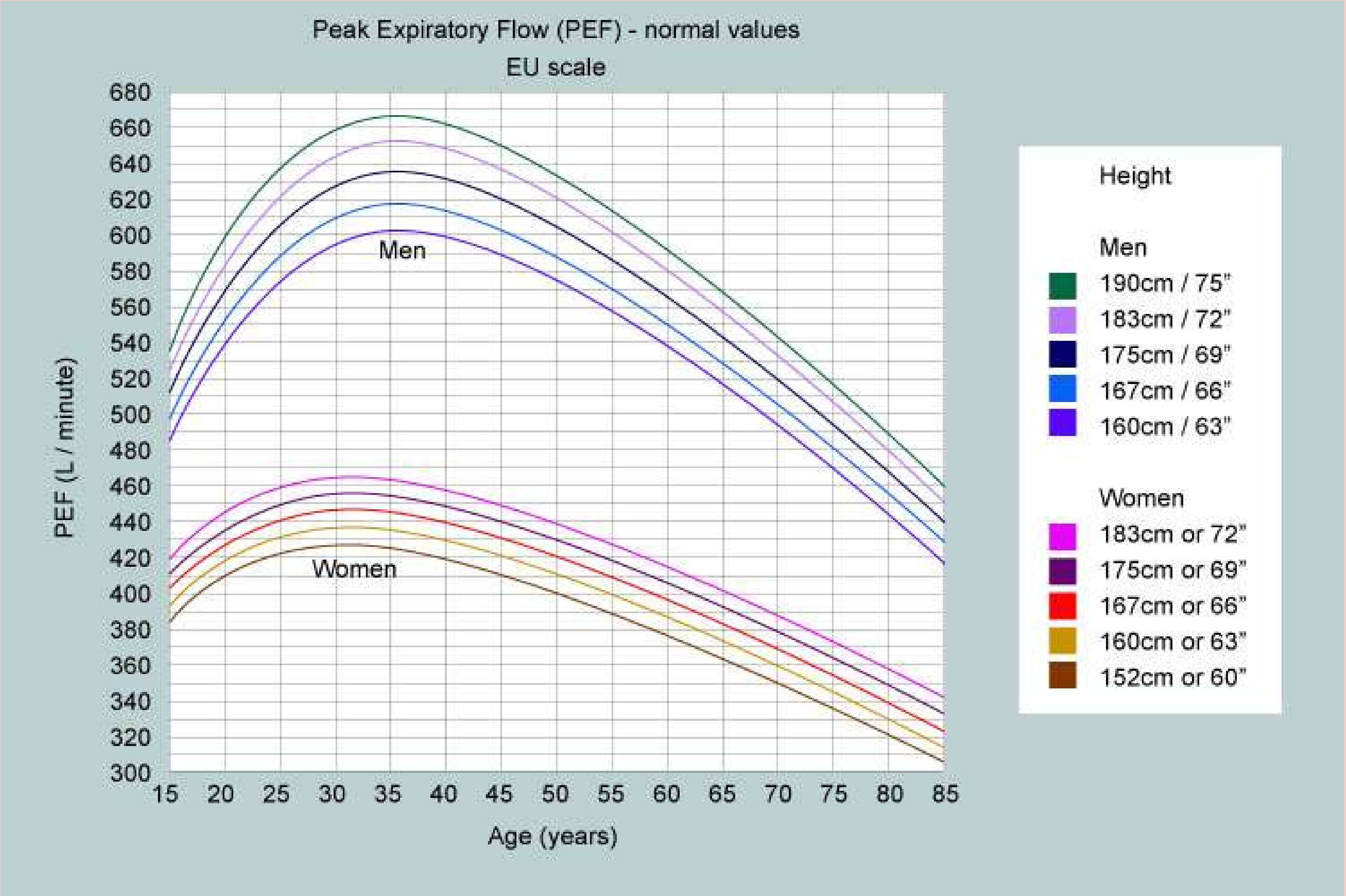
B. Emphysema

What is a Peak Flow Meter?

- A peak flow meter is a device, which records the peak or maximal flow during a forced expiratory manoeuvre (PEFR = Peak Expiratory Flow Rate).

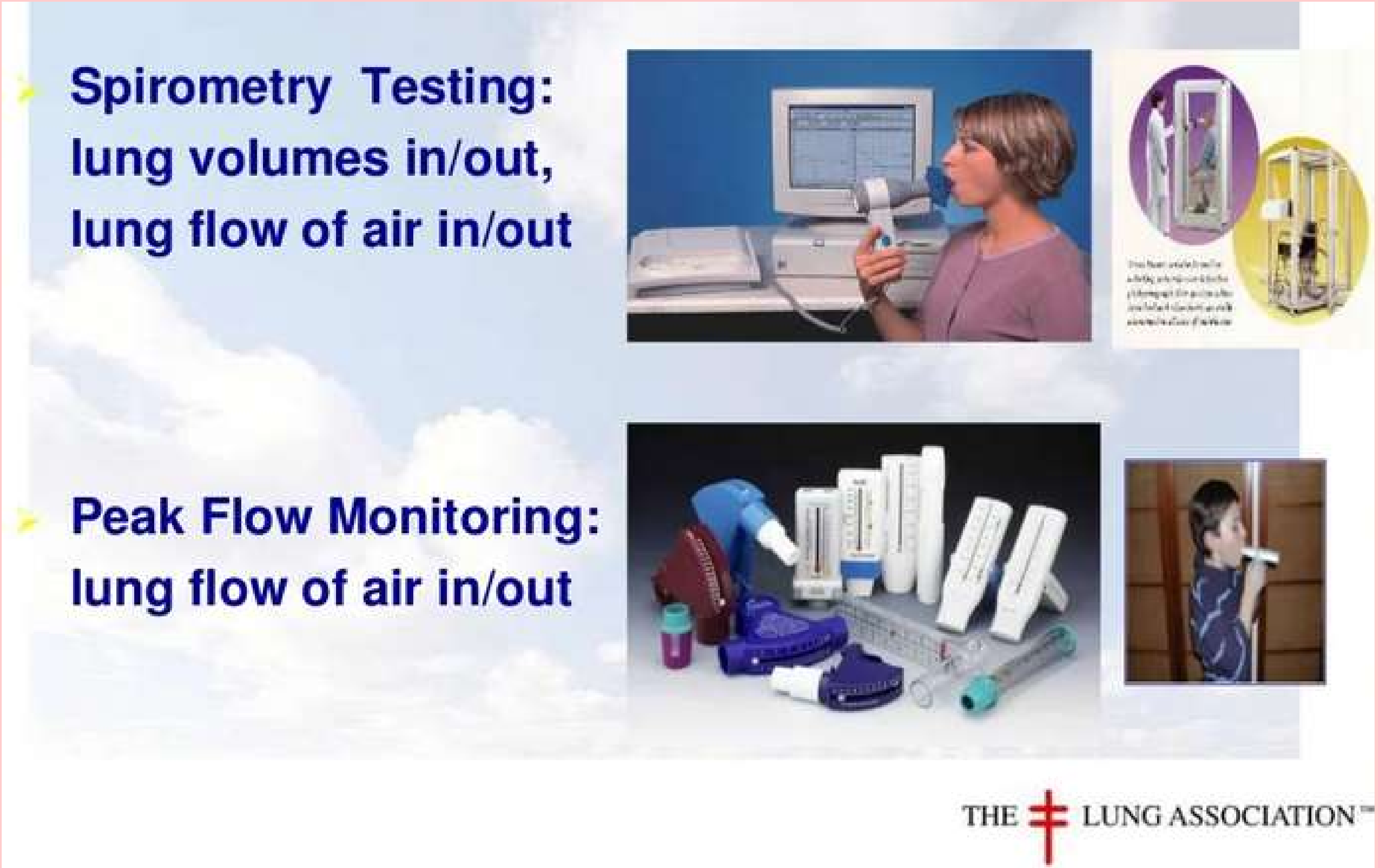
- In other words, a peak flow meter measures how fast air can be expelled from the lungs.

Peak Flow



Peak Expiratory Flow (PEF) - normal values
EU scale
PEF (L / minute)
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
Men
Women
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
Age (years)
Height
Men
190cm / 75"
183cm / 72"
175cm / 69"
167cm / 66"
160cm / 63"
Women
183cm or 72"
175cm or 69"
167cm or 66"
160cm or 63"
152cm or 60"

Breathing Tests



Normal Values Peak Flow

Normal Values:

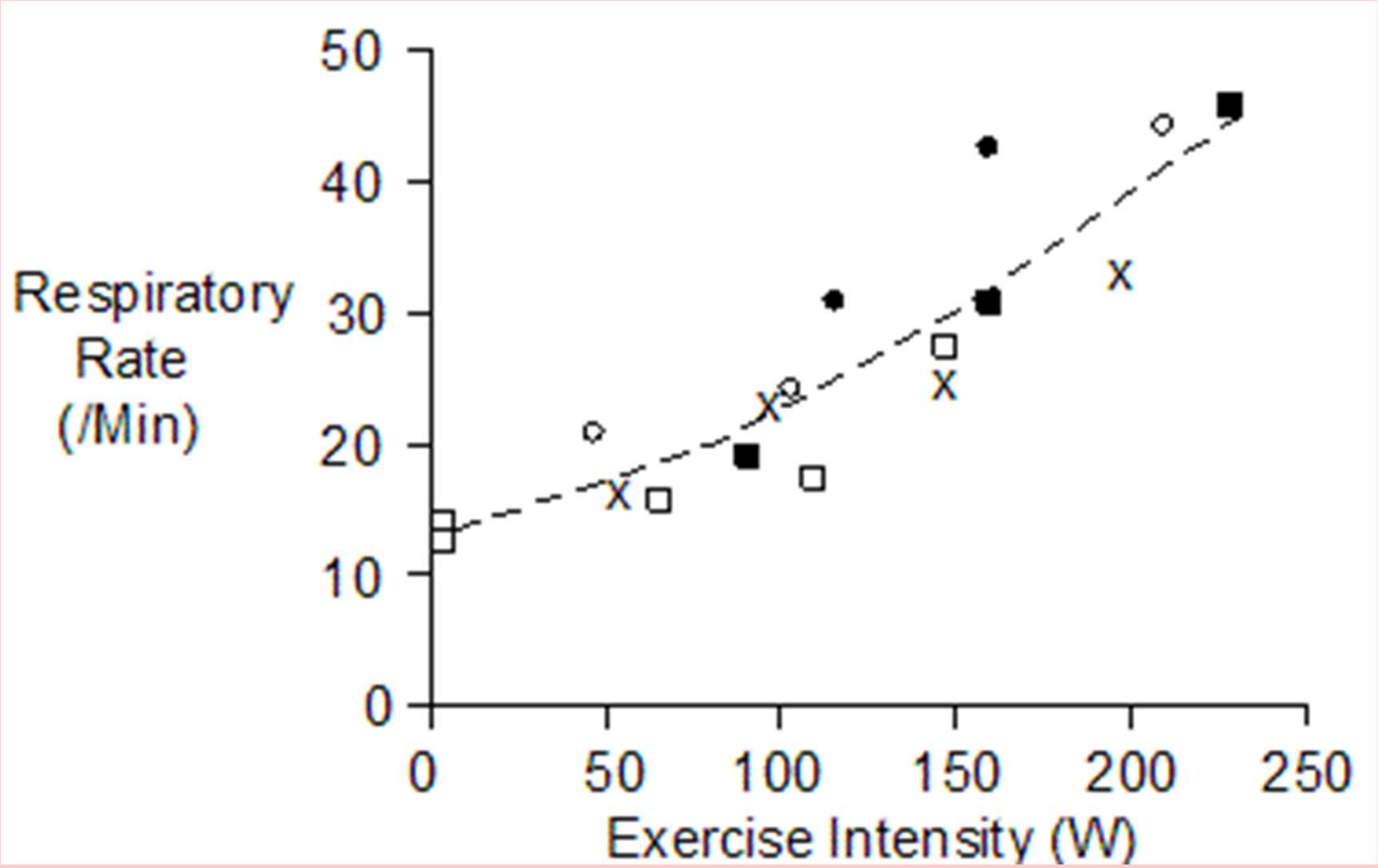
- Normal values are related to the patient's height as follows:

- An easy to remember approximation is:
  PEFR (L/min) = [Height (cm) - 80] x 5

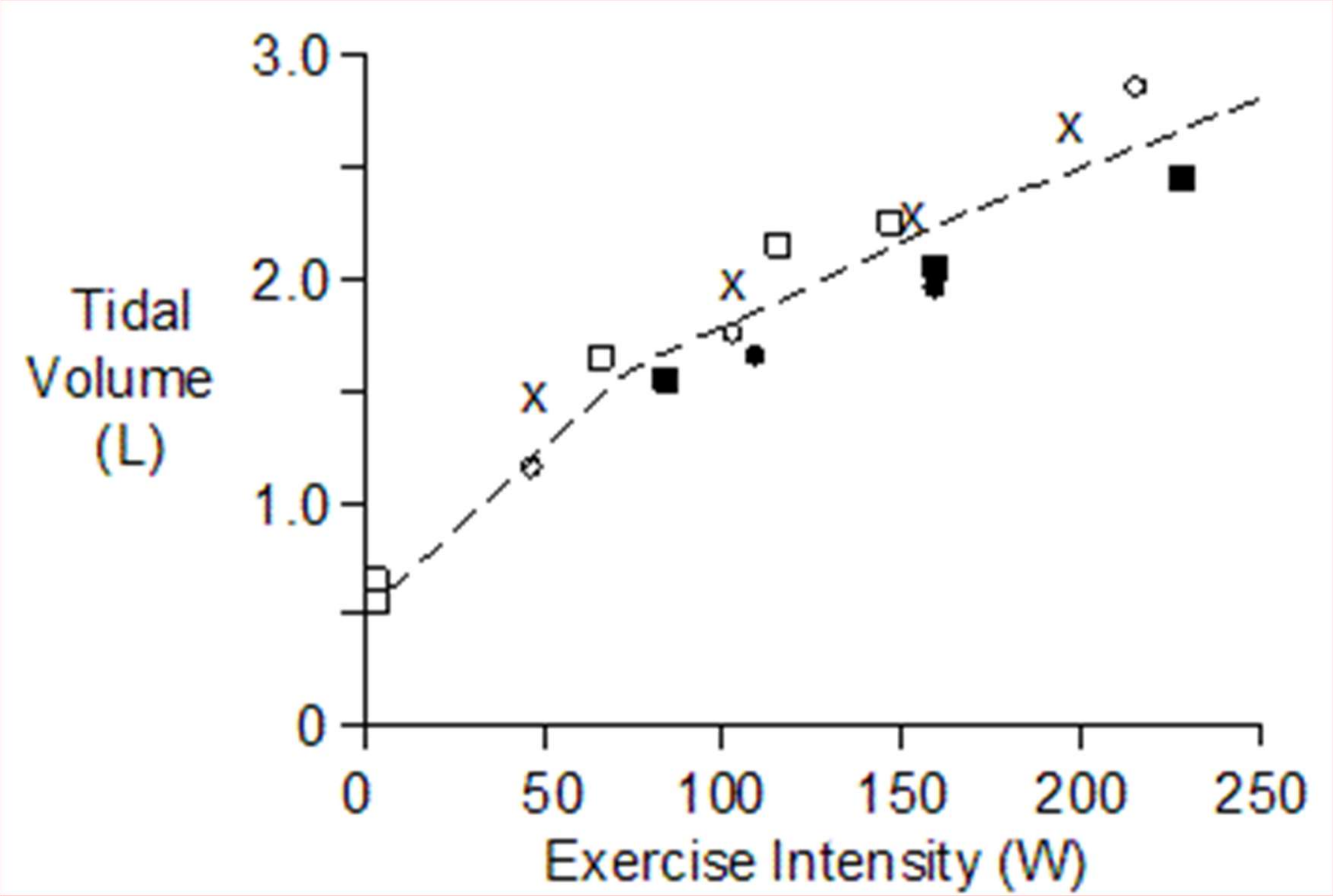
Incentive Spirometry

- An incentive spirometer is a handheld medical device used to help patients improve the functioning of their lungs. By training patients to take slow and deep breaths, this simplified spirometer facilitates lung expansion and strengthening.

Exercise And Breathing



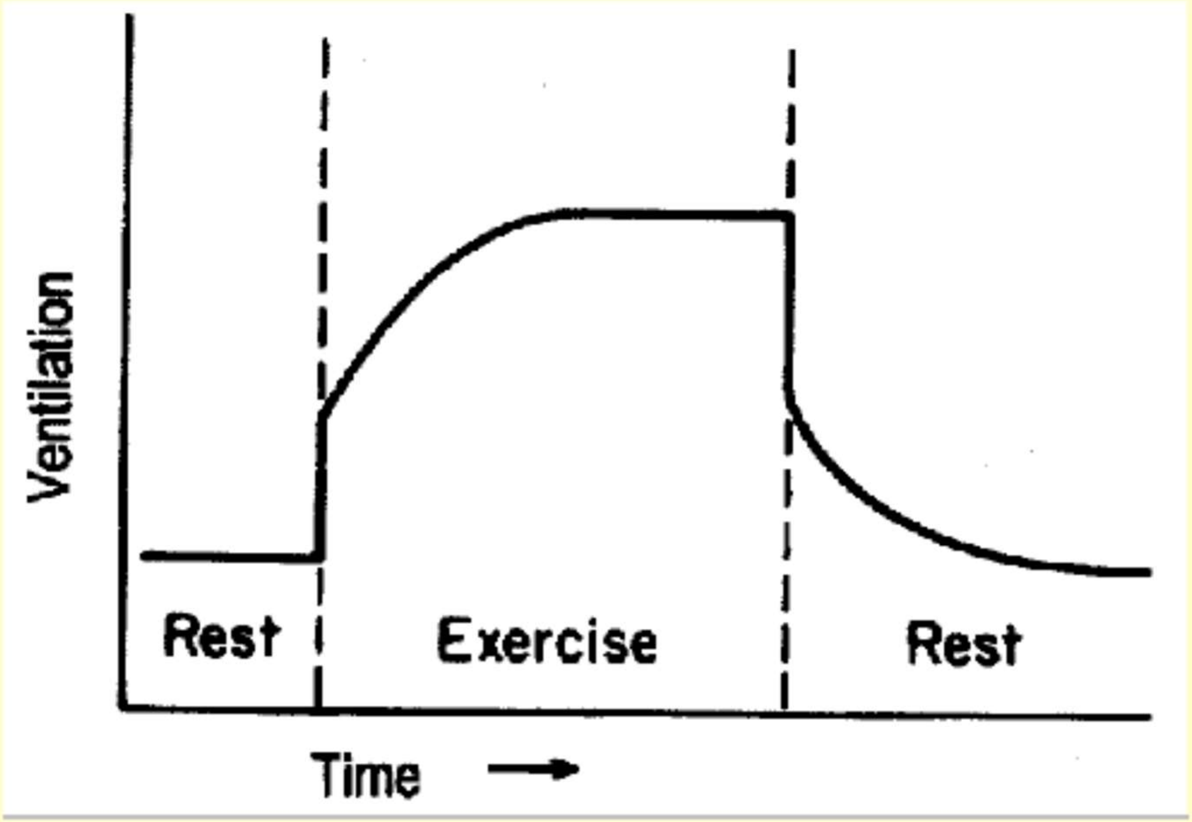
Exercise And Breathing (2)



Pulmonary Ventilation

- Ventilation is the mass movement of gas in and out of the lungs. Ventilation is regulated so as to provide the gaseous exchange required for aerobic energy metabolism.
- An average resting ventilation is about 6 liters/minute. The ventilation is a function of the tidal volume and the respiration rate:
  - $V_E = TV \times RR$

Rapid increase in ventilation at the start of exercise (neural?) followed by a slower increase to a steady-state over 5 minutes (humoral?)



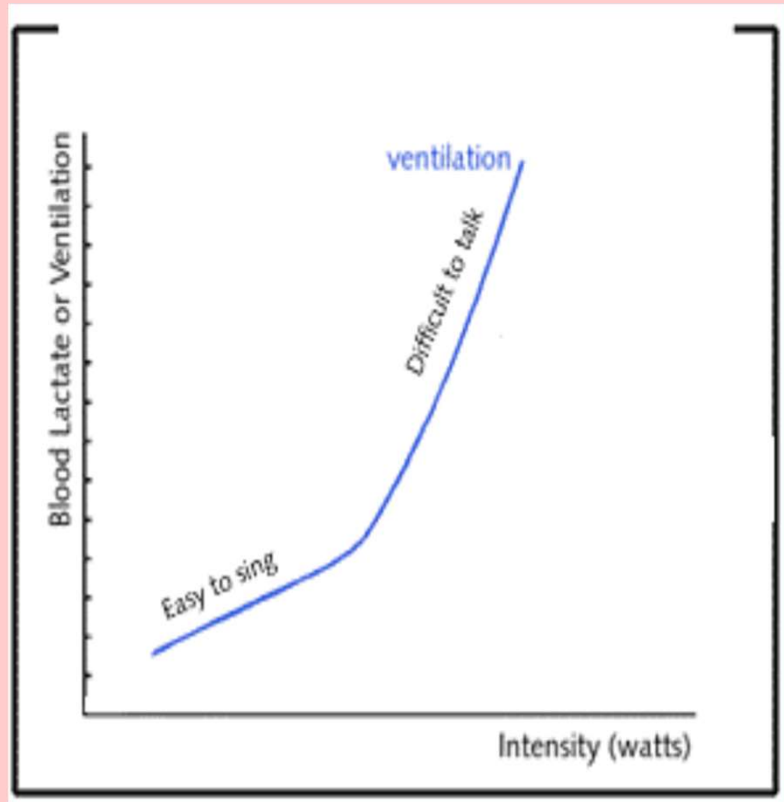
Pulmonary Ventilation

- Ventilation increases with exercise:
  - Tidal volume increases – each breath is deeper
  - Respiratory rate increases – breaths come faster

Ventilation can increase to 100-150 and possibly 200 liters/minute. This is a 20-30% increase

Pulmonary Ventilation

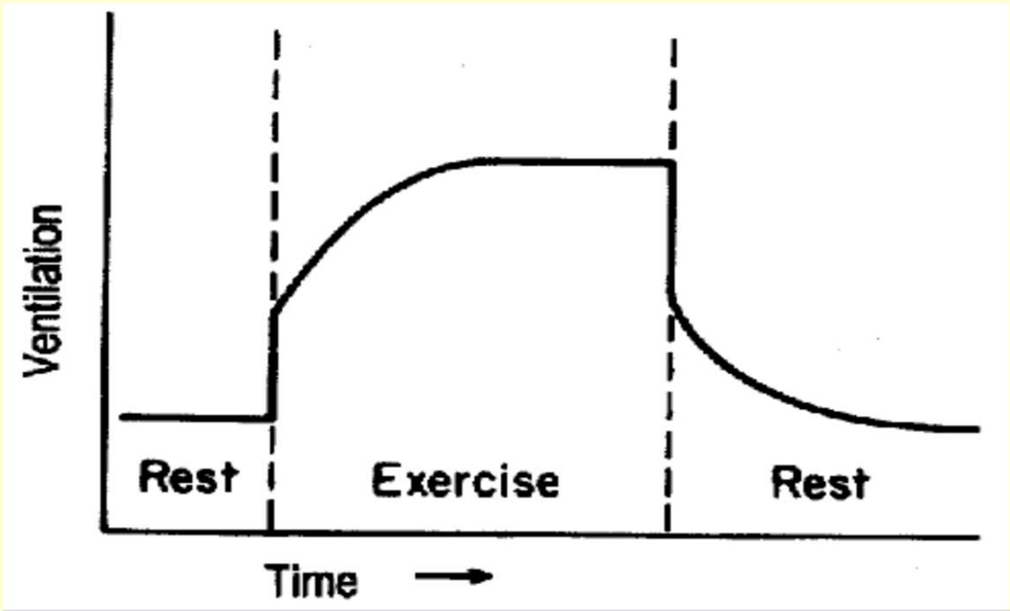
At heavy levels of exercise, lactic acid is produced. Through buffering in the blood, carbon dioxide levels go up, which triggers the lungs to further increase ventilation. Maximal levels of exercise are associated with a hyperventilatory state.



Ventilation = TV x RR

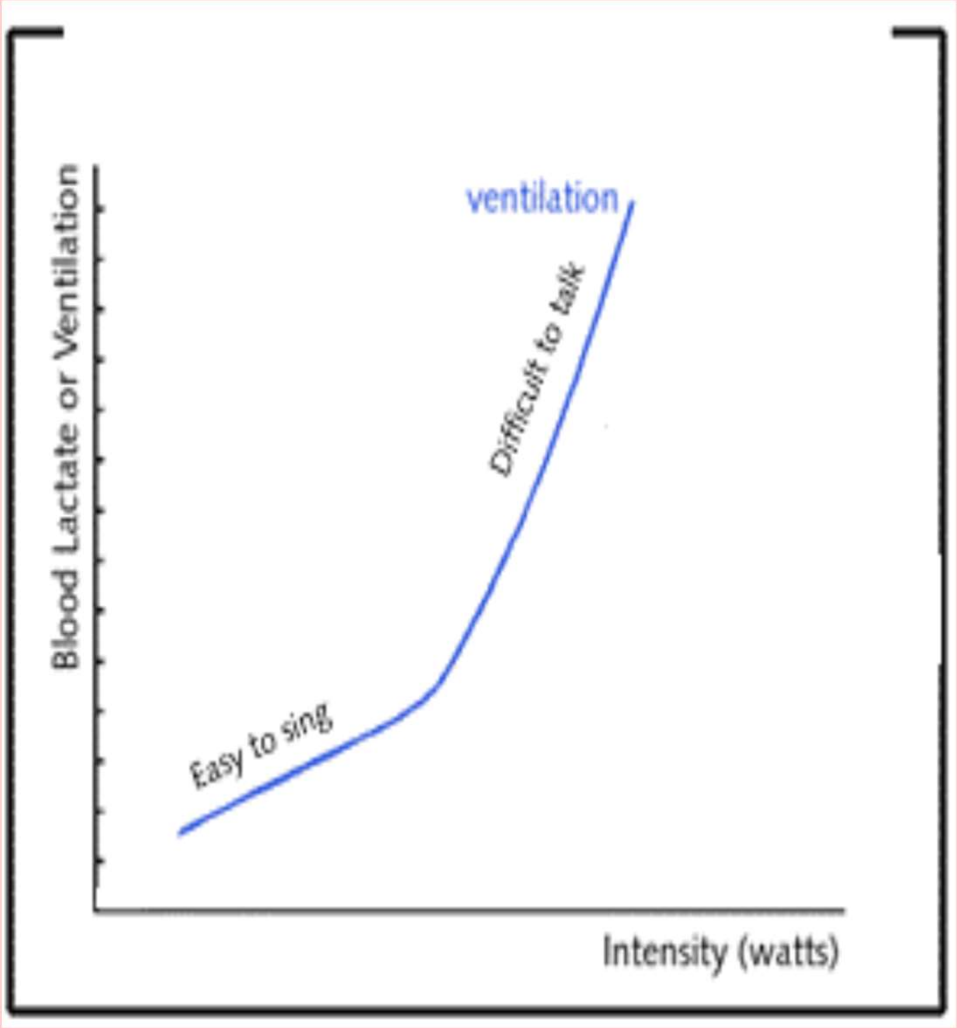
Breathing Increases

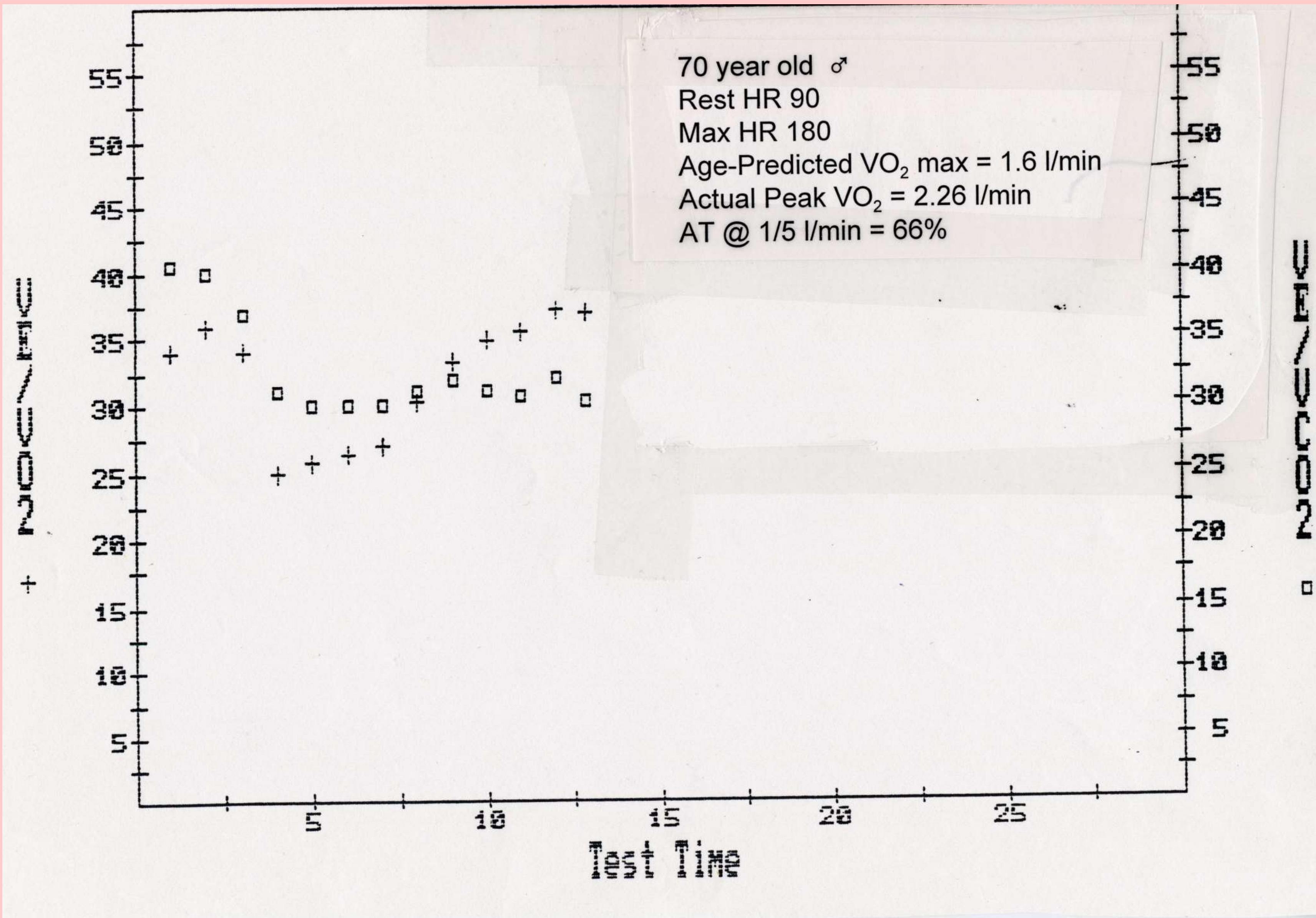
Rapid increase in ventilation at the start of exercise (neural?) followed by a slower increase to a steady-state over 5 minutes (humoral?)

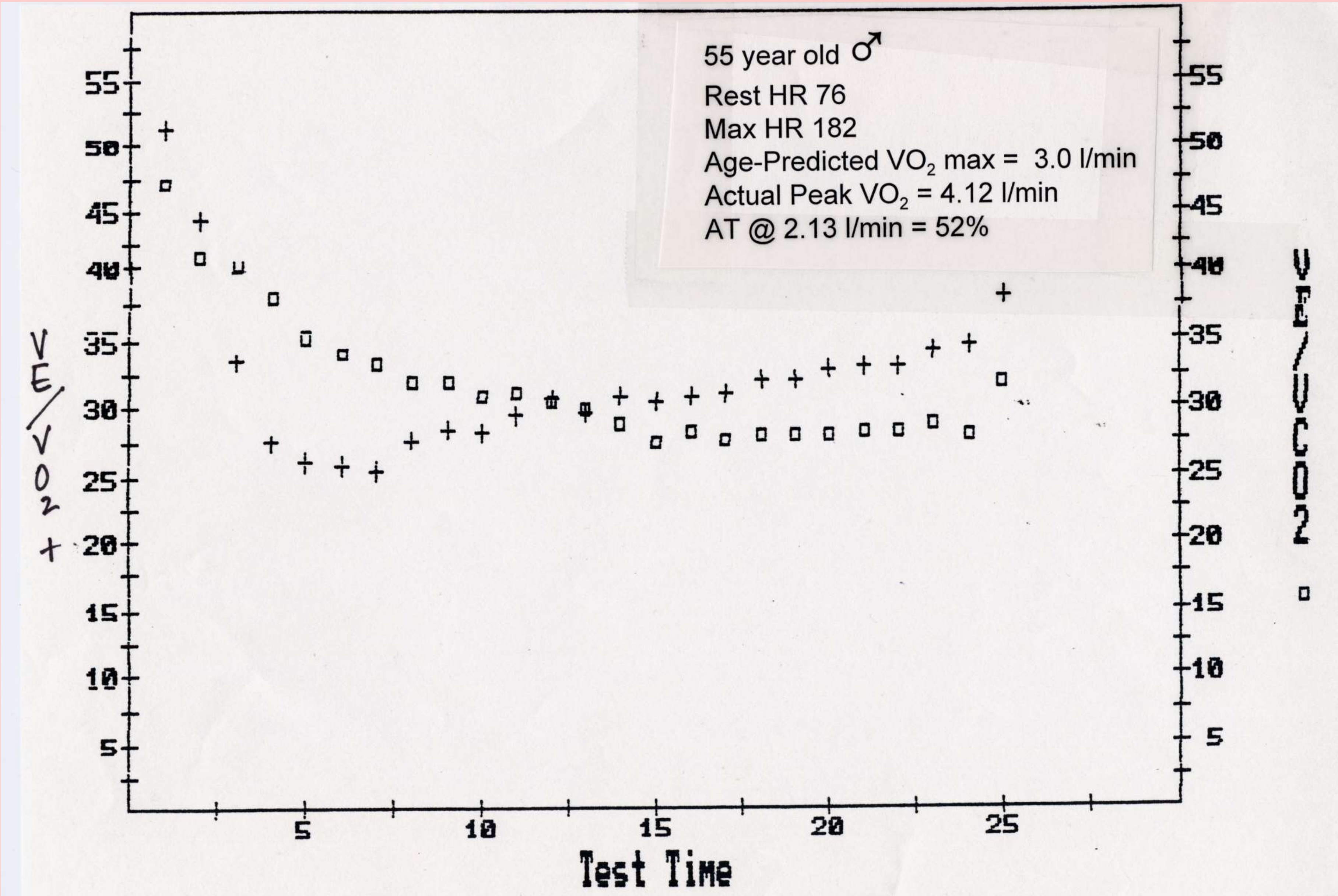


Exercise & Ventilation

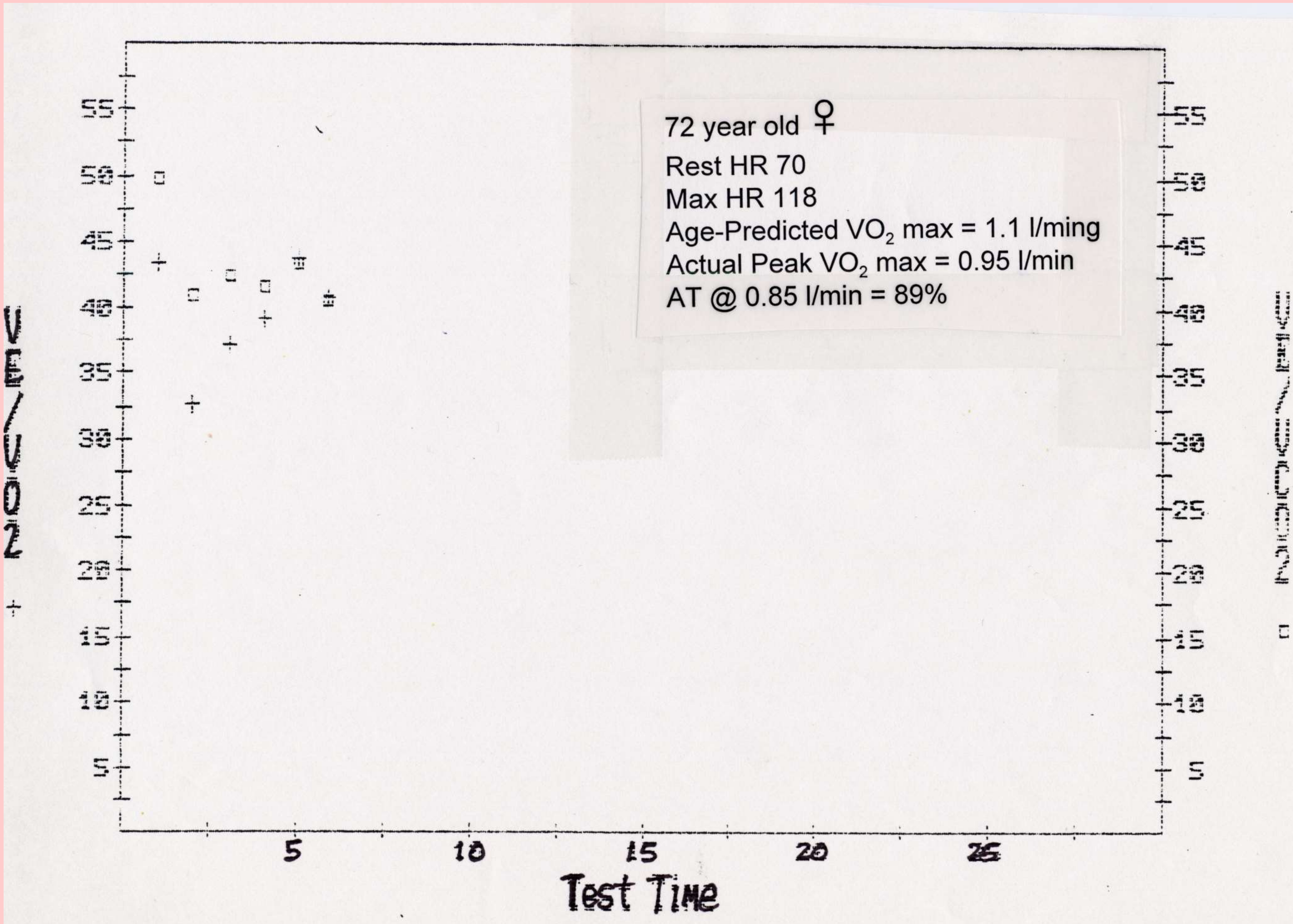
At heavy levels of exercise, lactic acid is produced. Through buffering in the blood, carbon dioxide levels go up, which triggers the lungs to further increase ventilation. Maximal levels of exercise are associated with a hyper-ventilatory state.




70 year old ♂
Rest HR 90
Max HR 180
Age-Predicted VO_2 max = 1.6 l/min
Actual Peak VO_2 = 2.26 l/min
AT @ 1/5 l/min = 66%
+ VO2/KG
VE/VCO2 □
Test Time



55 year old ♂
Rest HR 76
Max HR 182
Age-Predicted VO2 max = 3.0 l/min
Actual Peak VO2 = 4.12 l/min
AT @ 2.13 l/min = 52%
VE/VO2 +
VE/VCO2
Test Time



72 year old ♀
Rest HR 70
Max HR 118
Age-Predicted VO_2 max = 1.1 l/ming
Actual Peak VO_2 max = 0.95 l/min
AT @ 0.85 l/min = 89%
VE/VO2
Test Time
5
10
15
20
25

MEASURING LUNG VOLUMES WITH A BALLOON AND THE ARCHIMEDES PRINCIPLE

(Stephen Hales, UK, 1727)

Volume of displaced water
= Volume of air in balloon

https://www.youtube.com/watch?v=4yE89Z4qTiE

"Your breathing test results would be normal ...
if you were 3'8" and 150 years old."