



Analysis of Lung Mechanics During Artificial Ventilation

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Mechanical Ventilation is....

- ◆ The delivery of *FLOW* and *PRESSURE* to the patient's airway in order to effect changes in lung *VOLUME*



OUR MISSION...

◆ To deliver :

**Optimal Oxygenation and CO₂
removal with...**

**best Pressure - Volume Product
at the lowest FiO₂ and PEEP and
lowest Work of Breathing**



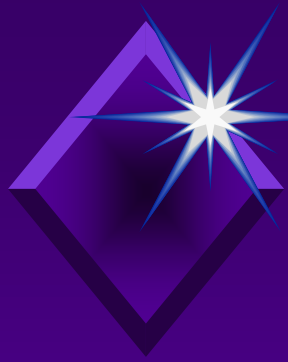
Goals of Mech. Ventilation

- ◆ **Alveolar Ventilation (eliminate CO₂)**
- ◆ **Arterial Oxygenation (deliver O₂)**
- ◆ **No adverse pressure effects (baro-trauma, cardiovascular compromise)**
- ◆ **Patient Comfort (Pt.-Vent. Synchrony)**
- ◆ **Muscle Rest and Reconditioning (gradual increase of work-load)**



Lecture Objectives

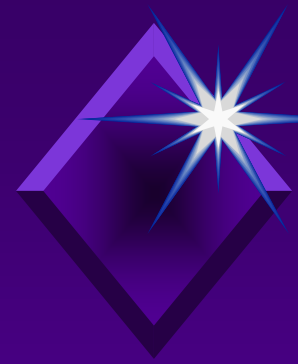
- ◆ Describe Flow, Pressure, Volume graphics & relation to Pulmonary mechanics
- ◆ Graphic patterns for ventilation modes
- ◆ Use graphics to optimize Mechanical Ventilation
- ◆ Use graphics for troubleshooting
- ◆ Use graphs to calculate respiratory system functions



Respiratory Monitoring

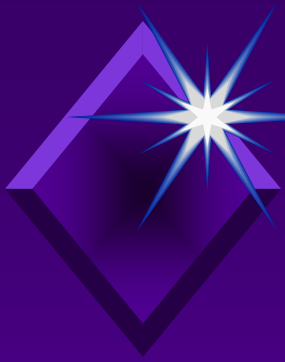
What do We Want to Know...

- ◆ **Ventilatory function of Lungs**
- ◆ **Patient - ventilator Interactions**
- ◆ **Acceptability of Respiratory Work**



Clinical Examination Comes FIRST (a)

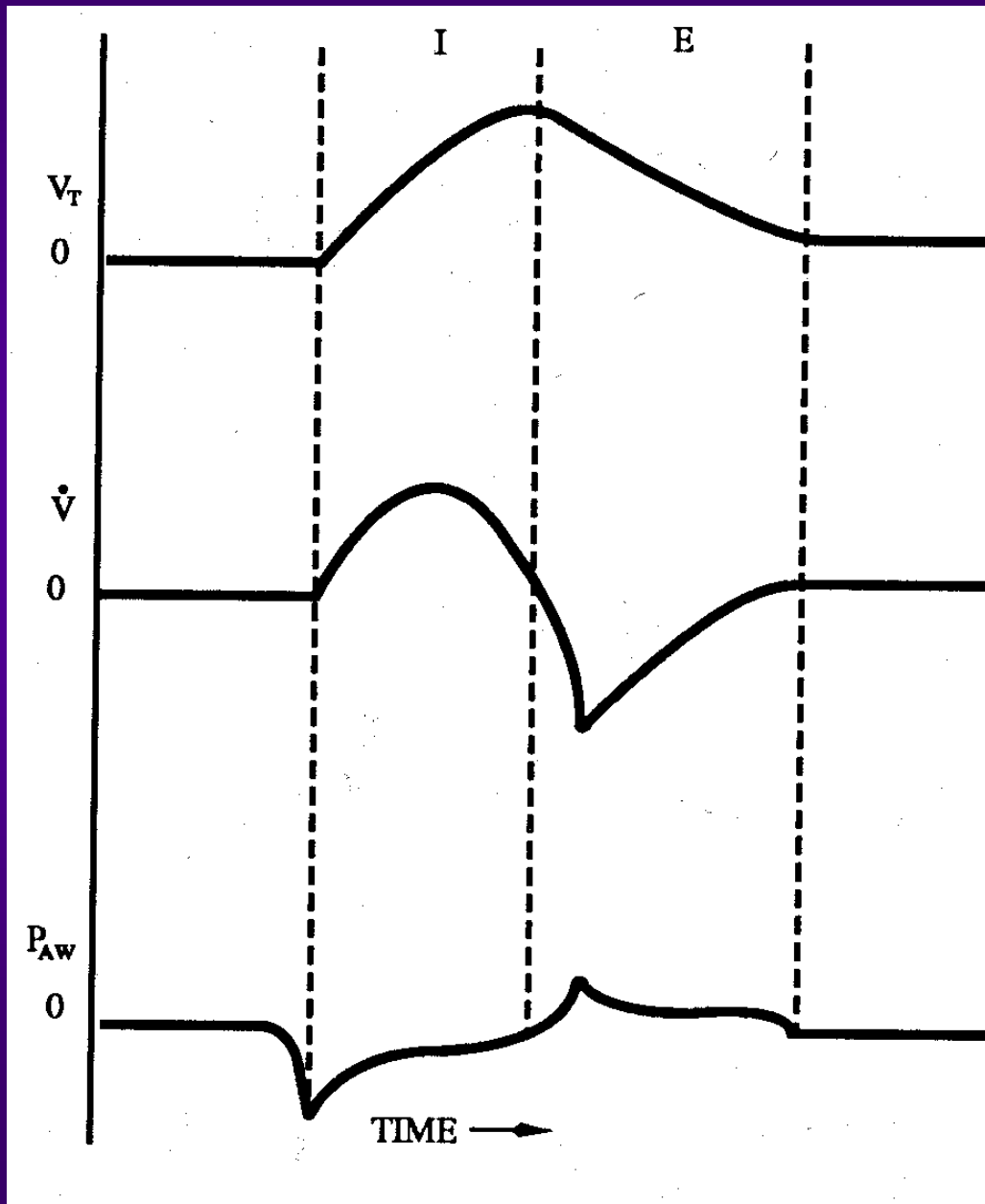
- ◆ Observation:
- ◆ Rate, Depth, Symmetry, I:E Time
- ◆ Assess the breathing effort - retractions, accessory I+E muscles
- ◆ Signs of Distress - HR, BP, Perspiration, Anxiety



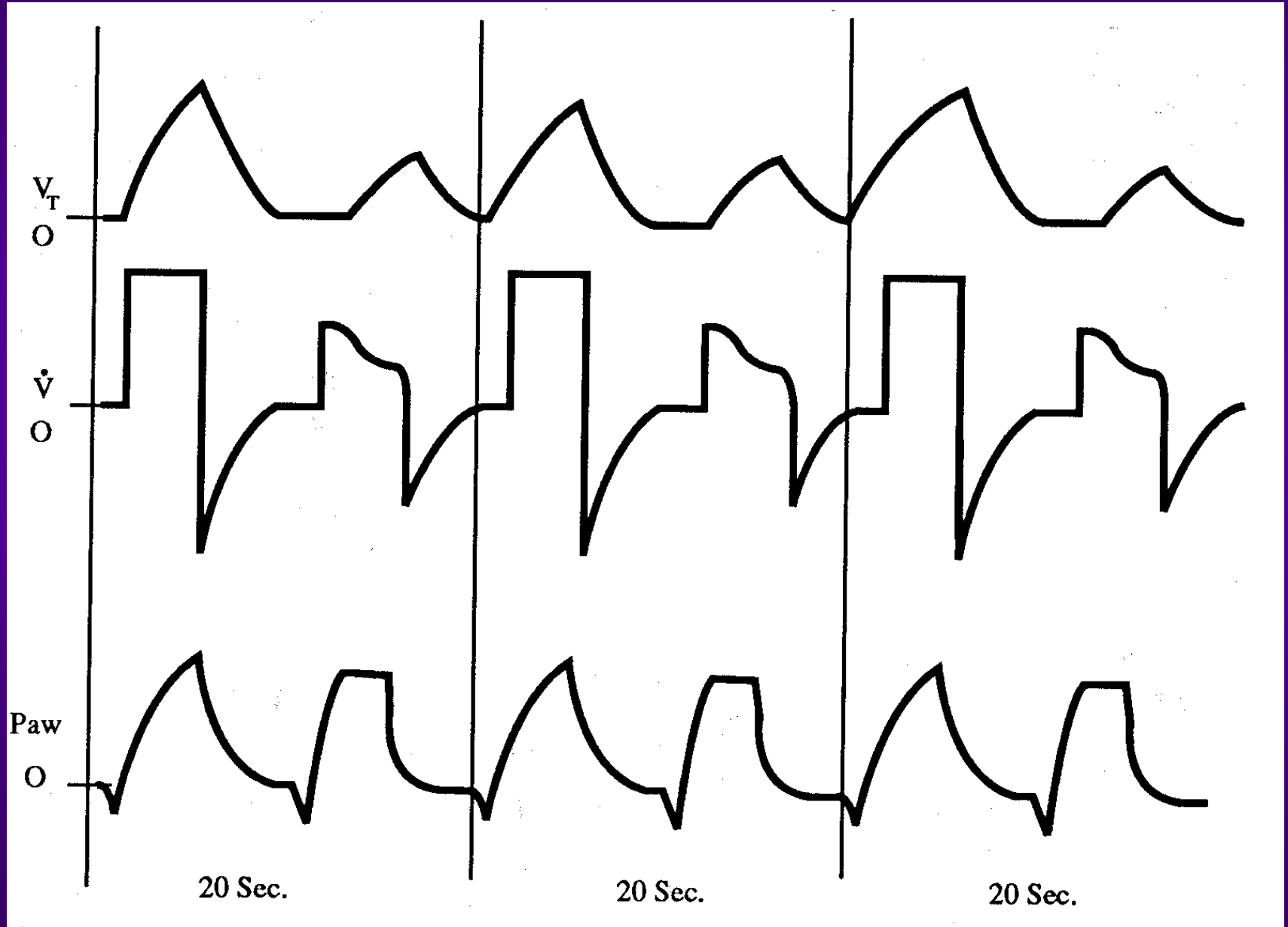
*Clinical Examination Comes **FIRST** (b)*

- ◆ *Palpation* - S.C. Emphysema, Hematoma, Broken Ribs, Flail Chest
- ◆ *Percussion* - Timpani Vs. Dullness
- ◆ *Auscultation* - Quality of breath sounds, Distribution of ventilation, Areas of Obstruction, Consolidation

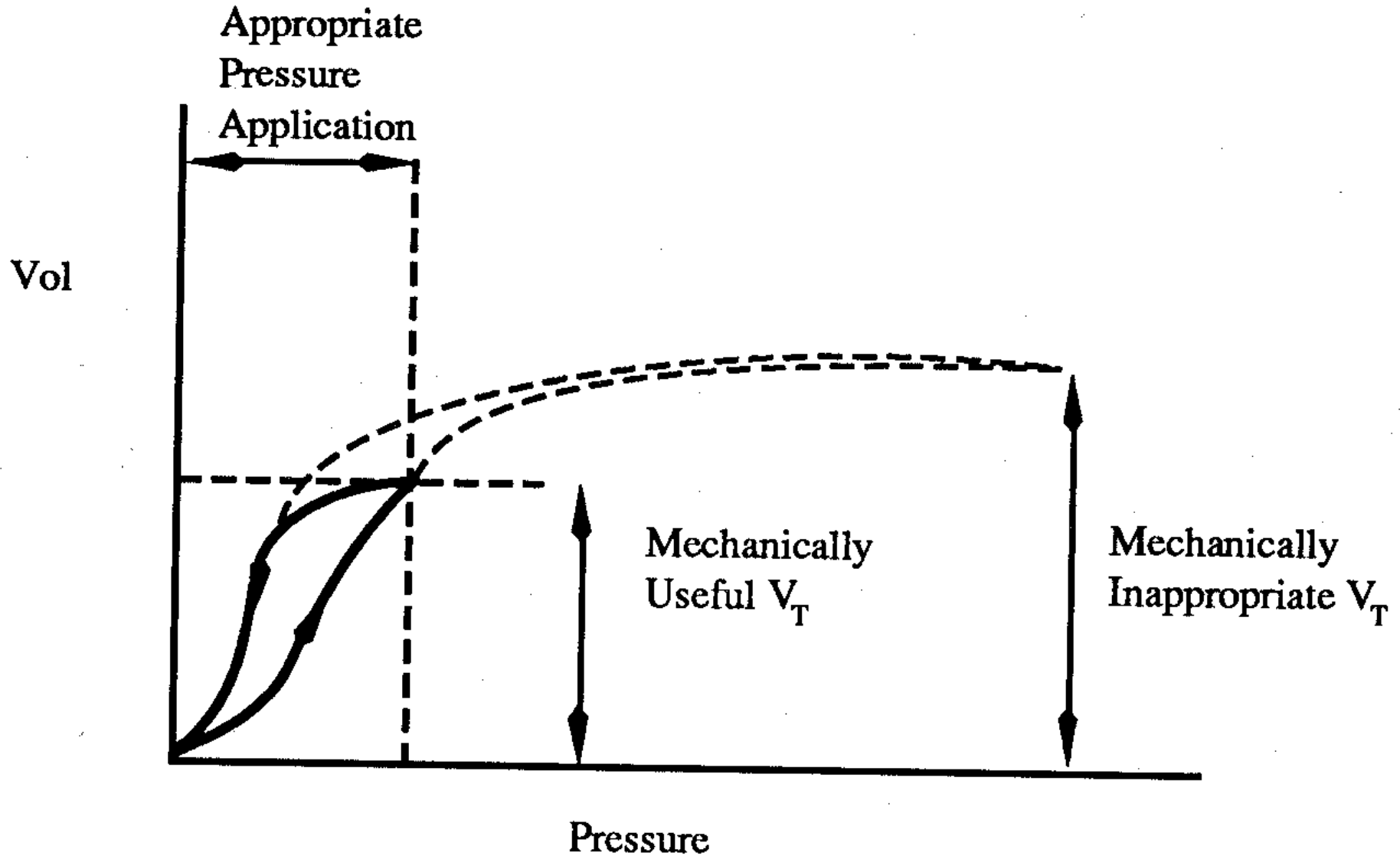
Spontaneous Breathing



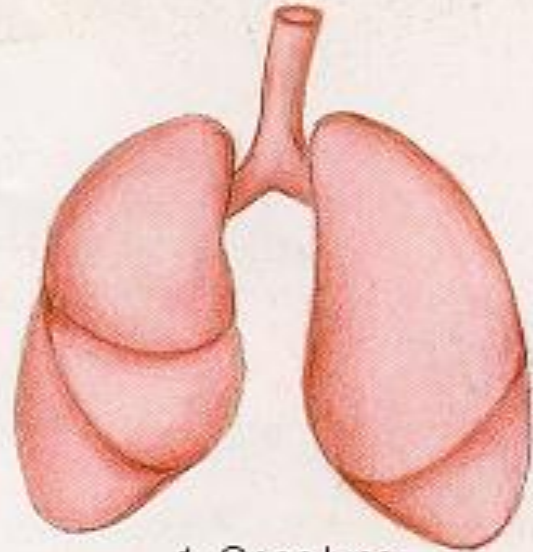
SIMV + Press. Supp.



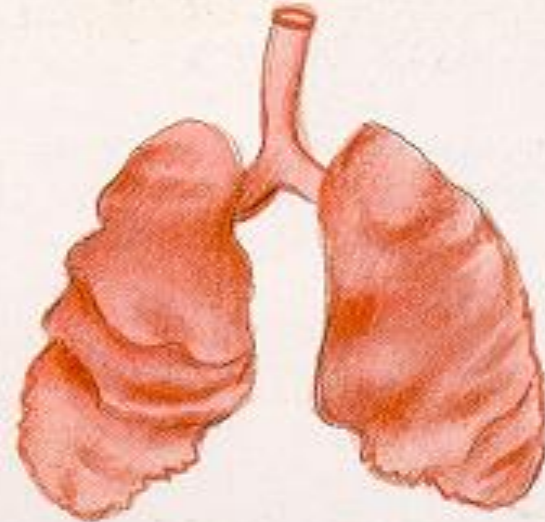
PV Loop in Ventilation



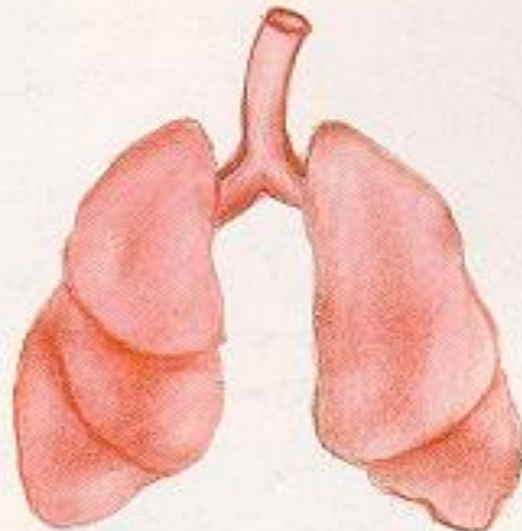
Lung Recruitment



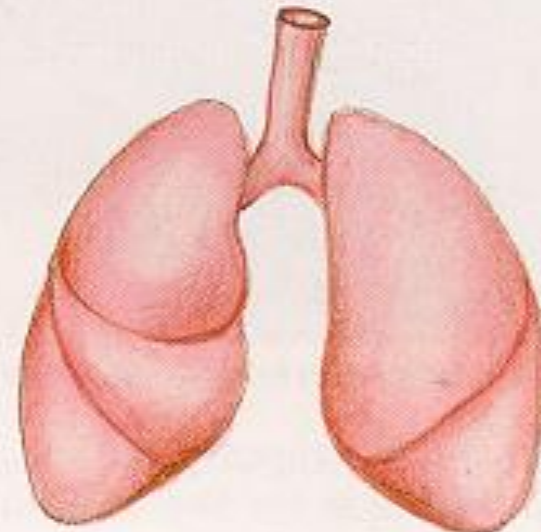
1. Open lung



2. Collapsed lung



3. Lung reopened



4. Fully reopened lung



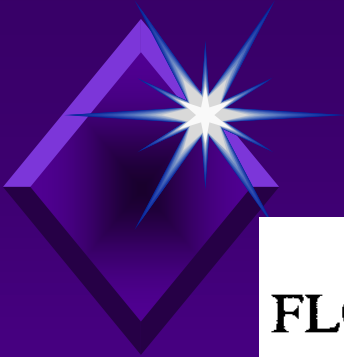
FLOW- “The neglected child”

- ◆ **Flow = Volume / Time (LPS or LPM)**
- ◆ **The driving force behind mechanical ventilation - Range up to 300 LPM**
- ◆ **Peak Flow = highest inspiratory flow**
- ◆ **Graphical pattern changes according to ventilation mode**

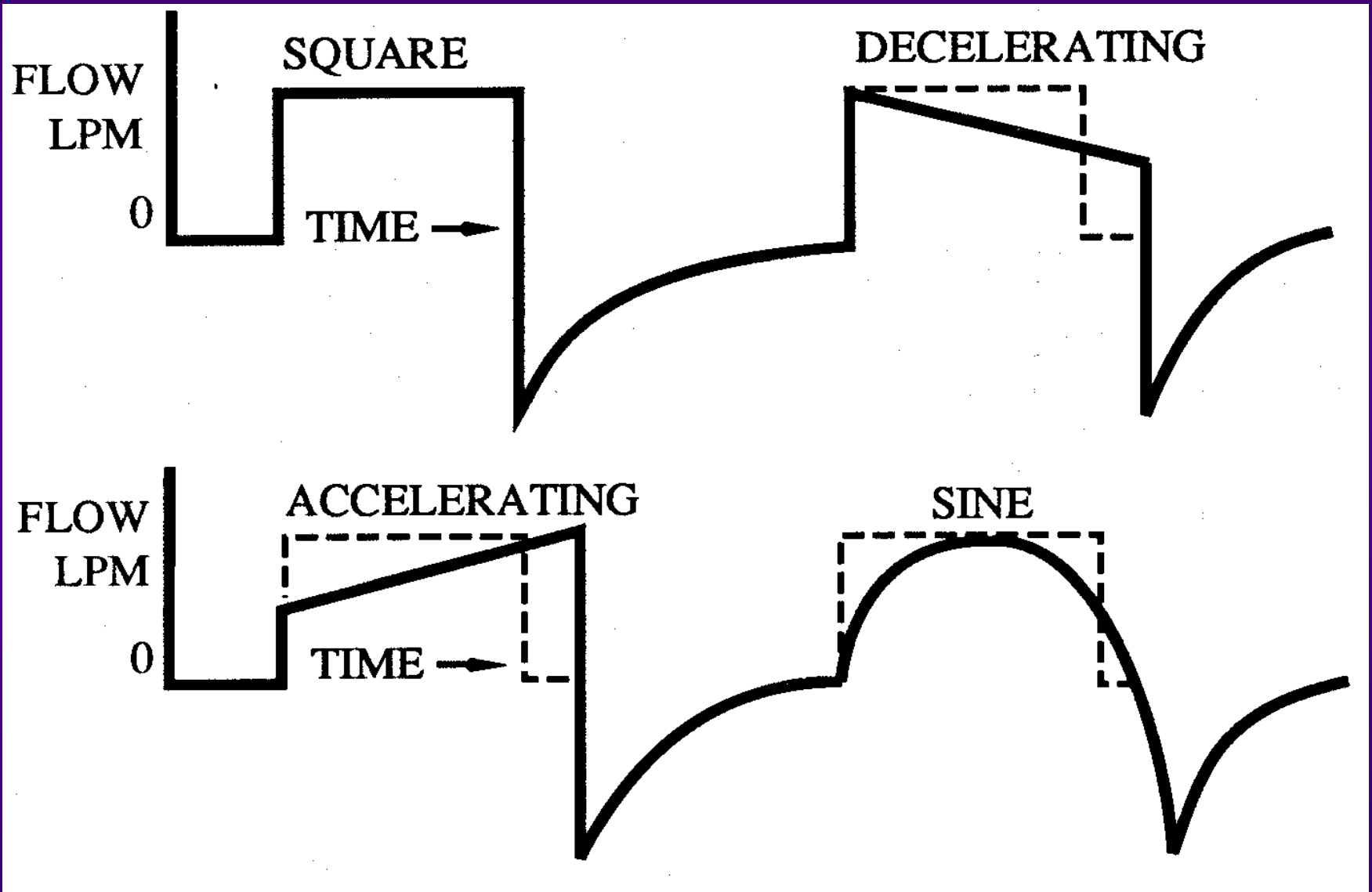


Inspiratory Flow

- ◆ **Spontaneous - Sinusoidal**
- ◆ **Volume Control - Constant**
- ◆ **Pressure Control - Decelerating**



Flow Patterns





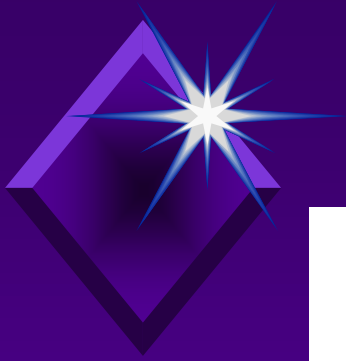
The End of Inspiration

- ◆ Volume Cycled
- ◆ Flow Cycled
- ◆ Pressure Cycled
- ◆ Time Cycled

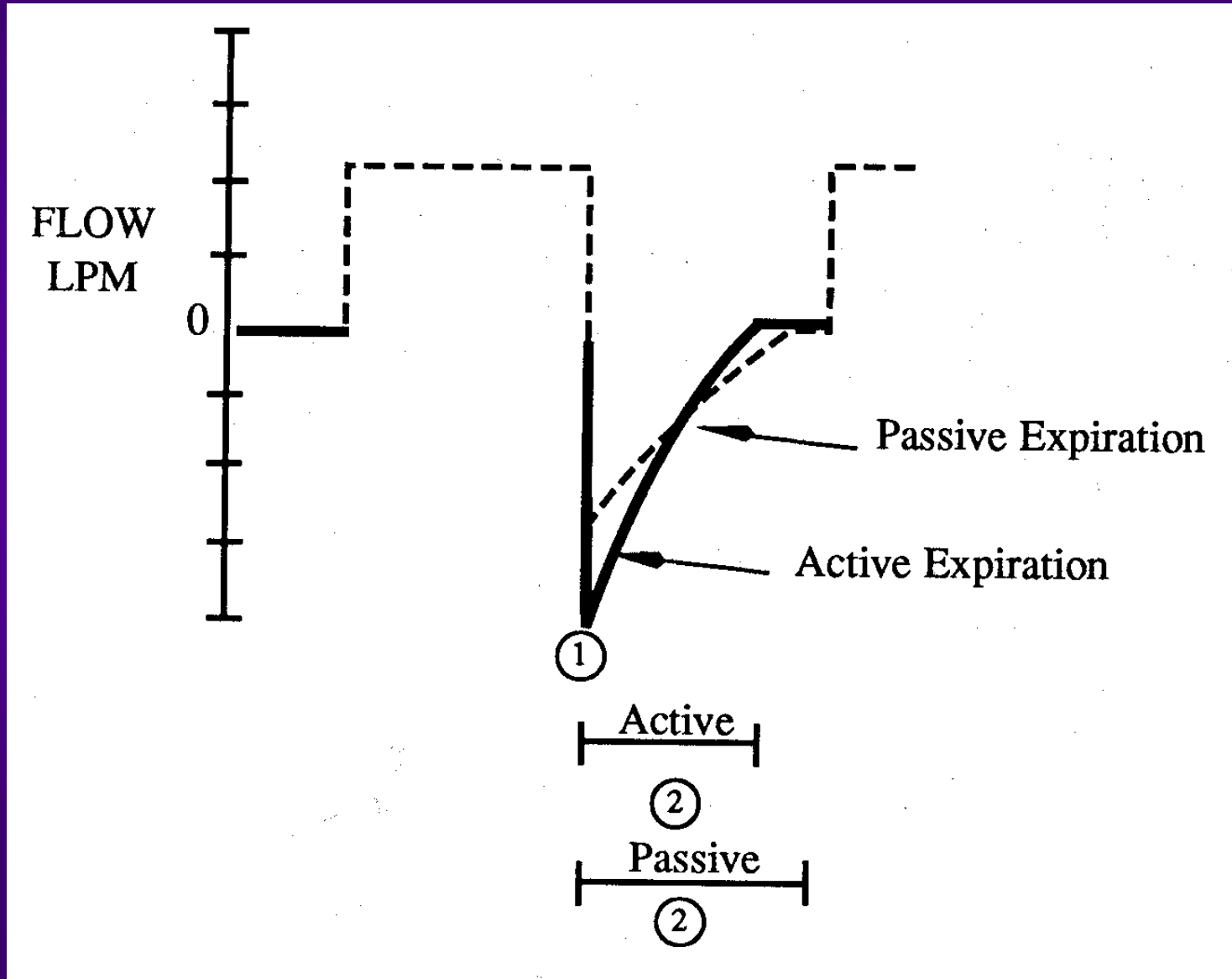


Expiratory Flow

- ◆ **Passive - Decelerating**
- ◆ **Active - Forced**
- ◆ **Obstructed - bronchospasm, secretions**
- ◆ **Cut-off = Air trapping**
(dynamic hyper-inflation, Auto-Peep)



Expiratory Flow

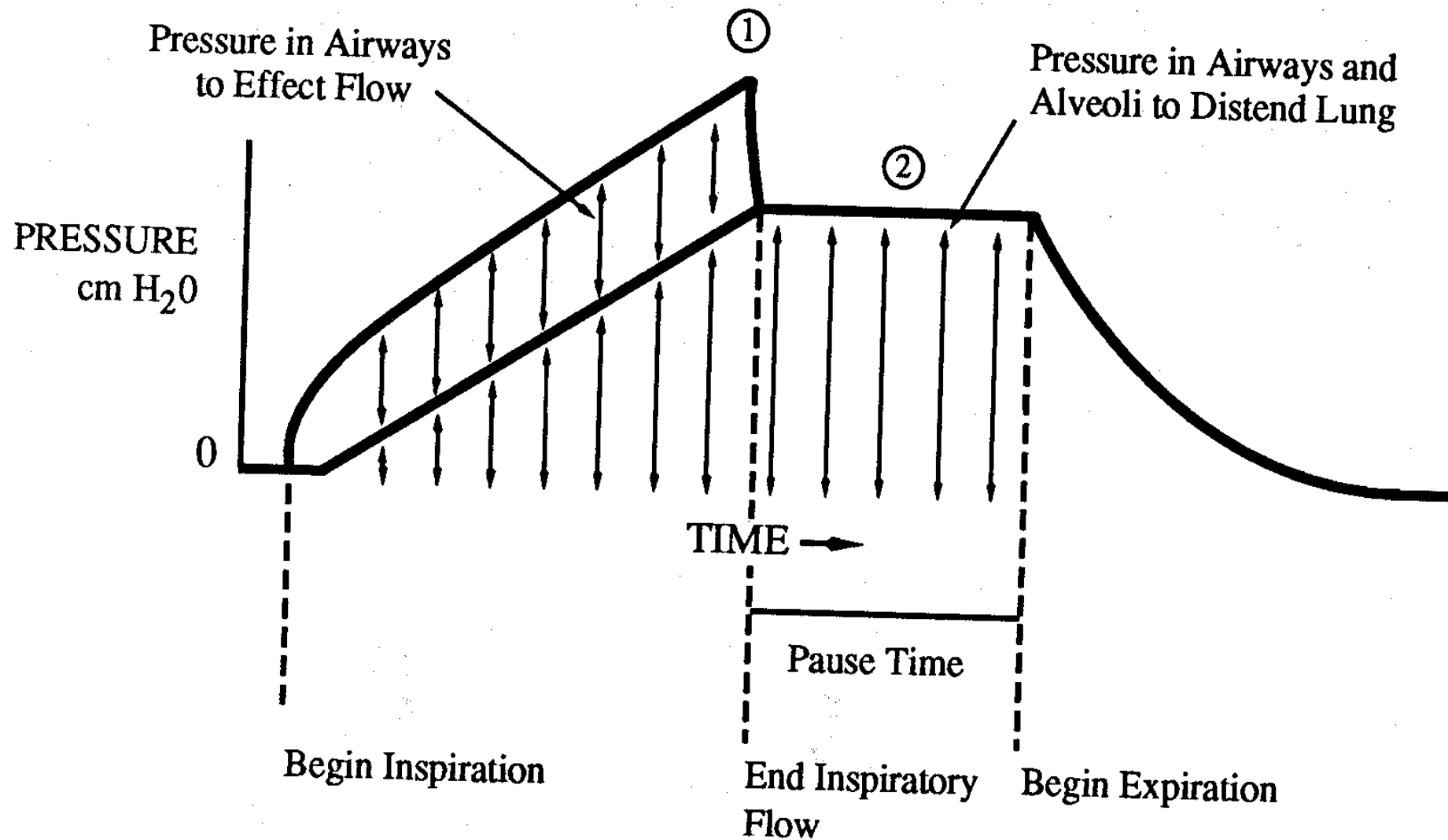




Airway Pressure

- ◆ **Most commonly measured variable**
- ◆ **Caused by flow through tubes**
- ◆ **Rate, Disconnection, Tubing Kinks**
- ◆ **Obstruction of tubing, AW**
- ◆ **Peak, Plateau, Mean, PEEP**
- ◆ **Compliance, Resistance**

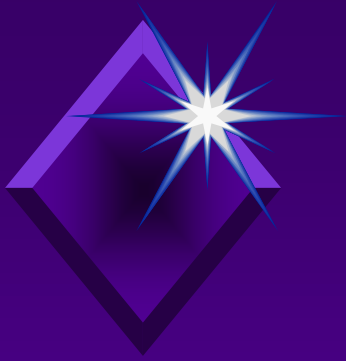
Pressure Curve



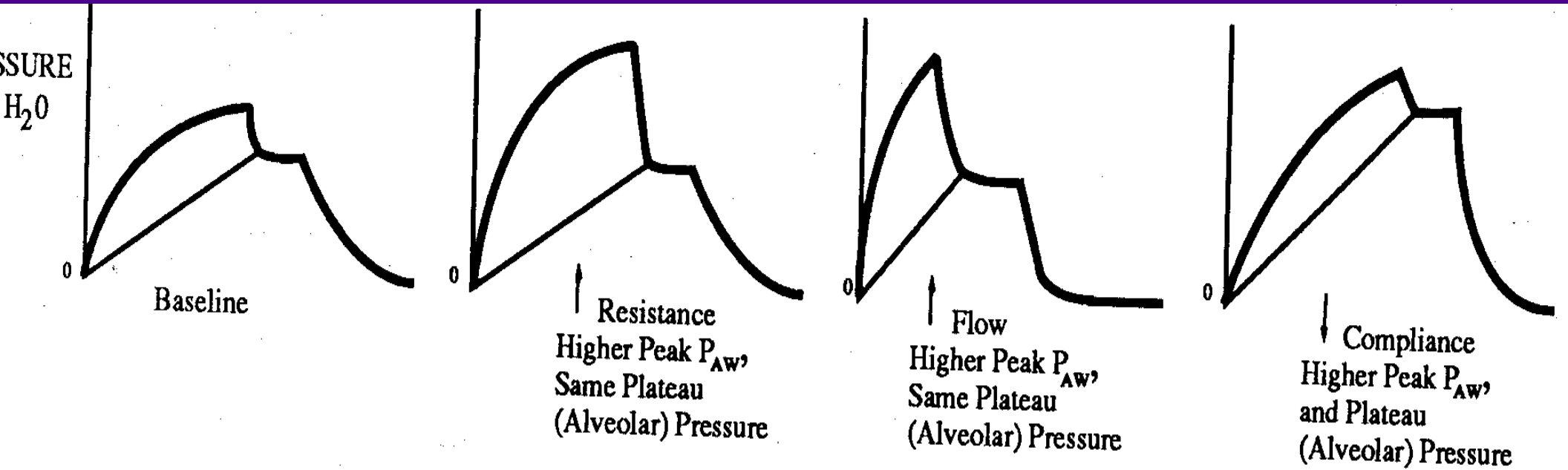


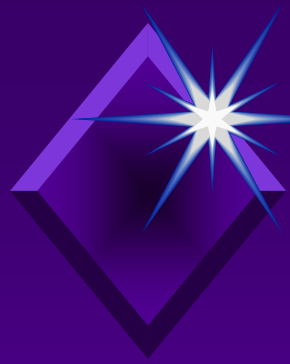
Airway Pressure - Uses

- ◆ Sensitivity threshold for assist
- ◆ Pressure - Volume Loops
- ◆ Pressure - Flow loops
- ◆ Work of Breathing Measurement
- ◆ Negative inspiratory force
- ◆ P-0.1sec or P-100m.sec



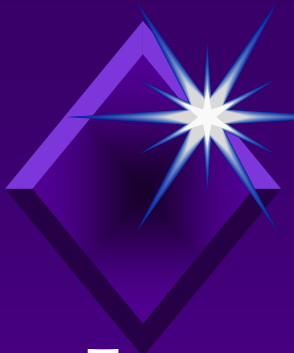
Pressure Changes





Airway Pressure - Limitations

- ◆ Provides information which reflects the breathing circuit mostly and not pulmonary ventilation.
- ◆ A normal pressure pattern does not guarantee ANY inspiratory or expiratory gas flow - as in Pressure Controlled ventilation techniques.



Volume - Inspiratory /Expiratory

- ◆ In new ventilators volume is measured by integrating the flow signal:

$$\text{Volume} = \text{Flow} \times \text{Time}$$

- ◆ Measurements:

Depth of breathing

Minute ventilation

V_{ti} to V_{te} difference - Leaks, Fistula

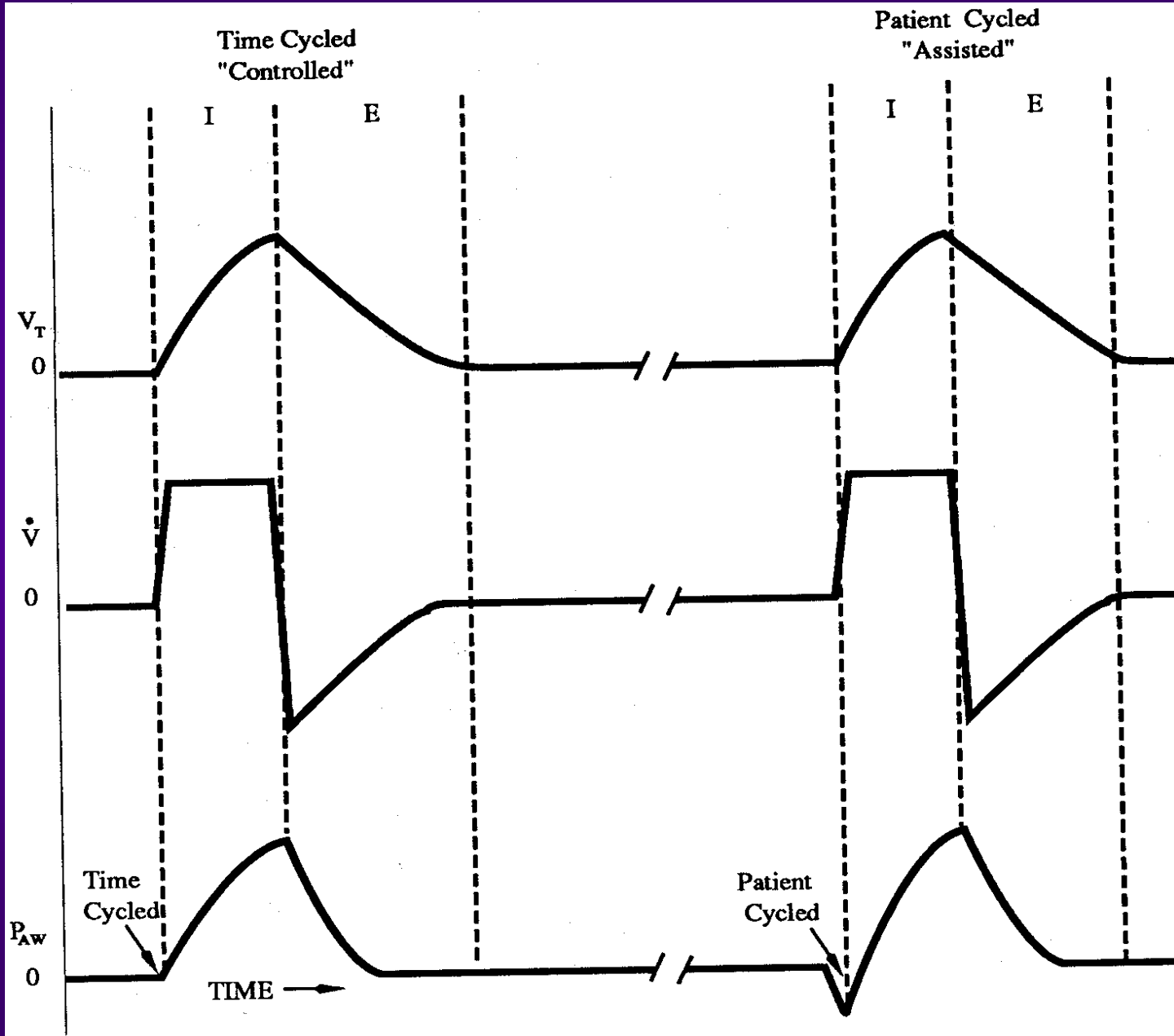
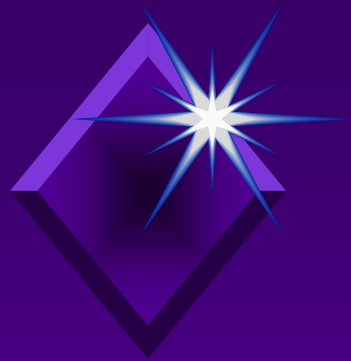
Compliance



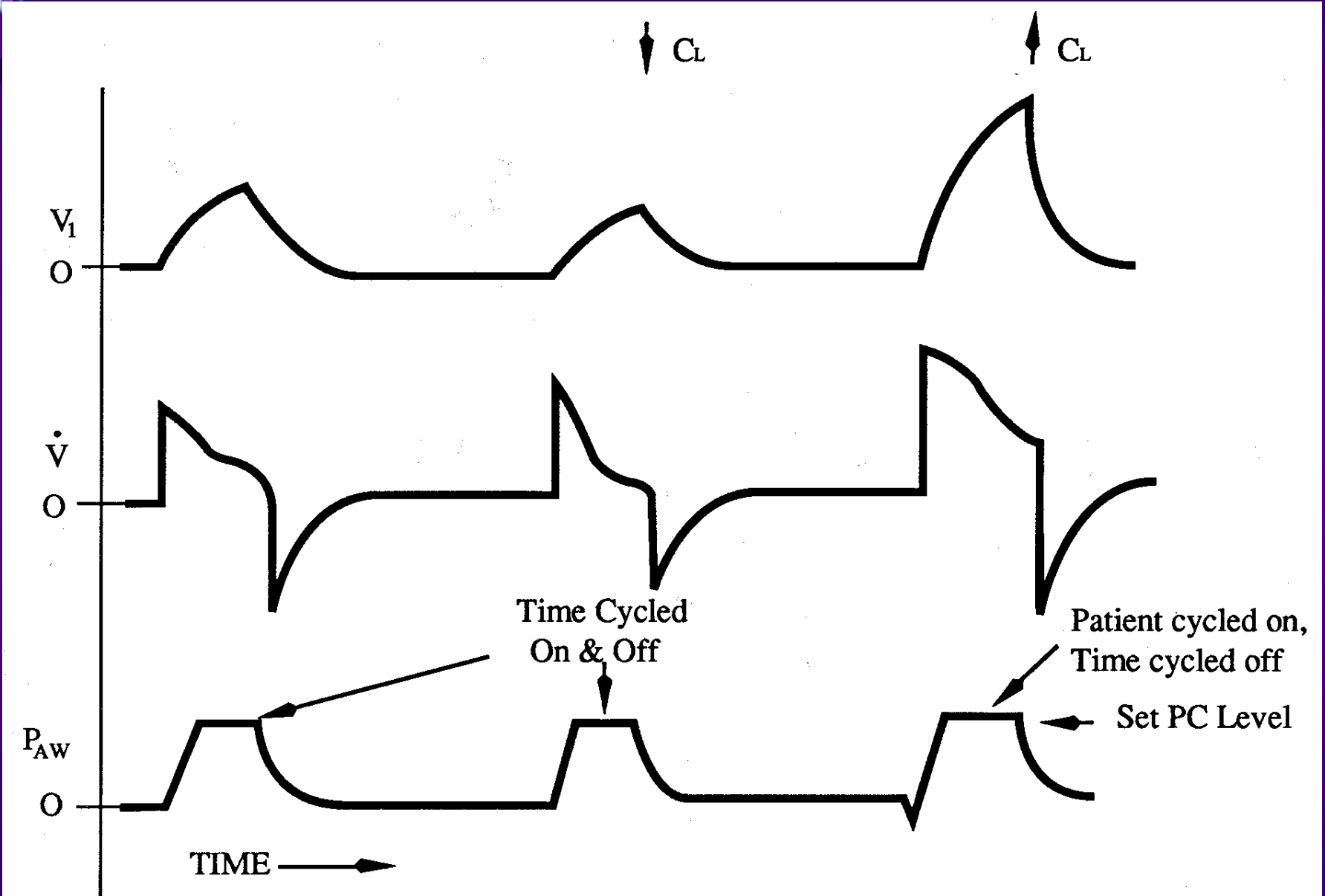
Volume - advanced

- ◆ **Pressure - Volume Loops**
- ◆ **Flow - Volume Loops**
- ◆ **Air Trapping**
- ◆ **Spontaneous breathing effort**

Volume Cont. Vent.



Press. Cont. Vent.





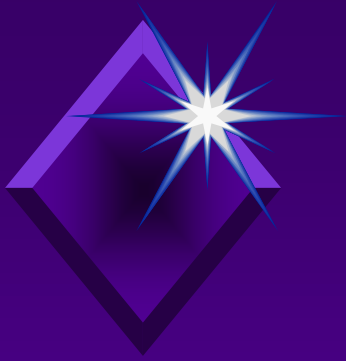
Compliance & Resistance

- ◆ $C_{stat} = \text{Tidal Vol} / (P_{plat} - PEEP)$
ml / cm H₂O (n=50-100)
- ◆ $C_{dyn} = \text{Tidal Vol} / (P_{peak} - PEEP)$
- ◆ C_{dyn} / C_{stat} - if < 0.8 = Small AW obstruction
- ◆ $\text{Resistance} = (P_{peak} - P_{plat}) / \text{Peak Flow}$
cmH₂O / LPS (norm < 10)

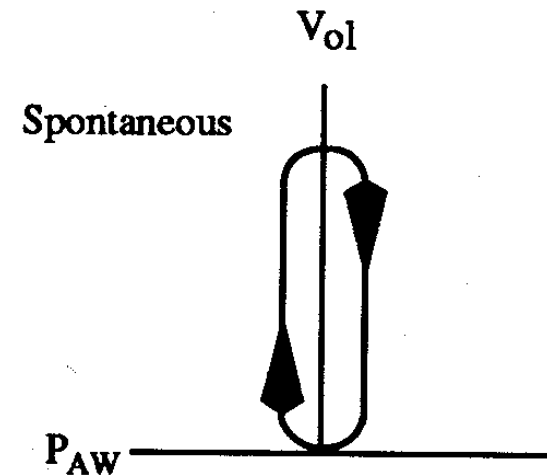
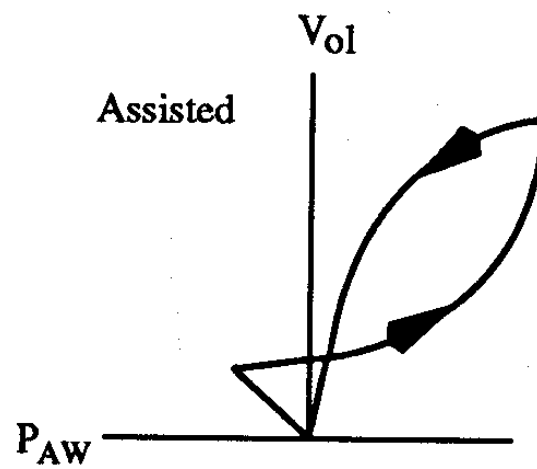
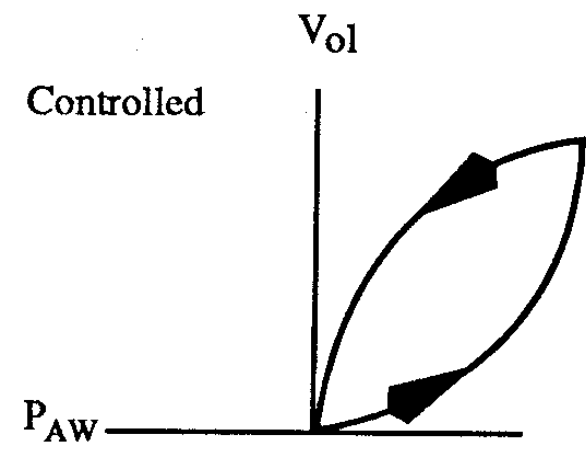


Press-Volume Loop = Compliance

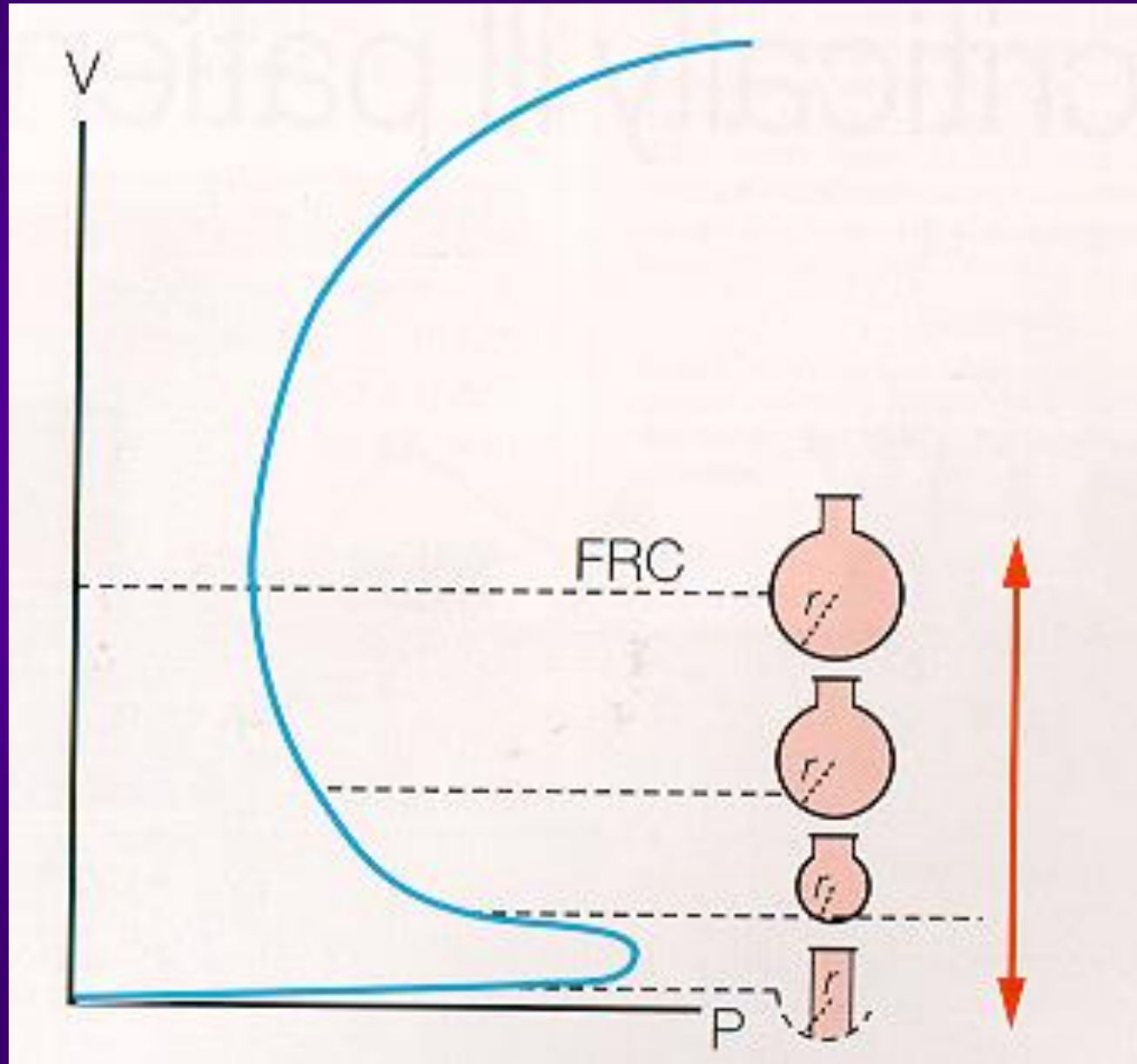
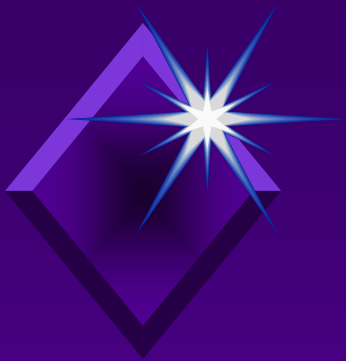
- ◆ **Static Press.-Vol. = Super syringe technique**
Flow is Zero at each point
- ◆ **Dynamic Press.-Vol. = in ventilation**
Flow has to be slow & **CONSTANT**
- ◆ **Loop direction :**
Mech. vent. - Counter Clockwise
Spont. Breathing - Clockwise
Assist - Clockwise followed by
CounterClckwz



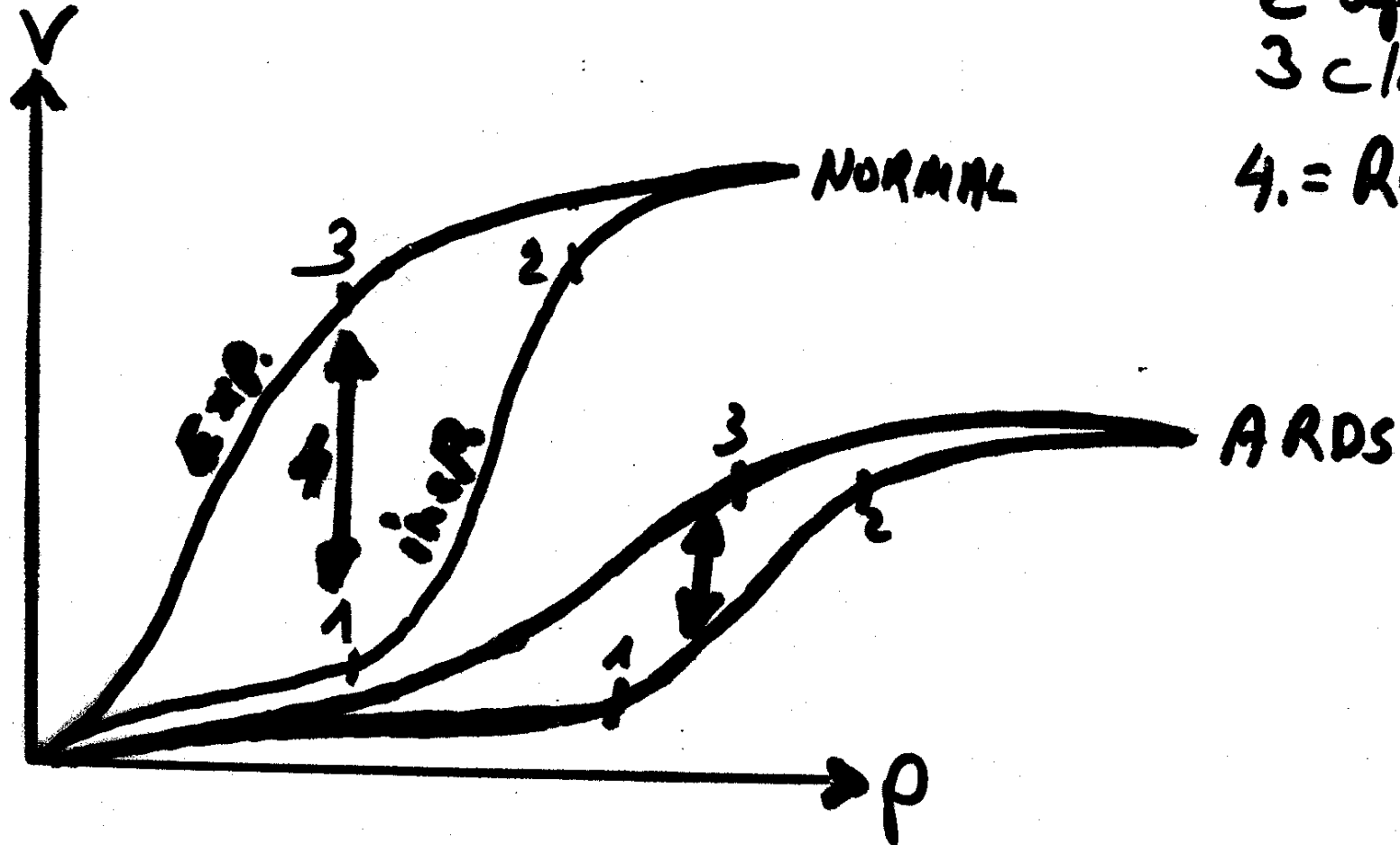
Pressure Volume Loop



Lung Inflation



Lung Inflation - deflation

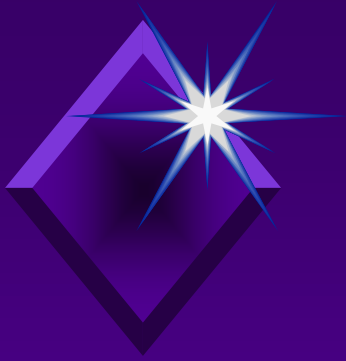


- 1 Lower inf. p.
- 2 upper inf. p.
- 3 closing p.
- 4 = Recruitment



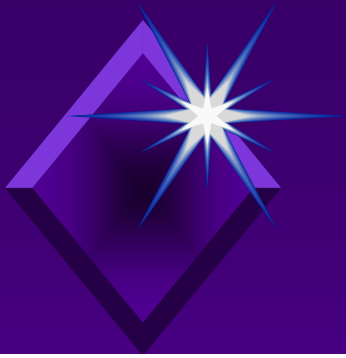
PV Loop - Troubleshooting

- ◆ **Decreased Comp. - Flat Insp. Limb**
- ◆ **Inc. Resist. - Right Shift Insp. Limb**
- ◆ **Over-Inflation - Flat upper insp. Limb**
- ◆ **Expiratory Limb - Closing Pressure**

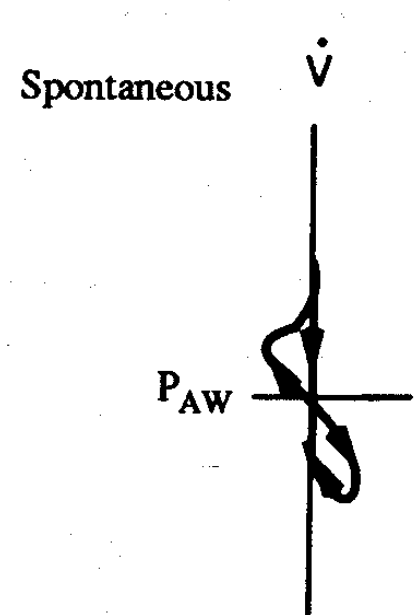
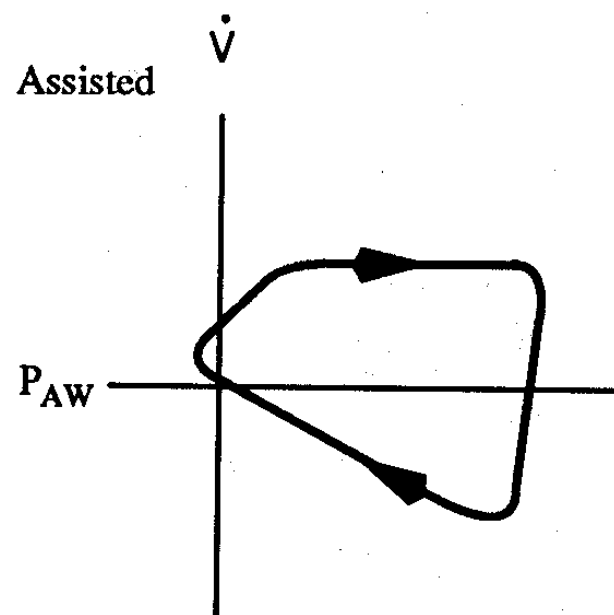
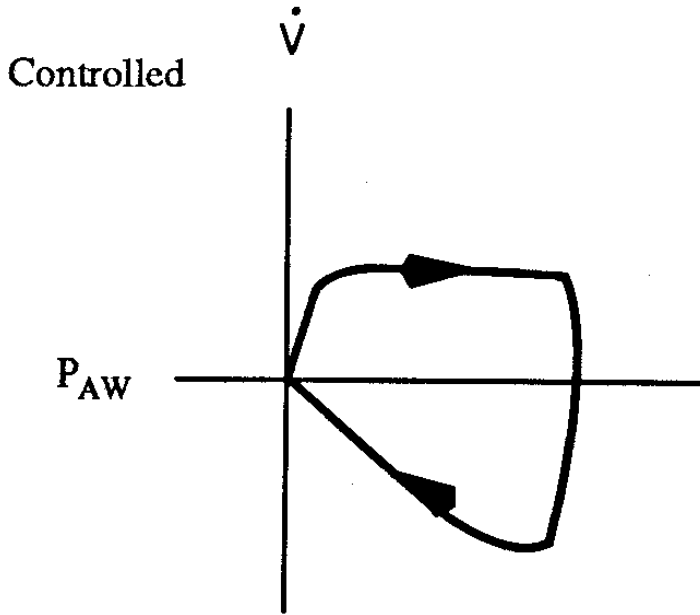


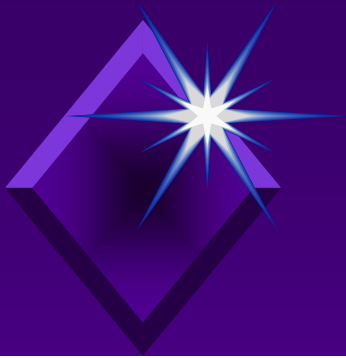
Pressure - Flow Loop

- ◆ Info = Airway Resistance
- ◆ Loop direction = Clockwise
- ◆ Secretions - Saw tooth shape
- ◆ Elevated resistance = Shallow curves

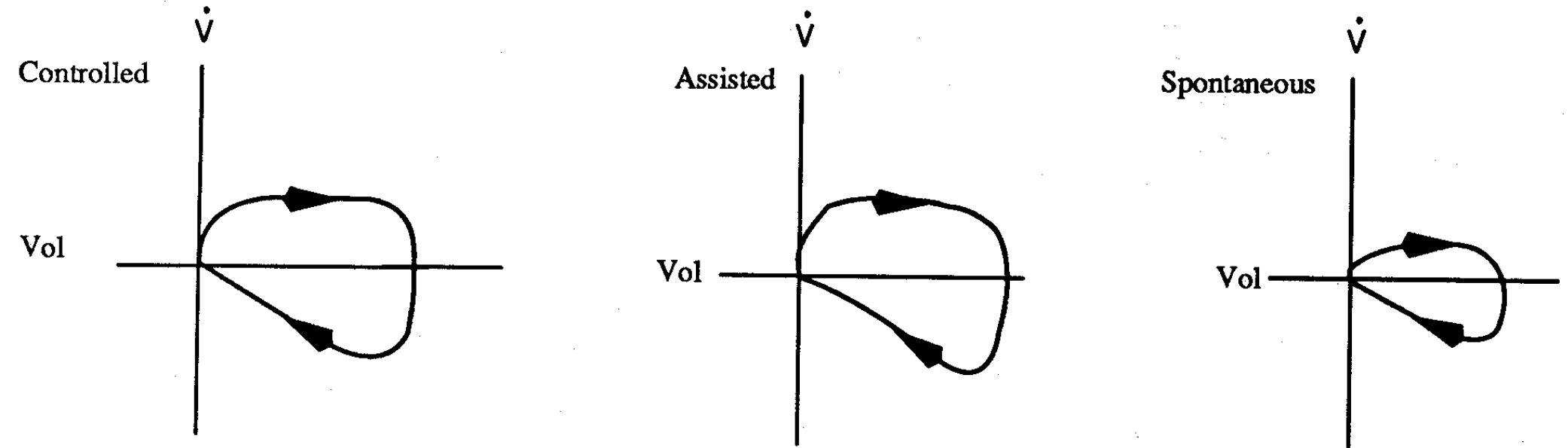


Pressure Flow Loop





Flow Volume Loop



Obstructive Vs. Restrictive Lung Disease



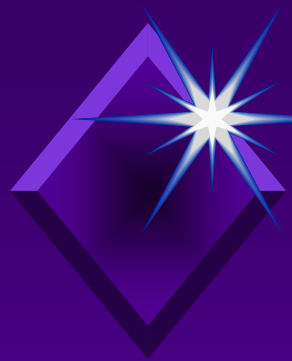
Work of Breathing

- ◆ **Work = Integral of Press. and Vol.**
- ◆ **A function of flow, vol., resist., comp.**
- ◆ **Index of Load on ventilatory muscles**
- ◆ **Proportional to O₂ demand & fatigue**
- ◆ **Measured by Joules per Minute**
- ◆ **Normal = 8-10 JPM**



Calculating WOB

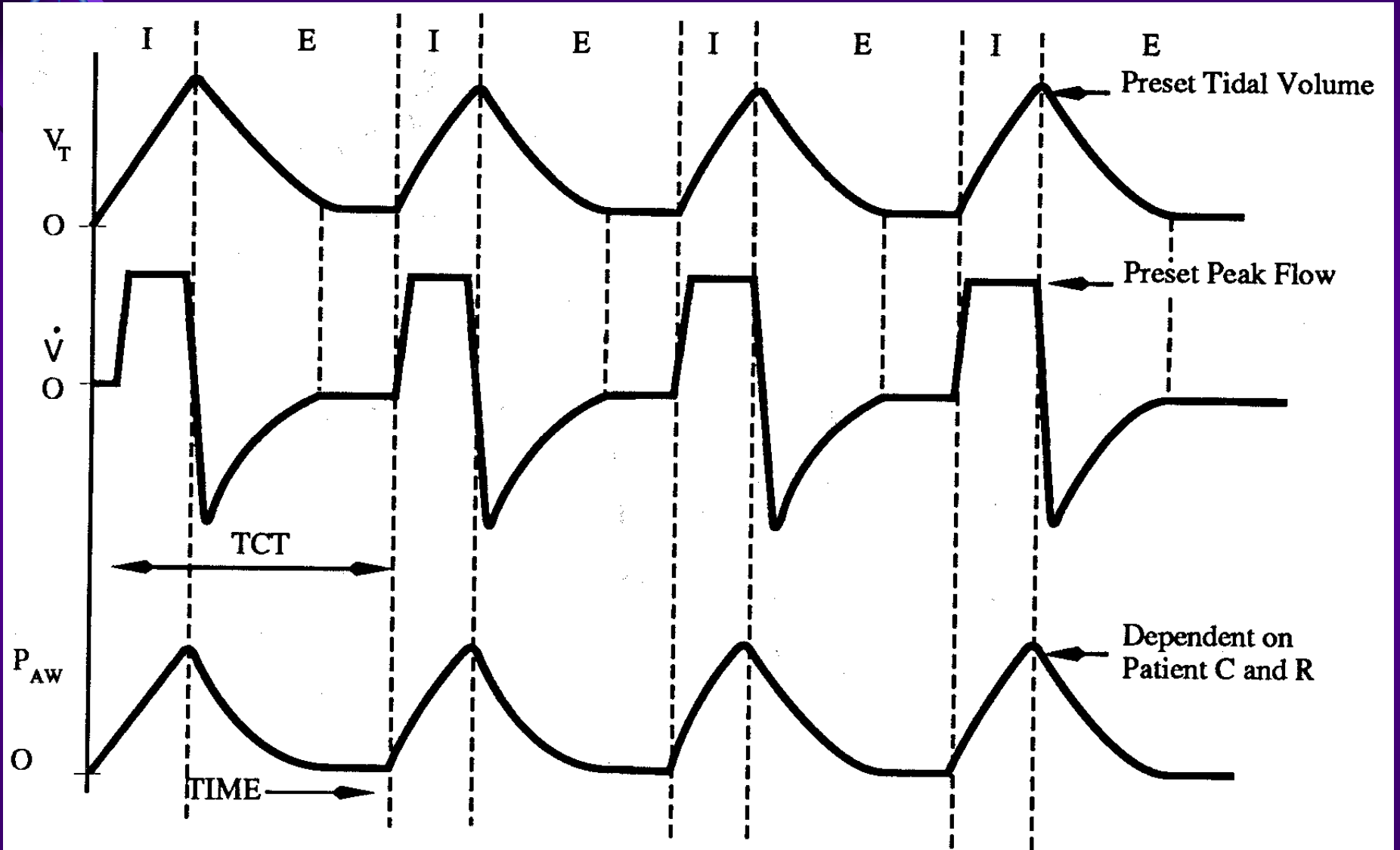
- ◆ **Work Per Breath = (WPB) =**
(P.peak - 1/2 P.plat) x Vt.
10
- ◆ **Work Per Minute = WPB x BPM**



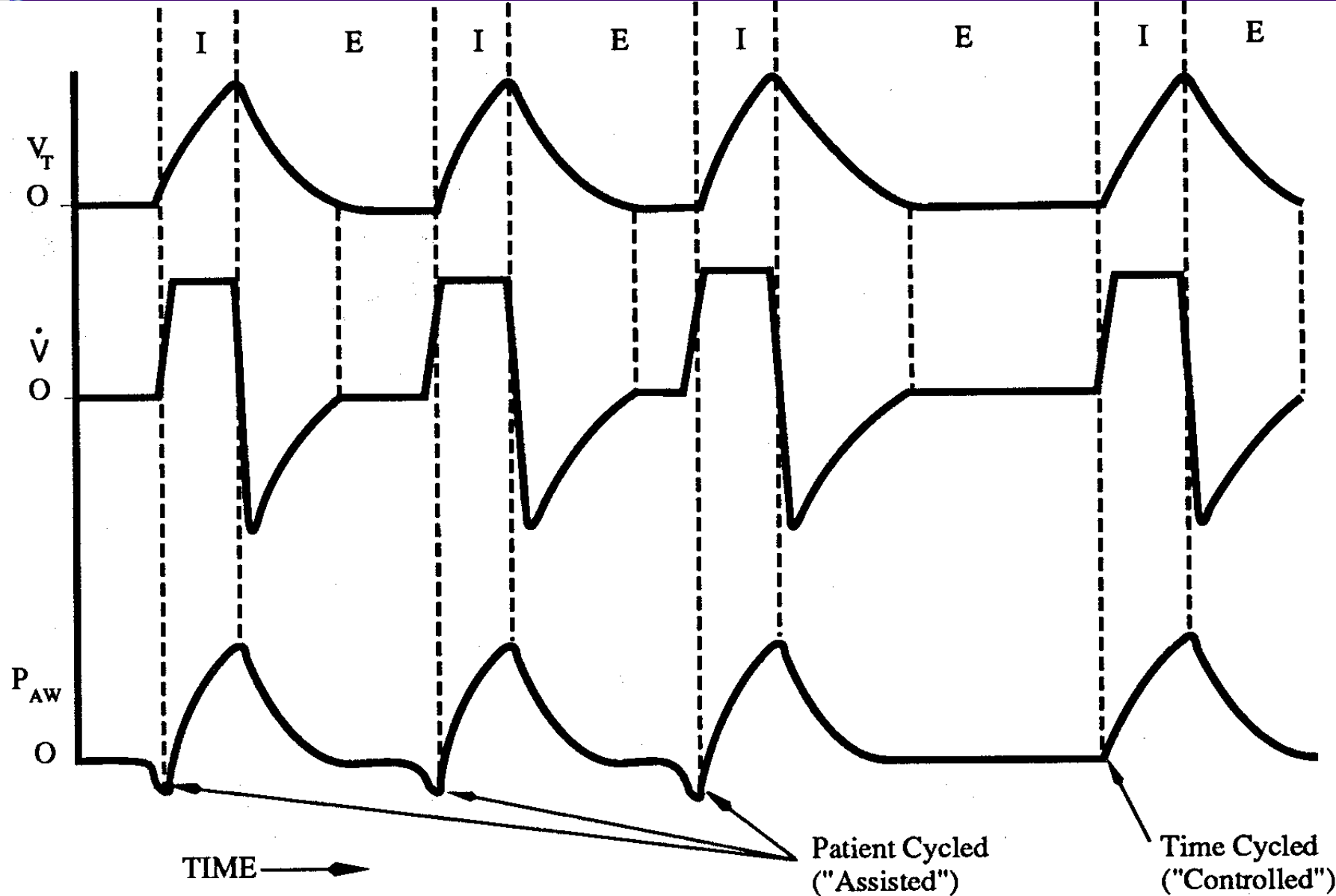
Optimizing Mechanical Ventilatory Support - “Shaping” the breathing pattern using graphics

- ◆ **1. Set V_t and frequency to assure adequate VA with minimal pressures**
- ◆ **2. Stabilize collapsed alveoli - PEEP**
- ◆ **3. Minimize imposed load**
- ◆ **4. Synchronize assisted breaths with patient efforts**
- ◆ **5. Partial ventilatory support during weaning**

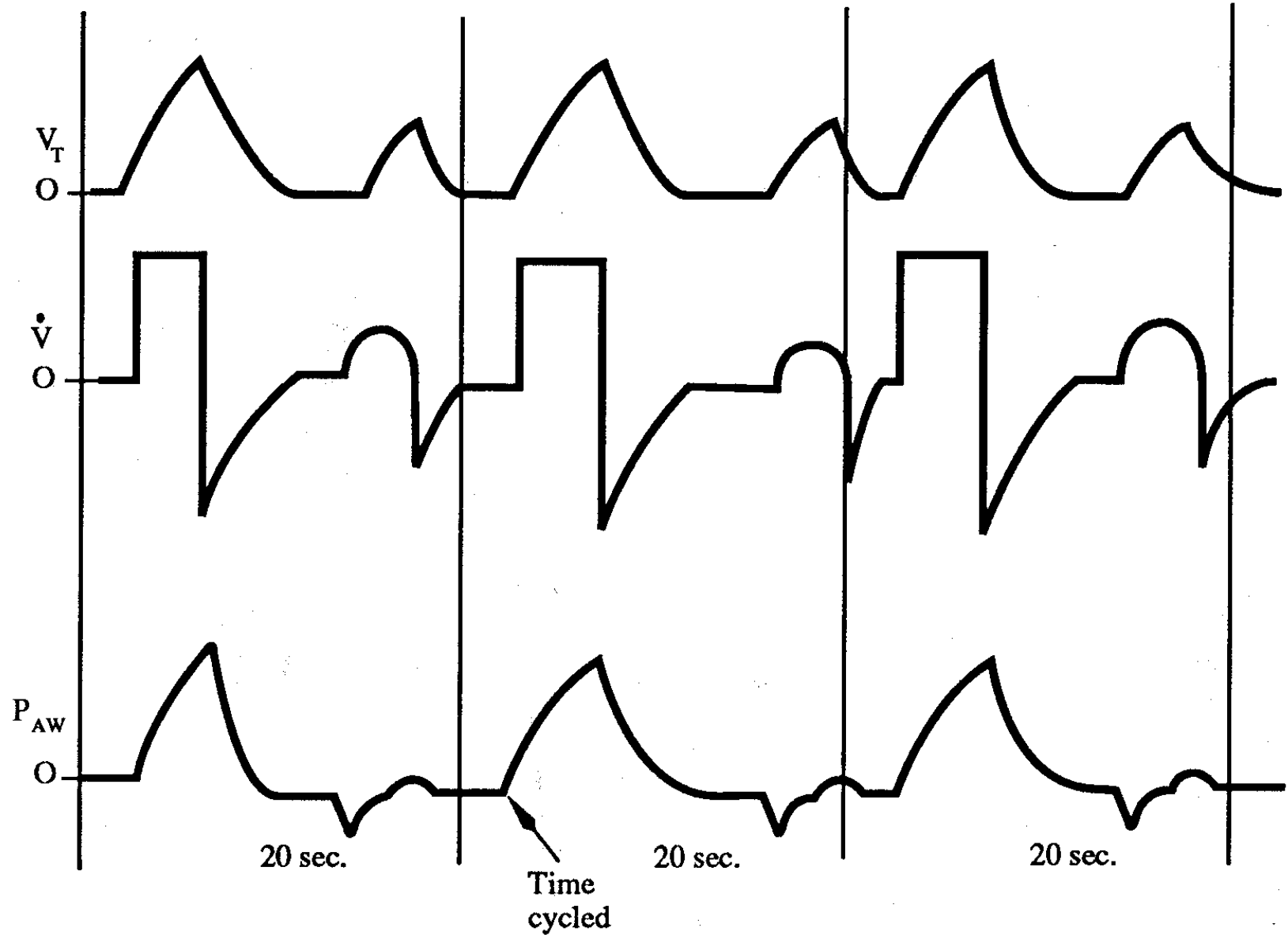
Cont. Mand. Vent.



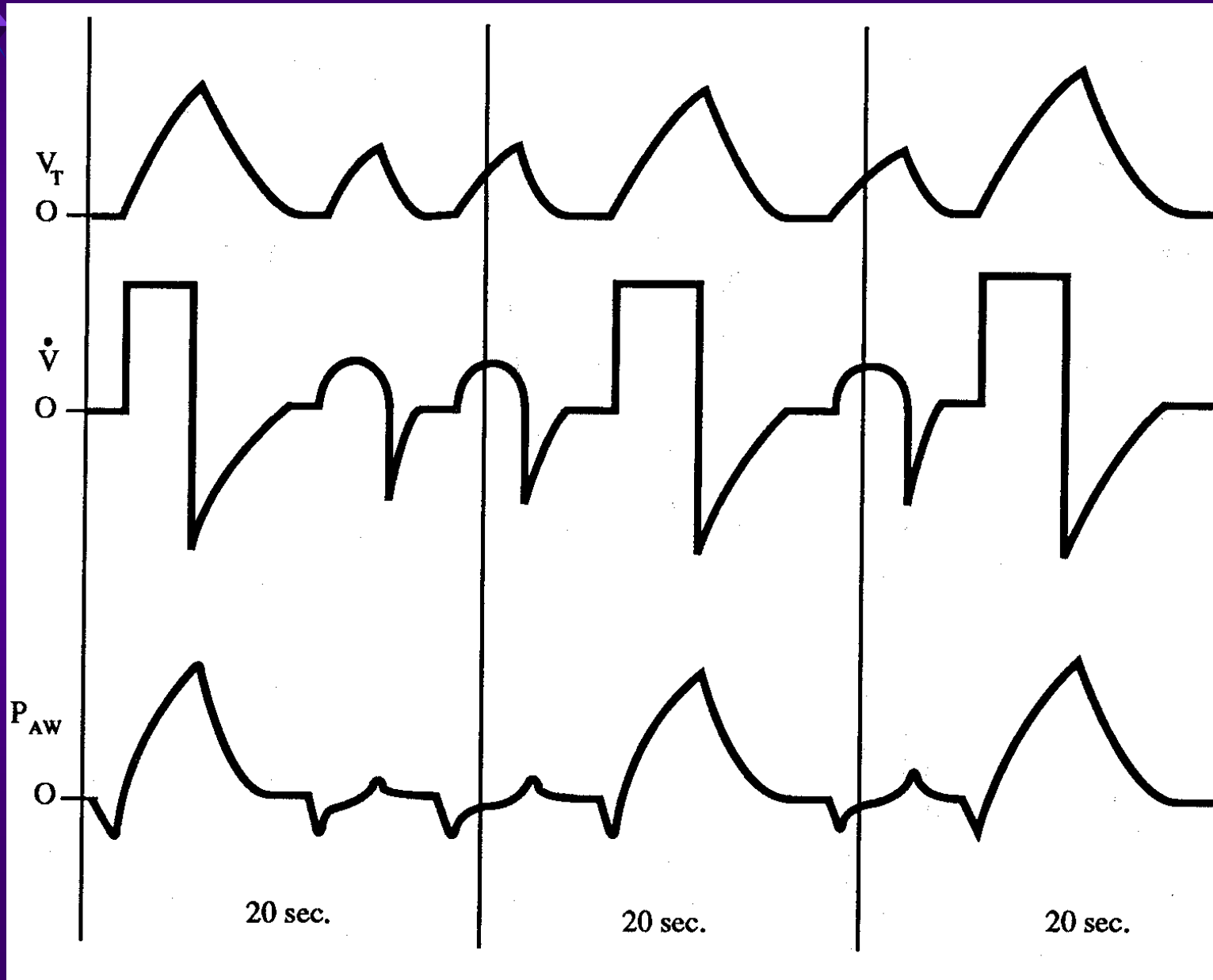
Assist CMV



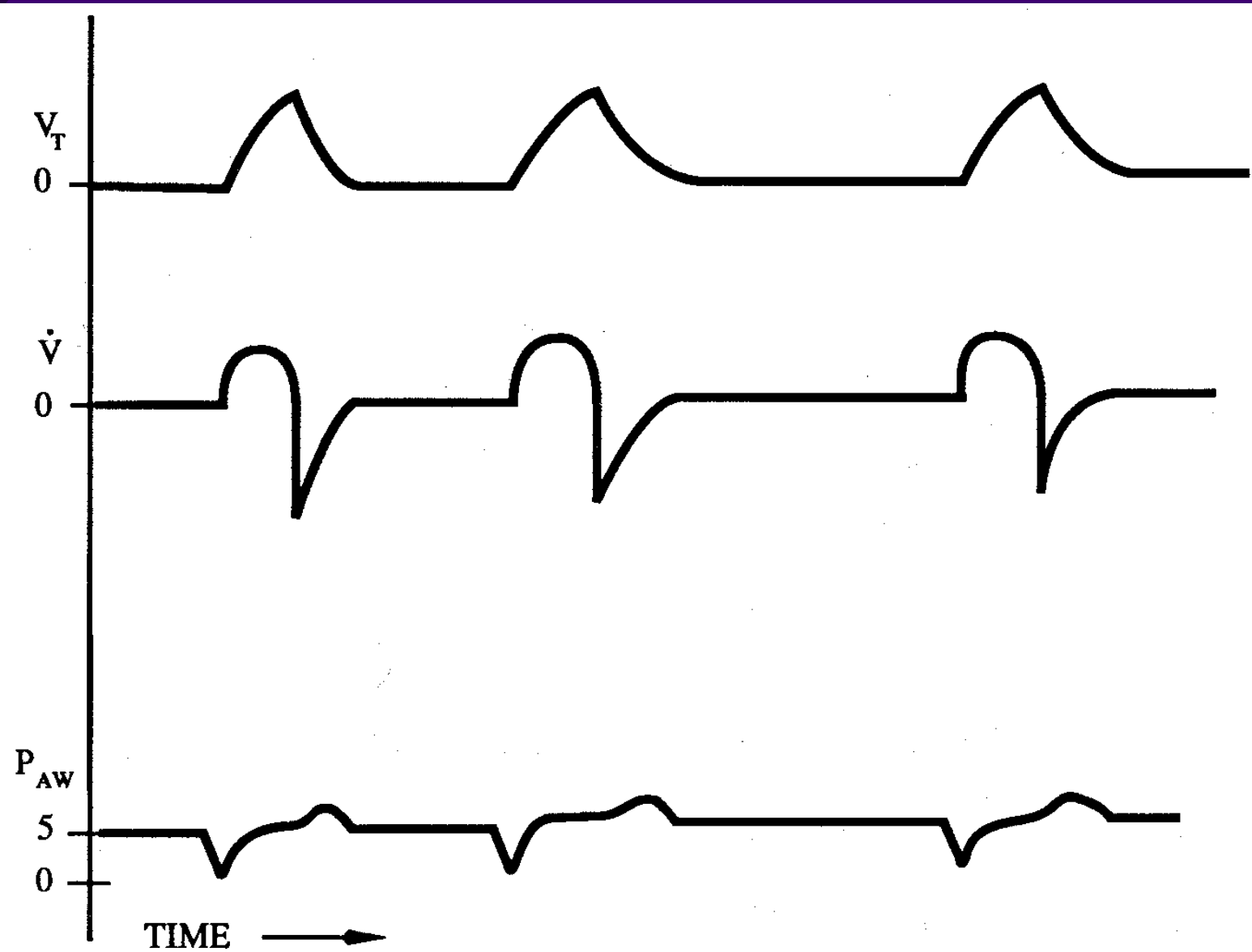
Intermittent Mand. Vent.



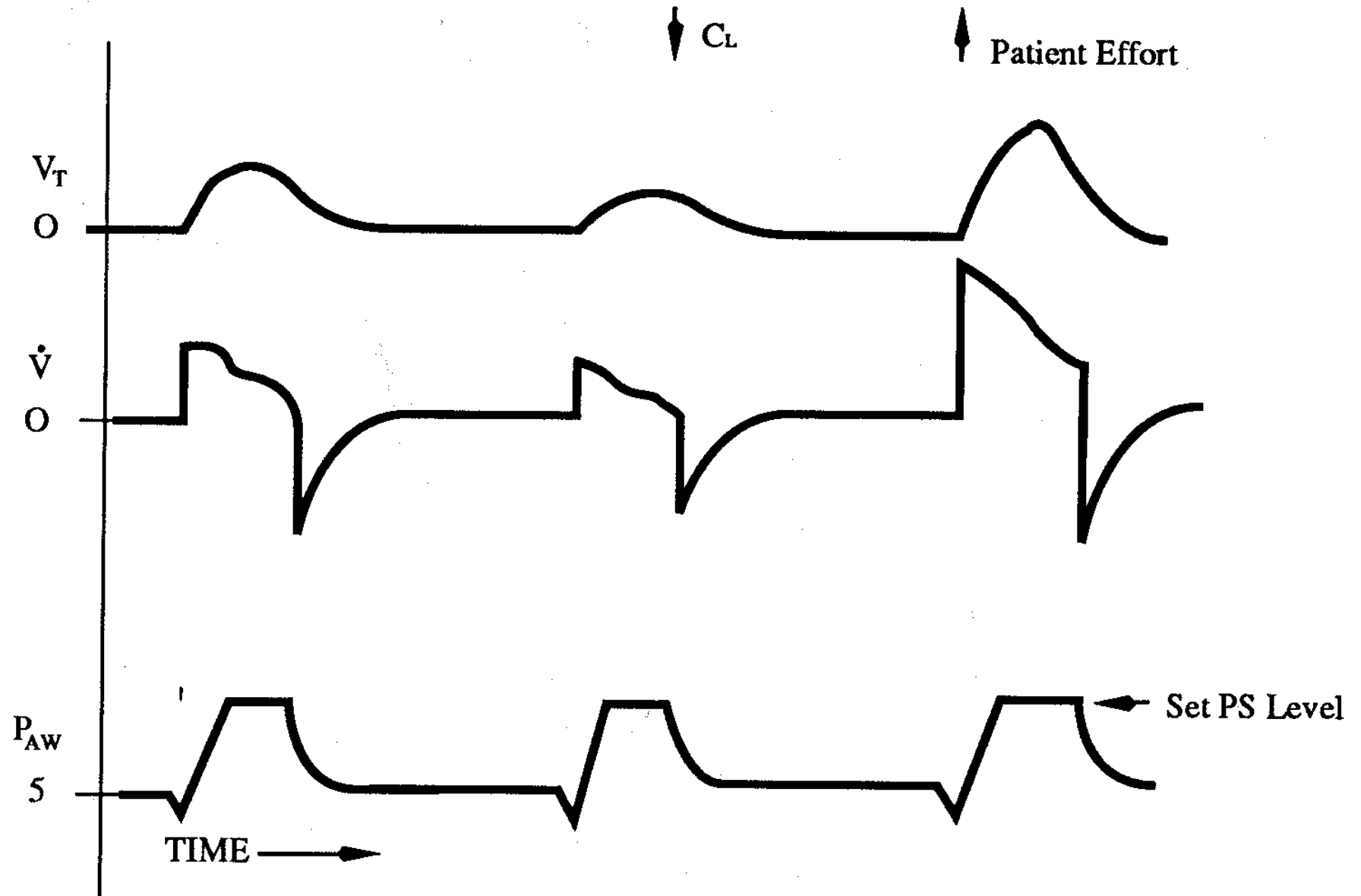
Sync. IMV

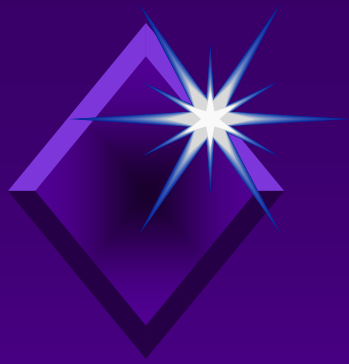


Cont. Pos. AW Press.

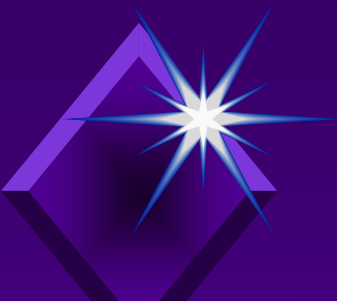


Pressure Support Vent.





The Open Lung Concept

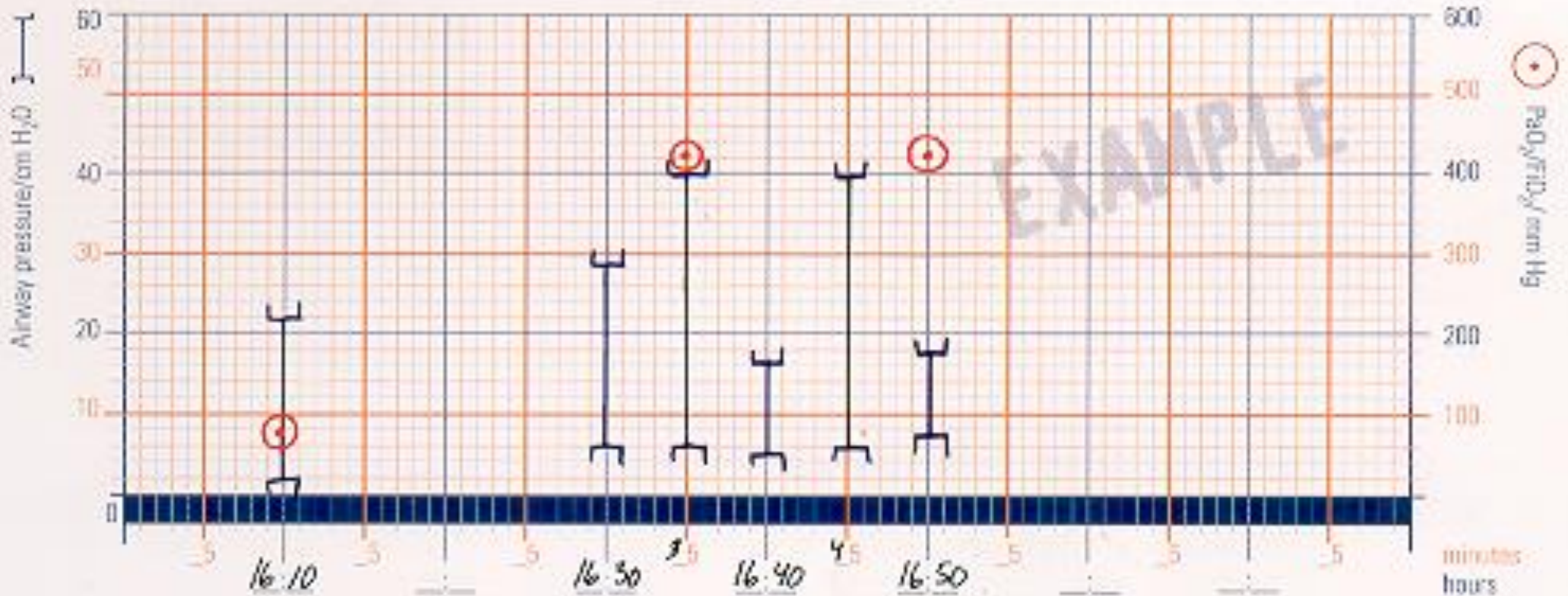


Recruitment Maneuver

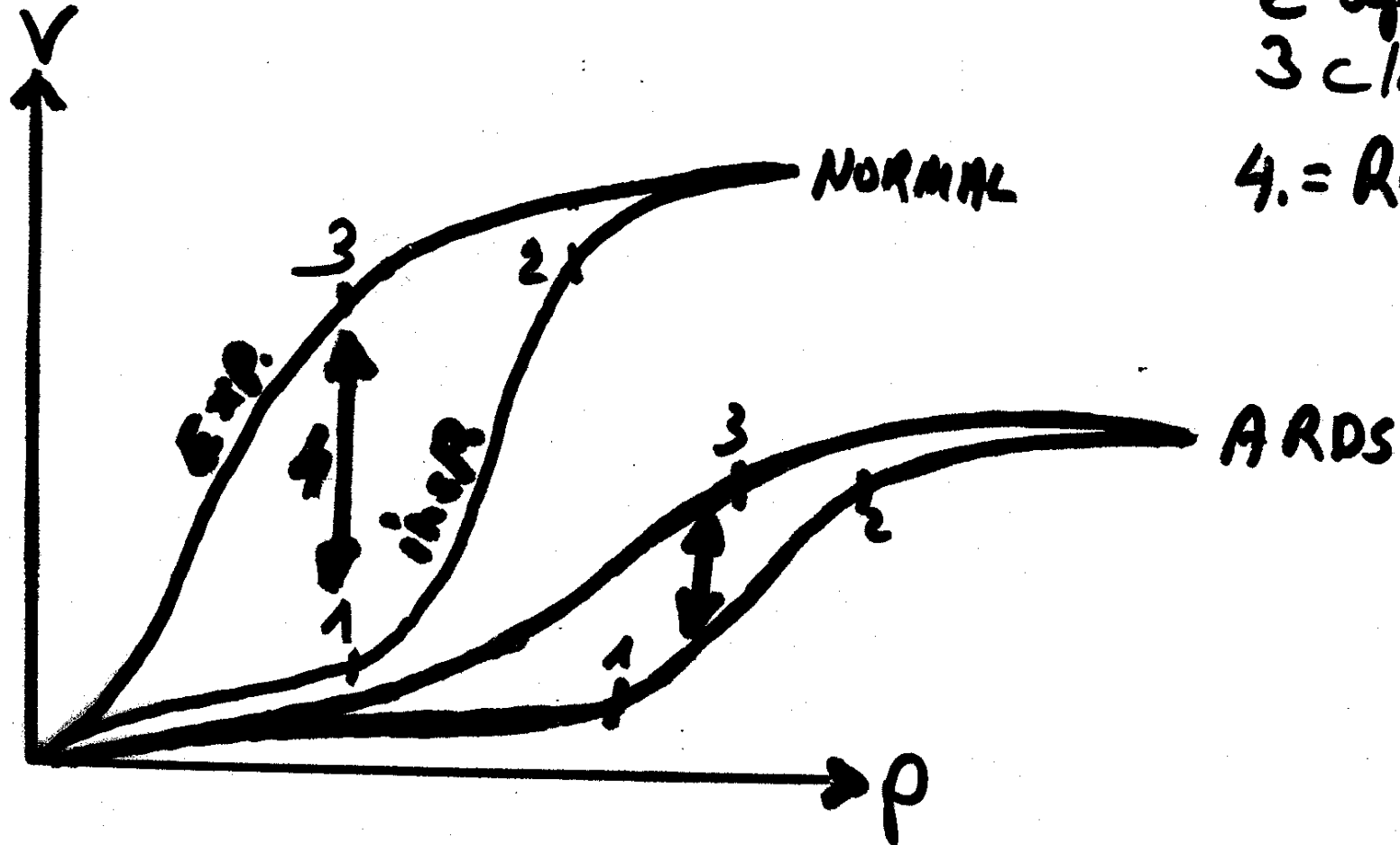
TREATMENT STEPS

- ① Find opening pressure
- ② Find closing pressure
- ③ Reopen
- ④ Keep open

- ①
- ②
- ③
- ④

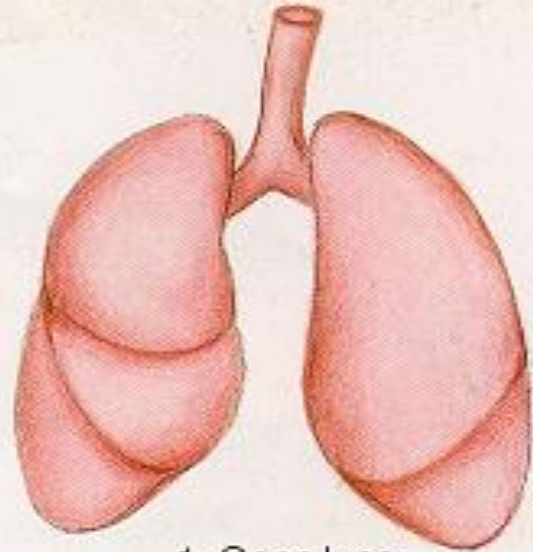


Lung Recruitment

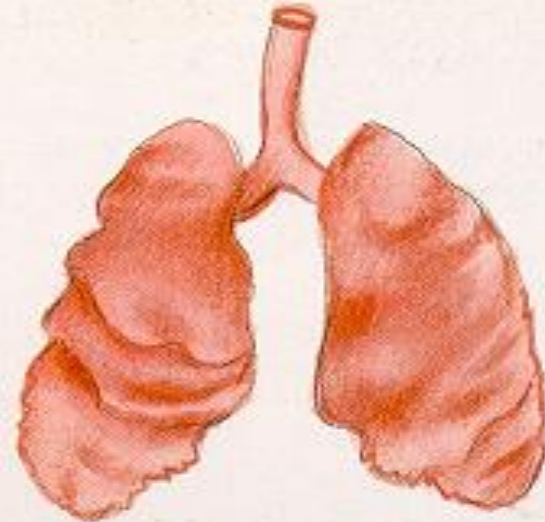


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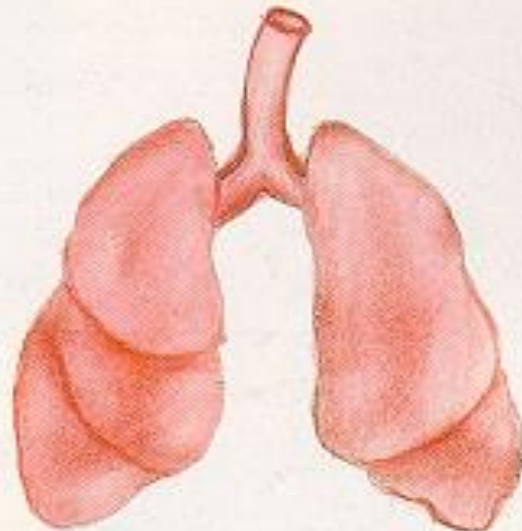
Lung Recruitment



1. Open lung



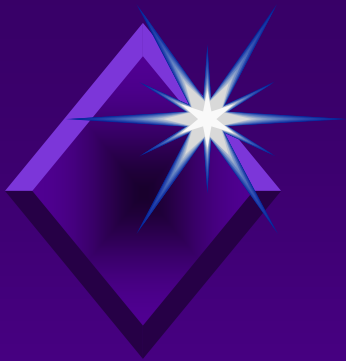
2. Collapsed lung



3. Lung reopened



4. Fully reopened lung



Thanks - תודה רבה

