Physiology of ventilation & work of breathing

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Goals of respiration

1. Ventilation
2. Diffusion of O_2 & CO_2
3. Transport of O_2 & CO_2
4. Regulation of respiration

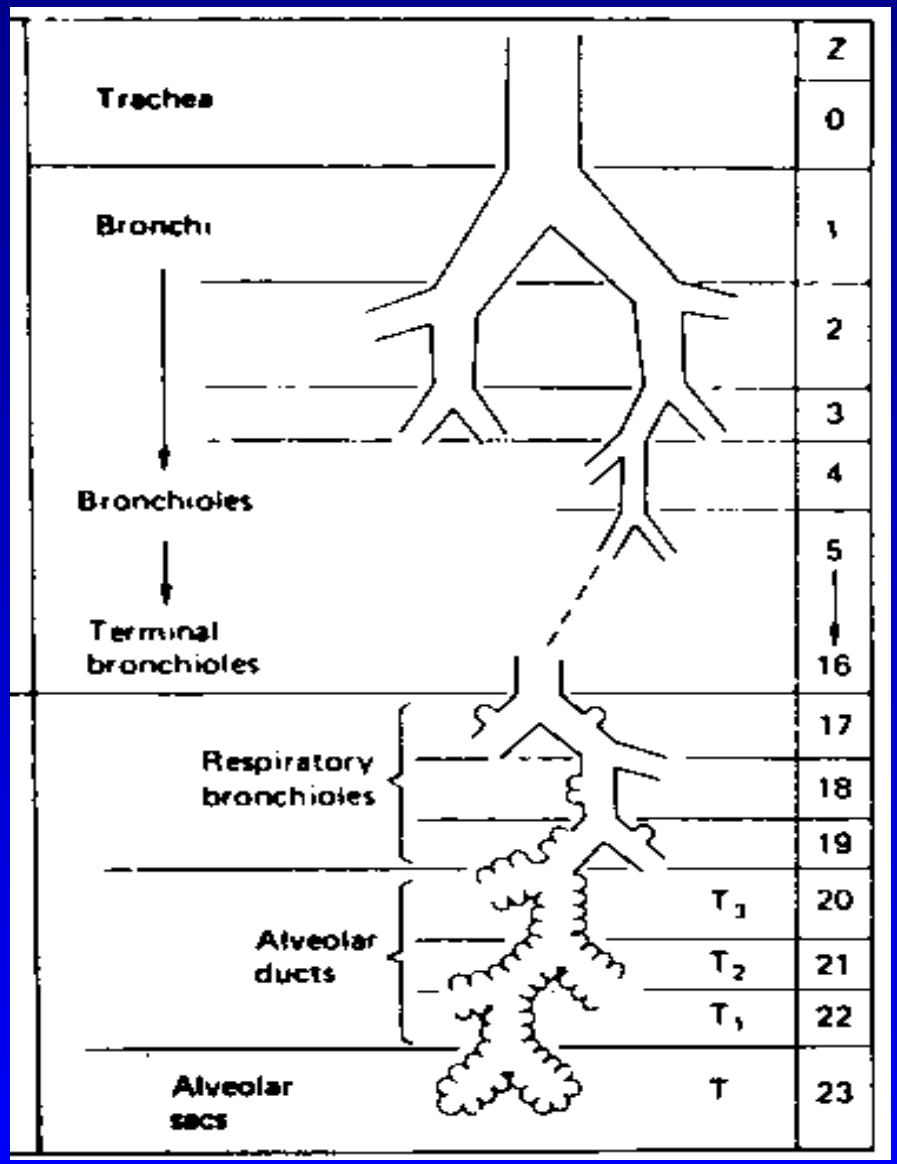
Ventilation

- Movement of air in & out of lungs
  - the airways
  - respiratory muscles
  - dead space ventilation
- Measurement of ventilation
- The work of breathing
- Importance in the ICU

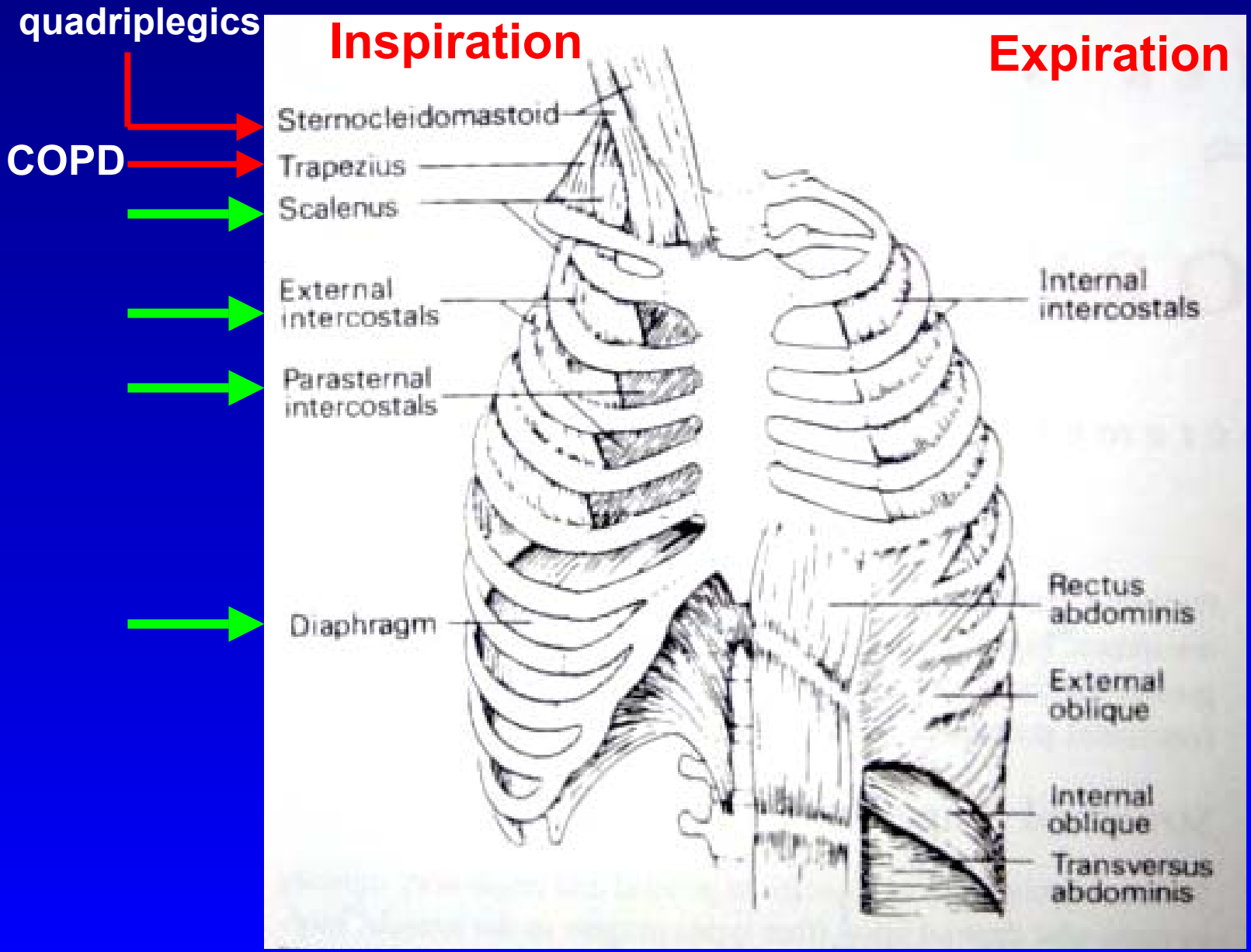
Movement of air in & out of lungs

The airways

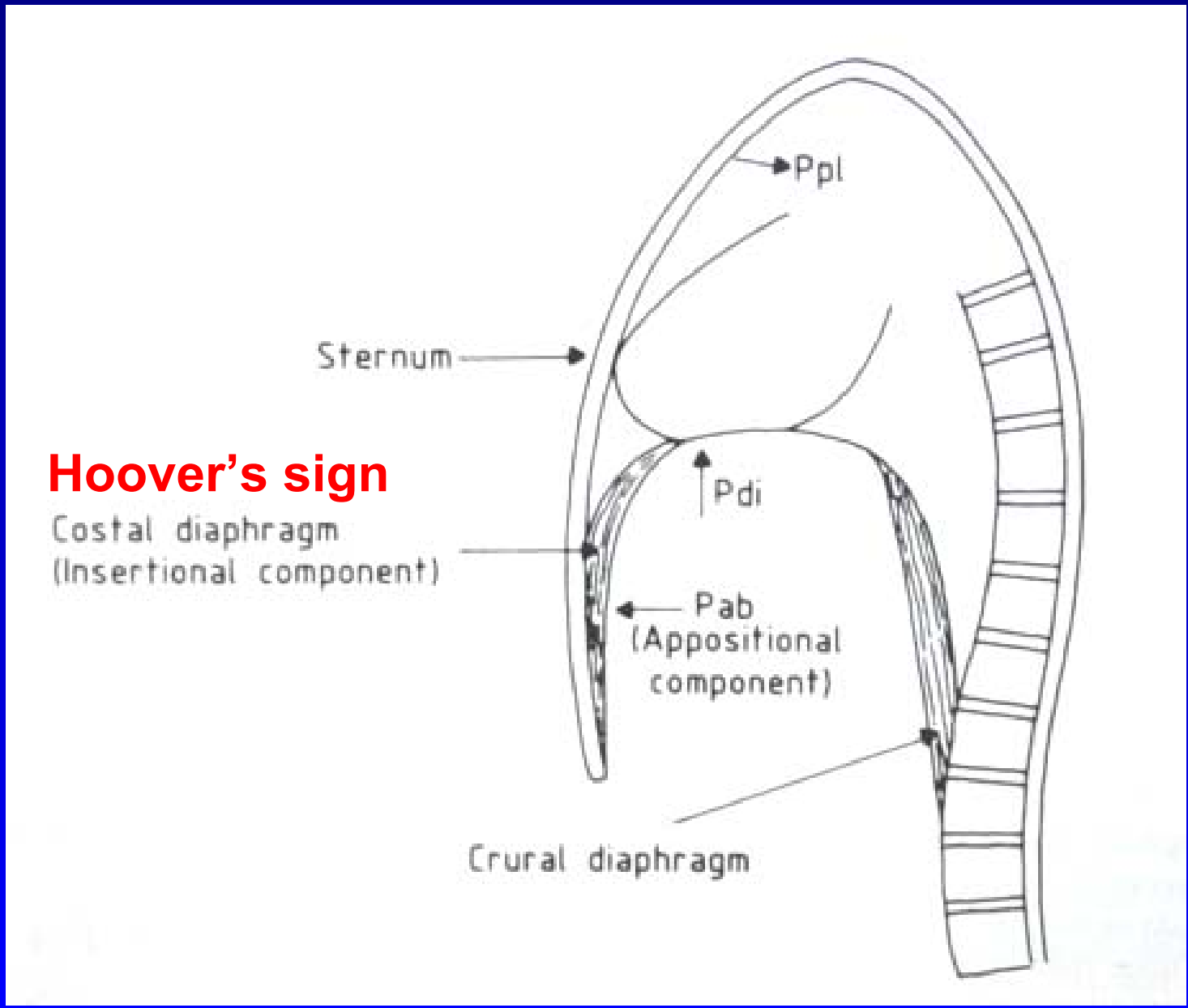
Anatomic dead space



Respiratory Muscles



The diaphragm



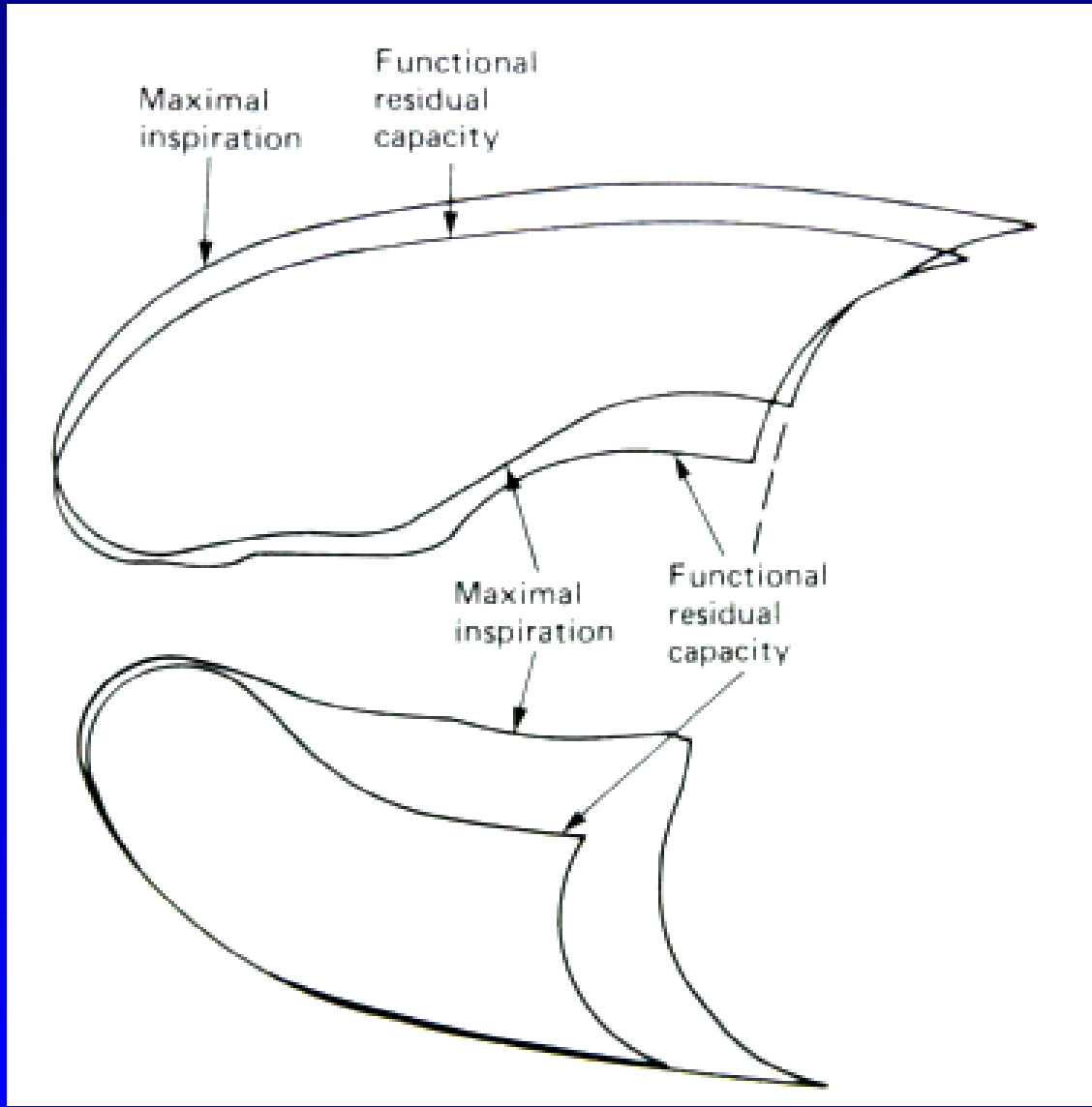
Hoover's sign

Effect of posture on respiratory muscles

Upright: ↑FRC

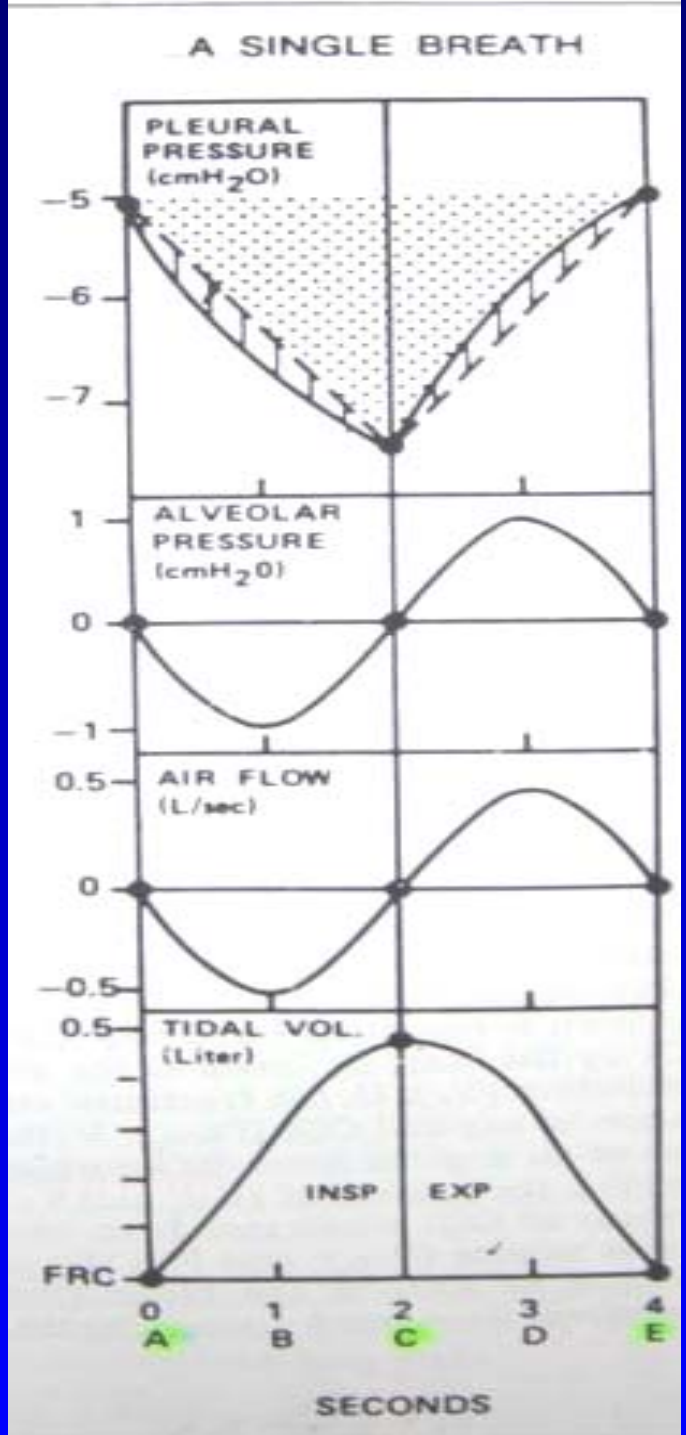
Supine: ↓FRC

Lateral: →



The pressures

- Pressure differences > airflow
- P_{pl} precede P_{alv}
- P_{alv} and air flow in phase
- At points of no flow $P_{alv} = 0$



Dead space ventilation

- 3 types
- Anatomic dead space

  1ml/lb ideal body wt., 150 ml/500ml VT

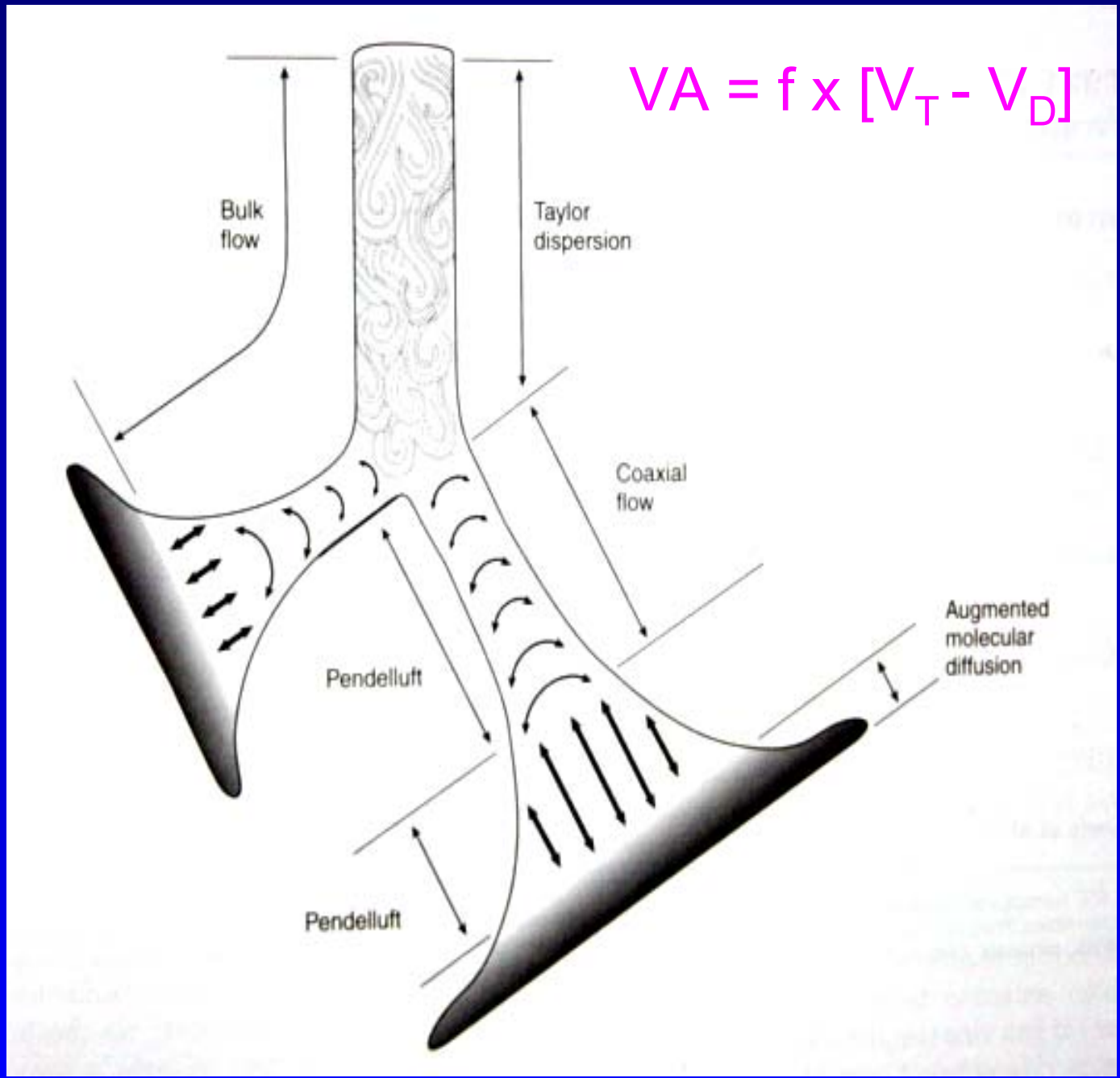
  ↓ VT- ↑ anat dead space/VT ratio

  e.g.150/500=30%, 150/300=50%

  can gas exchange occur if pt. is ventilated with VT< anat dead space?

Yes:
high freq
ventilation

$VA = f \times [V_T - V_D]$



- Alveolar dead space

  V/Q = Infinity

  PTE, Pulm vasoc, ↓CO

- Physiologic dead space (V_D)

  anat + alveolar dead space

  Normally V_D = anat dead space

  $V_D/V_T = (P_aCO_2-P_ECO_2) / P_aCO_2$

  <30% normal

  <60%=> successful weaning

  ↑ratio:↓VT or↑alv dead space

Measurement of ventilatory capacity

- MIP, MEP
- FVC (FEVC, FIVC)
- FEV_1
- PEFR
- MBC/MVV

depend on a single maneuver

depends on continued maximal effort

Work of breathing

- Work to overcome “afterload” on resp system
- Spont ventilation: resp muscles

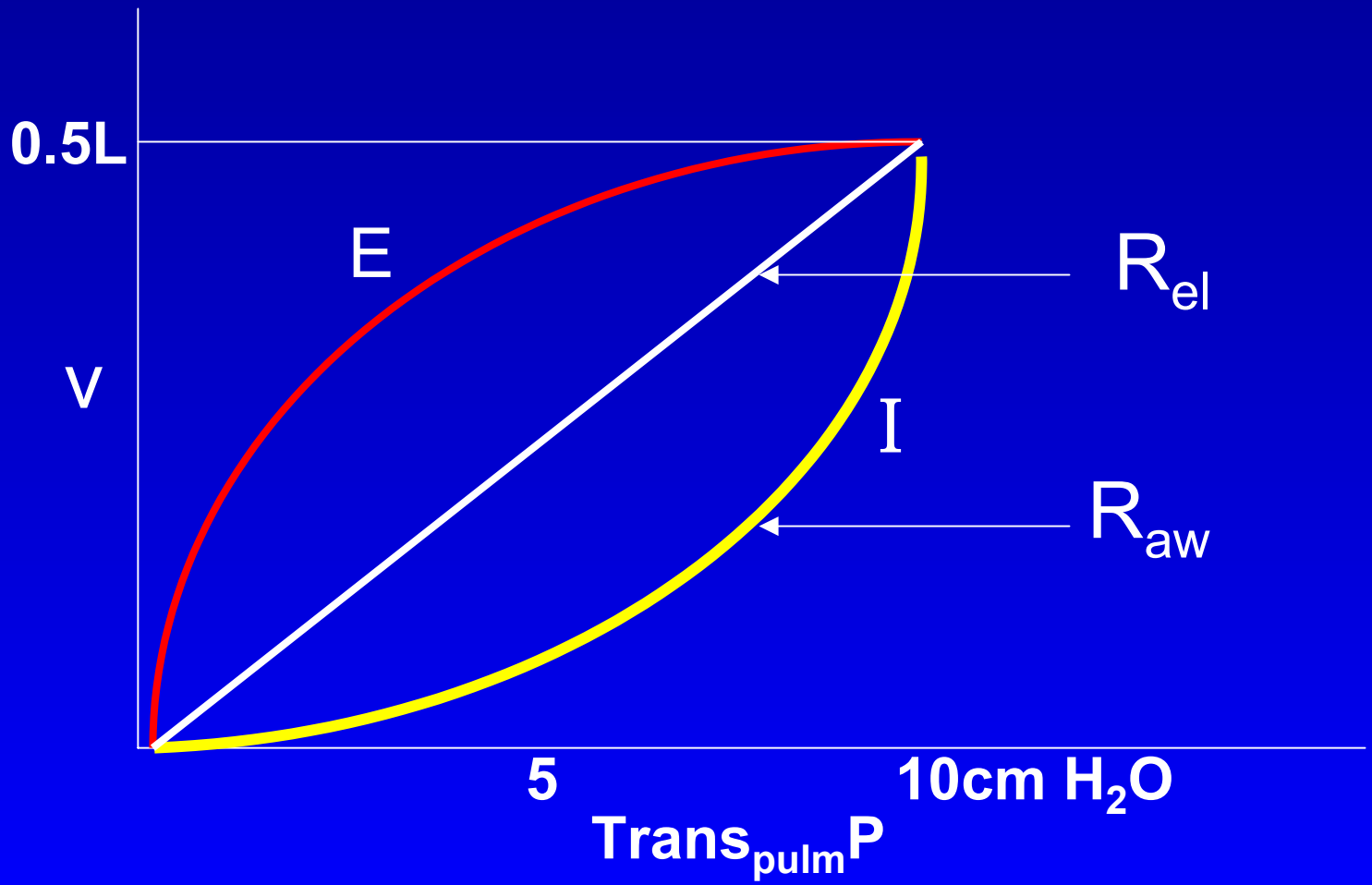
  Controlled ventilation: ventilator

  Partial support: both
- Work = Force x Distance

  = Pressure x Volume
- SI unit = Joule/L

Normally work is performed only for inspiration

Divided into 2 fractions



“minimal” work of breathing

Actual work performed by resp m. in health is minimal

VO2R = 3ml/min (<5% of total VO2)

Interstitial lung disease: rapid shallow breathing

Increased effort reqd. to expand lungs → pts. breath at a lower FRC

COPD: pts. Breath slow & deep i.e. at higher FRC to prevent airway collapse at low lung volumes

Importance in the ICU

- Measurement of WOB in ICU not routine
- Until recently performed by physiologists>clinicians
- Most ICU pts. are extubated < 96 hrs using standard weaning criteria
- “advantages” of measuring WOB

  ensure pt.-vent synchrony

  aid to weaning

  comparison of diff. modes of MV

Measurement of WOB in ICU

2 ways:

a) Determination of O_2 cost of breathing

b) Measurement of mechanical WOB

a) O_2 cost of breathing

Total VO_2 – VO_2 during spont breathing

[$VO_2 = CO \times (CaO_2 - CVO_2)$]

drawbacks:

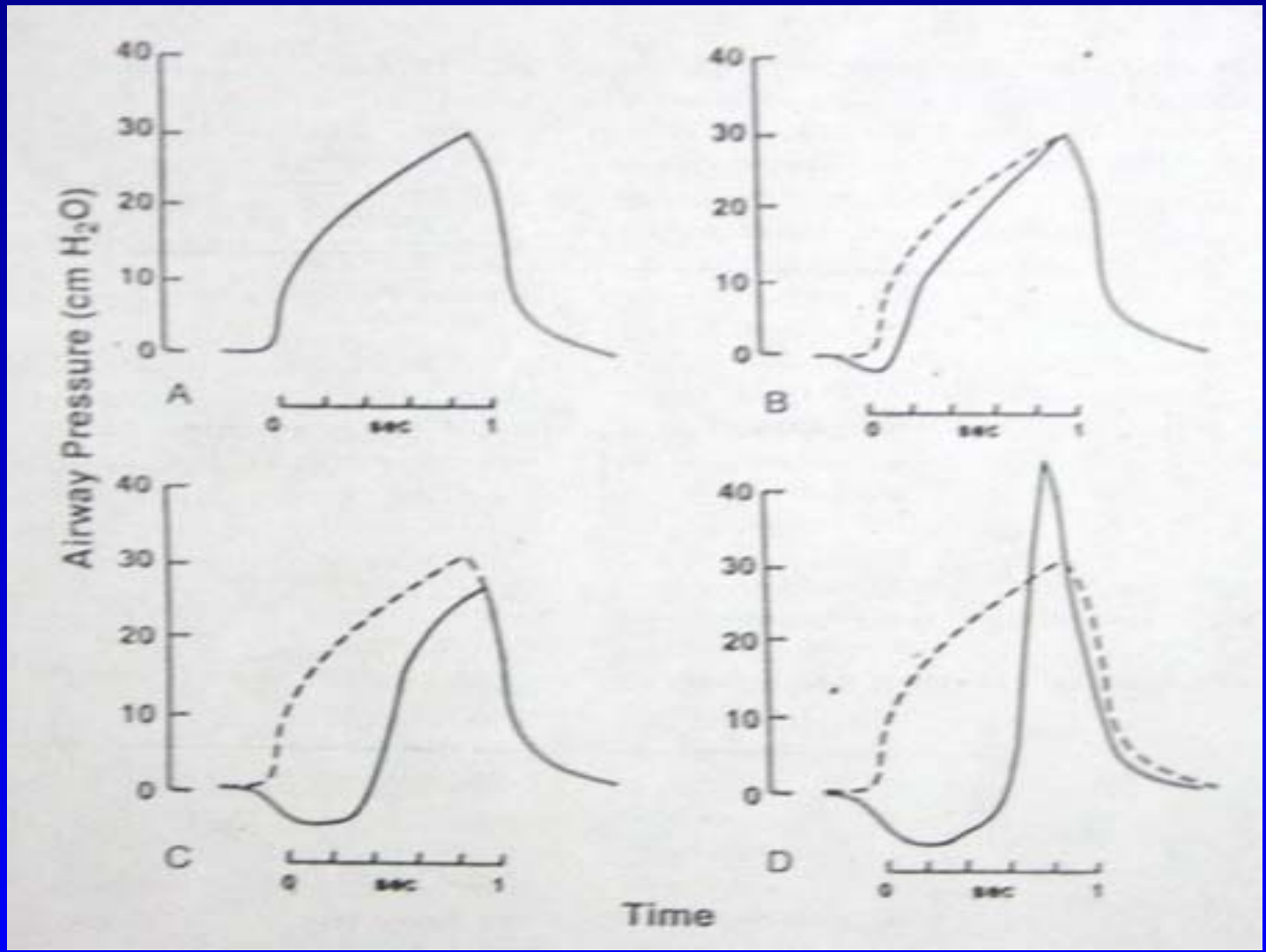
in ICU O_2 COB may represent small % of VO_2

VO_2 itself influenced by many other factors

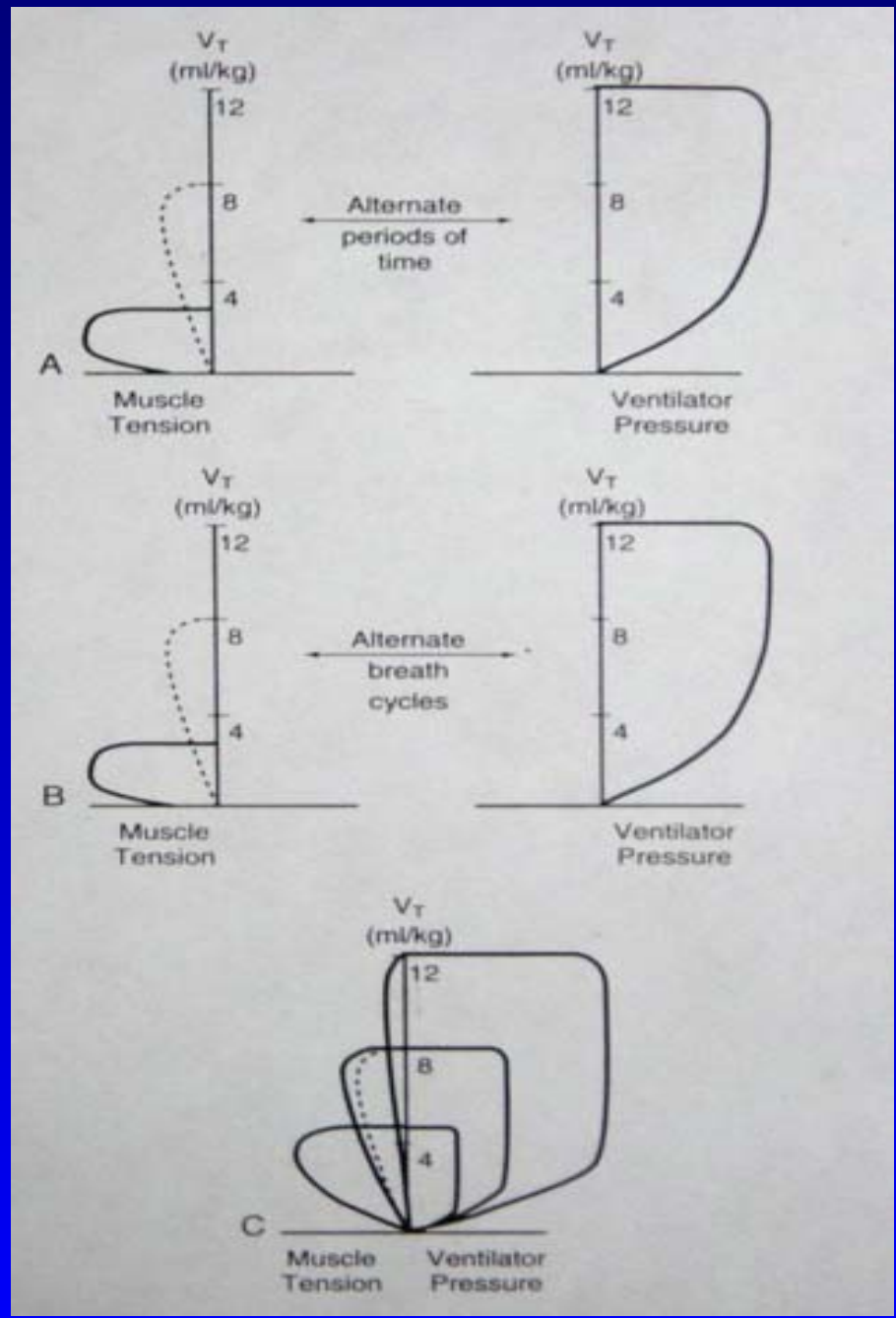
b) Measurement of mechanical WOB

- 2 ways
  - a) Graphics
    - P_{aw} tracings
    - P/V curves
  - b) Pressure time product

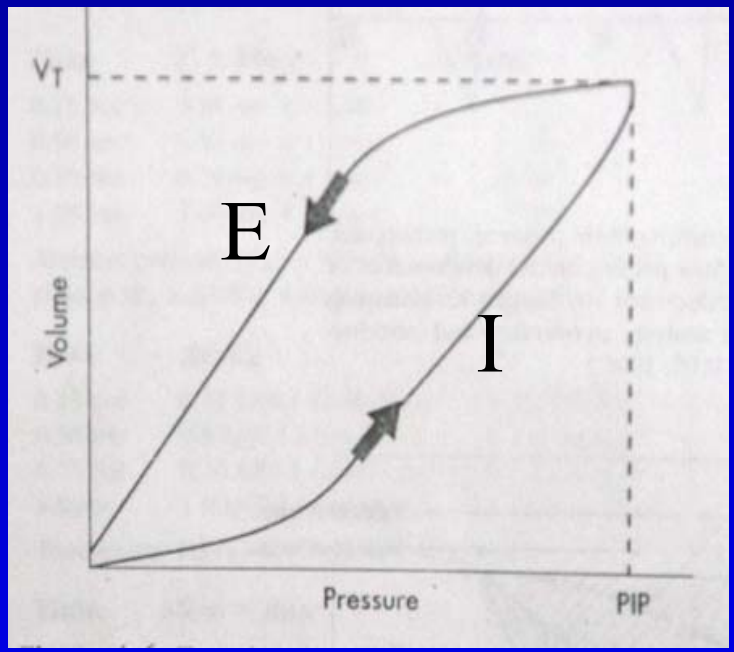
P_{aw} tracings



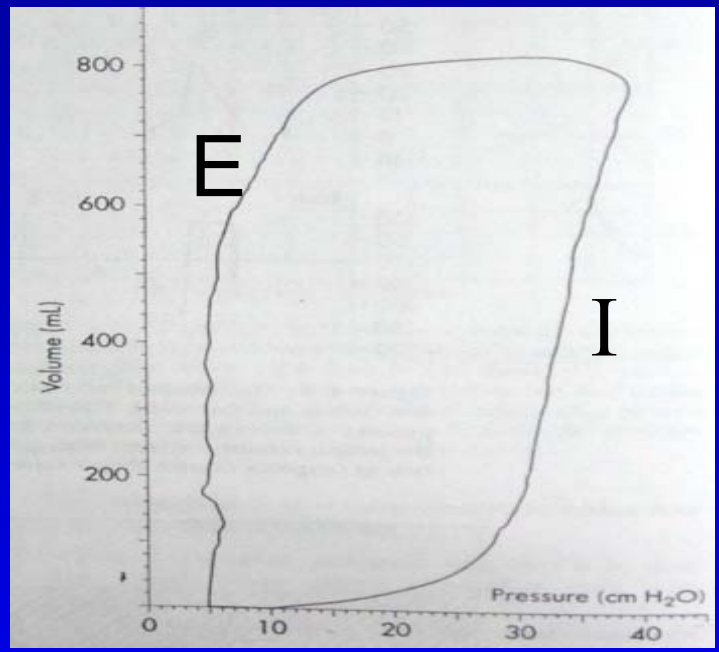
P/V curves Example 1



P/V curves Example 2

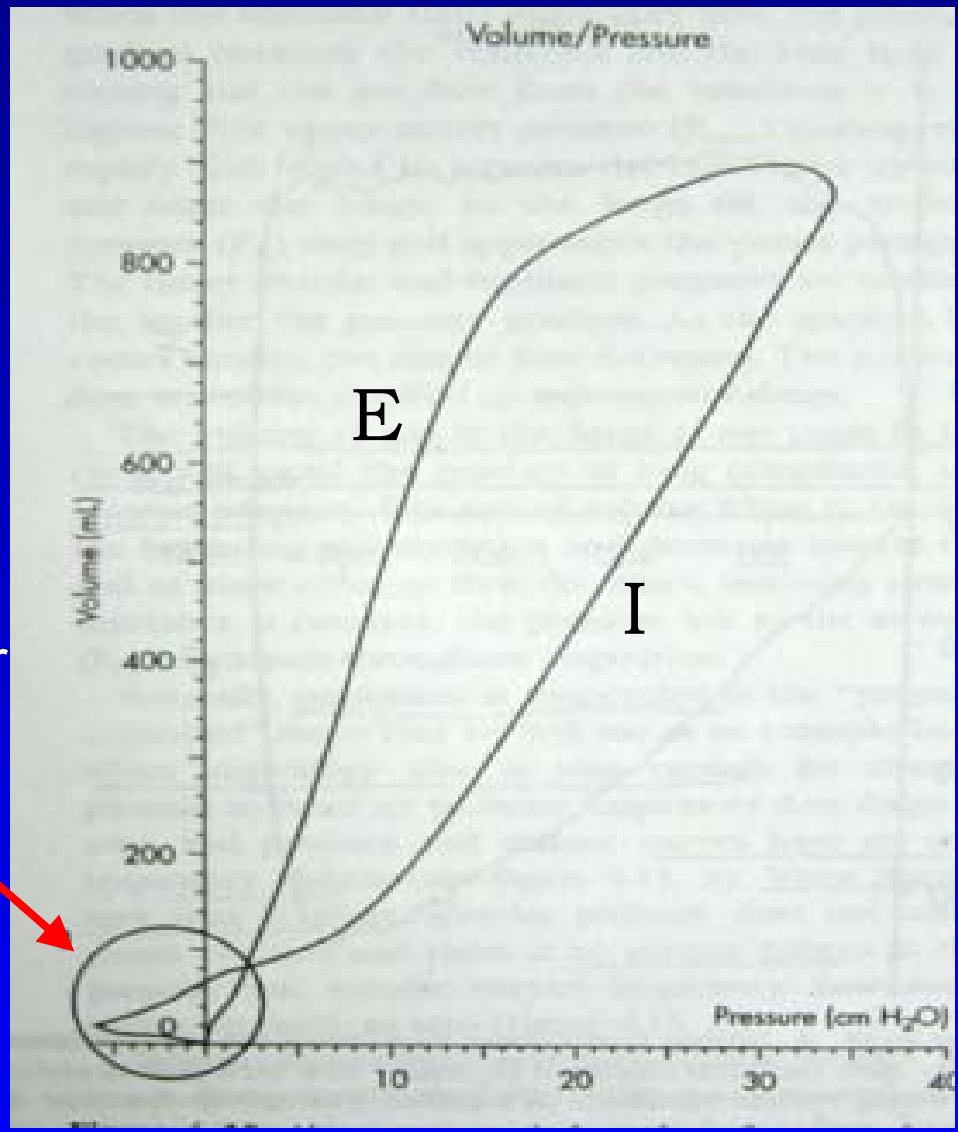


Normal PV loop



PV loop in COPD

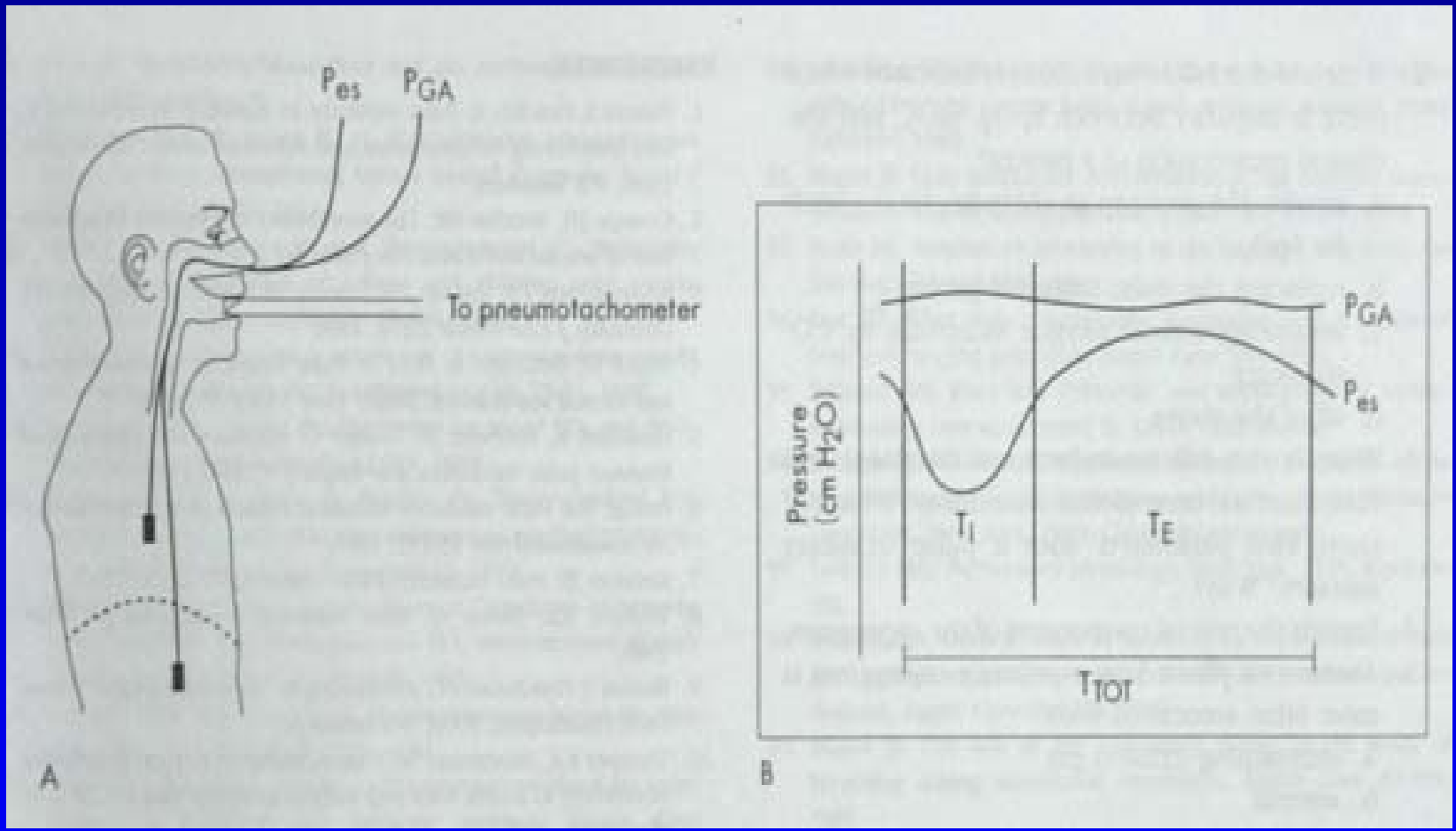
P/V curves Example 3



Pt. effort to trigger ventilator

Solution: increase trigger sensitivity

Pressure time product



Pressure time product (contd.)

- Work = P.dV
- Underestimates isometric work i.e. resp m. work which consumes O_2 but doesn't result in dV e.g. against PEEPi
- Under heavy loading conditions e.g. ARDS PTP correlates better with fatigue potential
- Pressure time index = P/Pmax x Ti/Ttot

  >0.15 => fatigue

WOB measurement at the bedside

- Bicore CP-100 Pulmonary Monitor
- Automated measurement of
  - VA, Pulm mechanics
  - WOBv and WOBp
  - Respiratory drive
- Oesophageal balloon, pnemotachograph