Principles of Mechanical Ventilation

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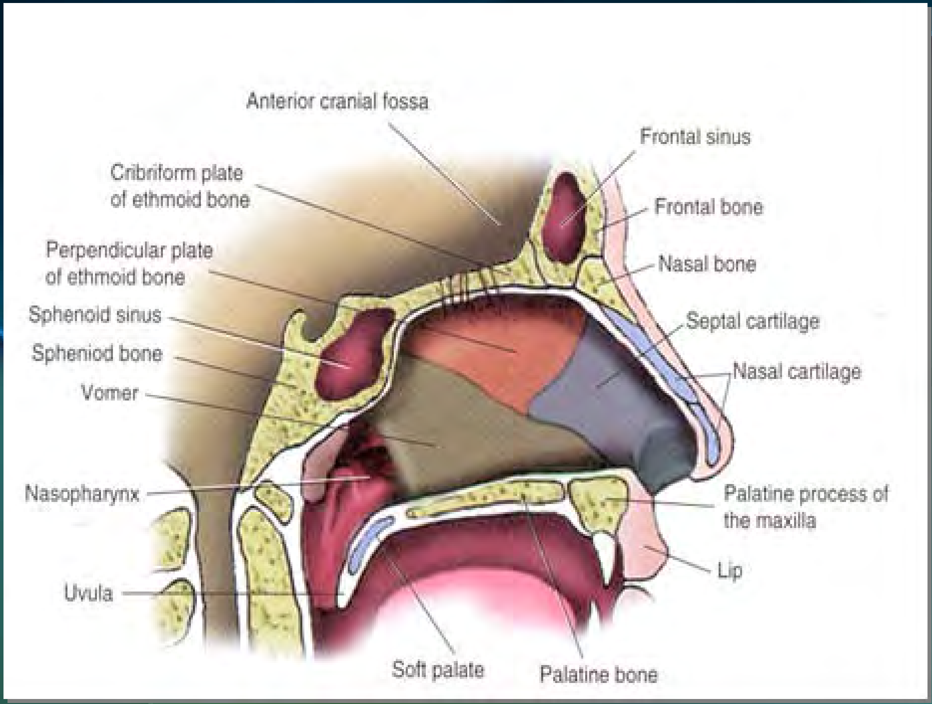
Anatomic Components of Respiratory System:

- Upper Airways
  - Nasal cavity and pharynx
- Lower Airways
  - Larynx, trachea, bronchial tree
- Lung Lobes
  - 2 on left, 3 on right
- Tracheobronchial tree
- Alveolar unit

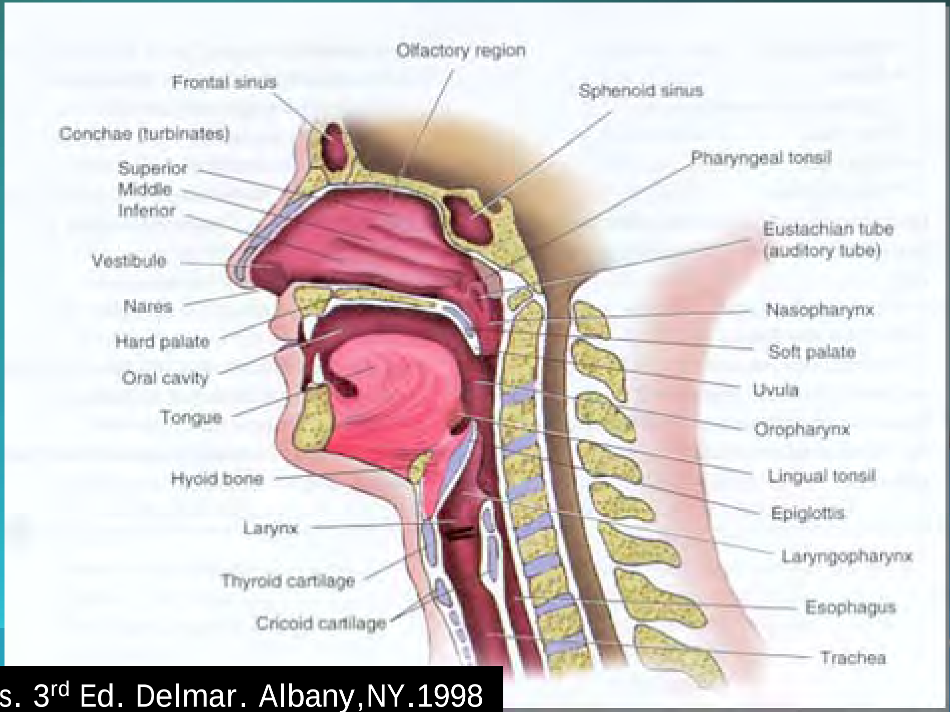


Pharynx:

- NASOPHARYNX
- OROPHAYNX
- LARYNGOPHARYNX

Nose primary functions:

- Filter
- Humidify
- Warm inspired gas



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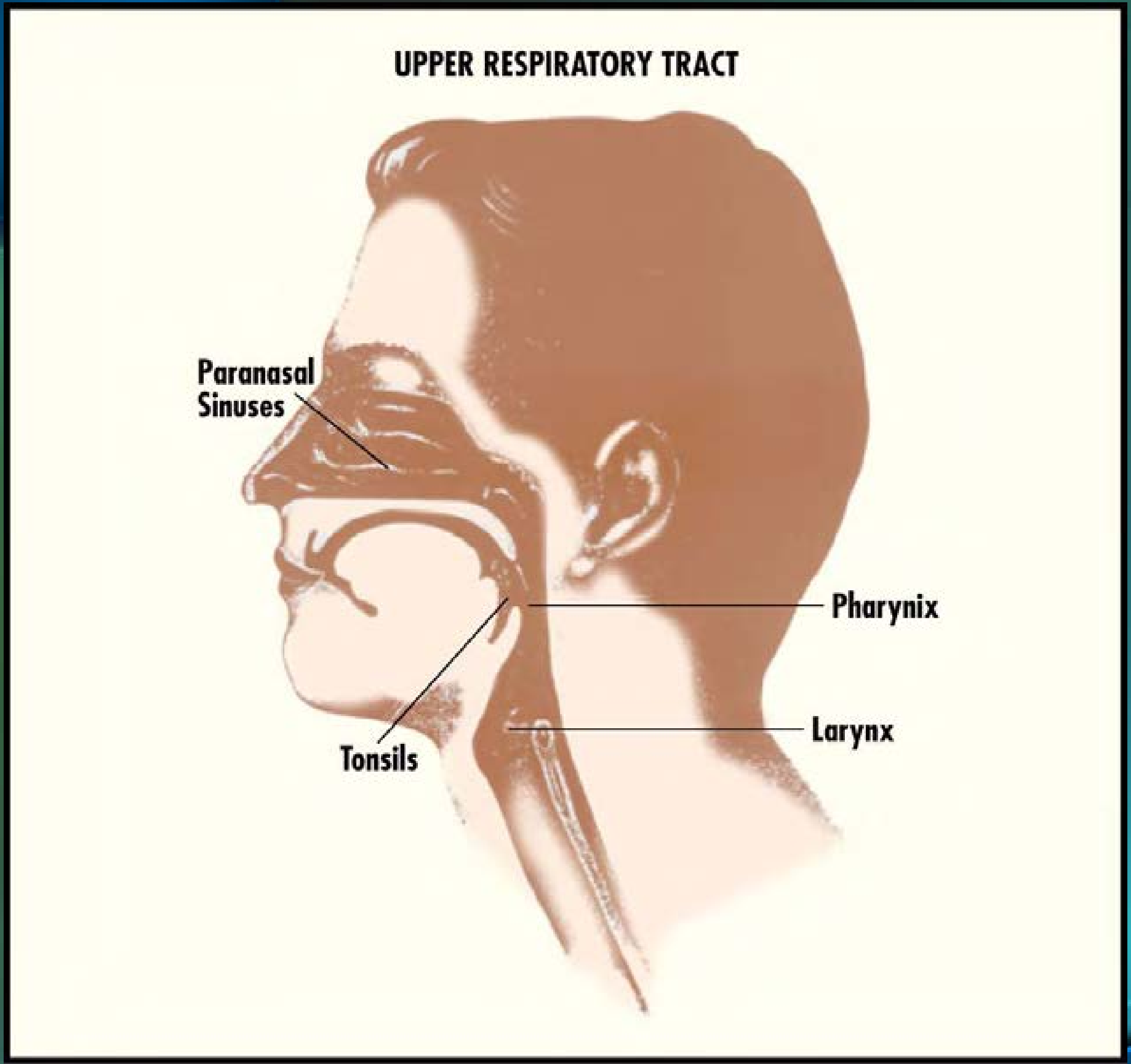
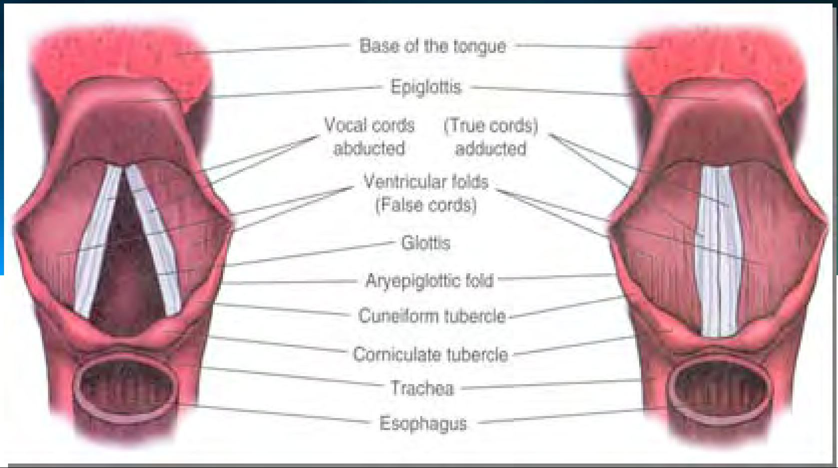
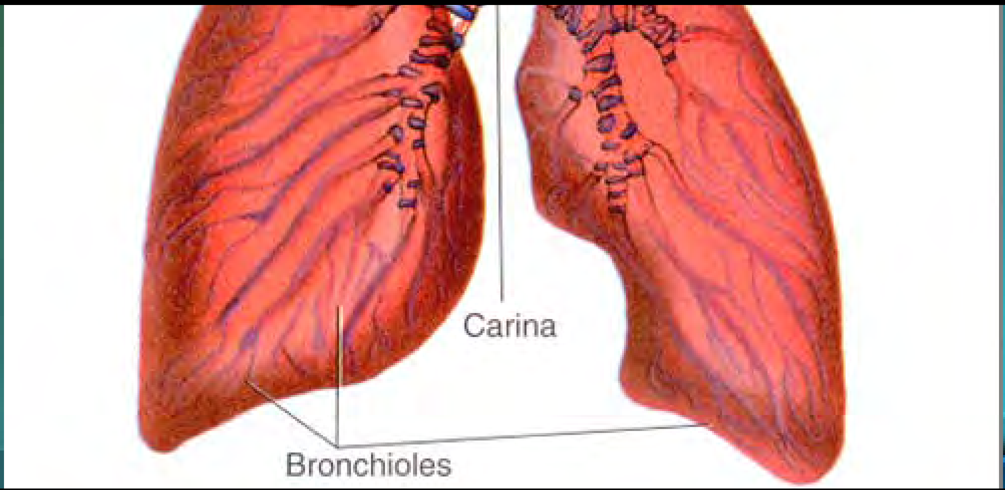

UPPER RESPIRATORY TRACT
Paranasal Sinuses
Pharynix
Larynx
Tonsils



VOCAL CORDS

- Lined by mucous membrane that forms two folds that protrude inward.
- Upper folds are called false vocal cords.
- Lower pair are the true vocal cords.
- Medial border is composed of a strong band of elastic tissue called the vocal ligament.
- Space in between the true vocal cords is called the rima glottidis or glottis.



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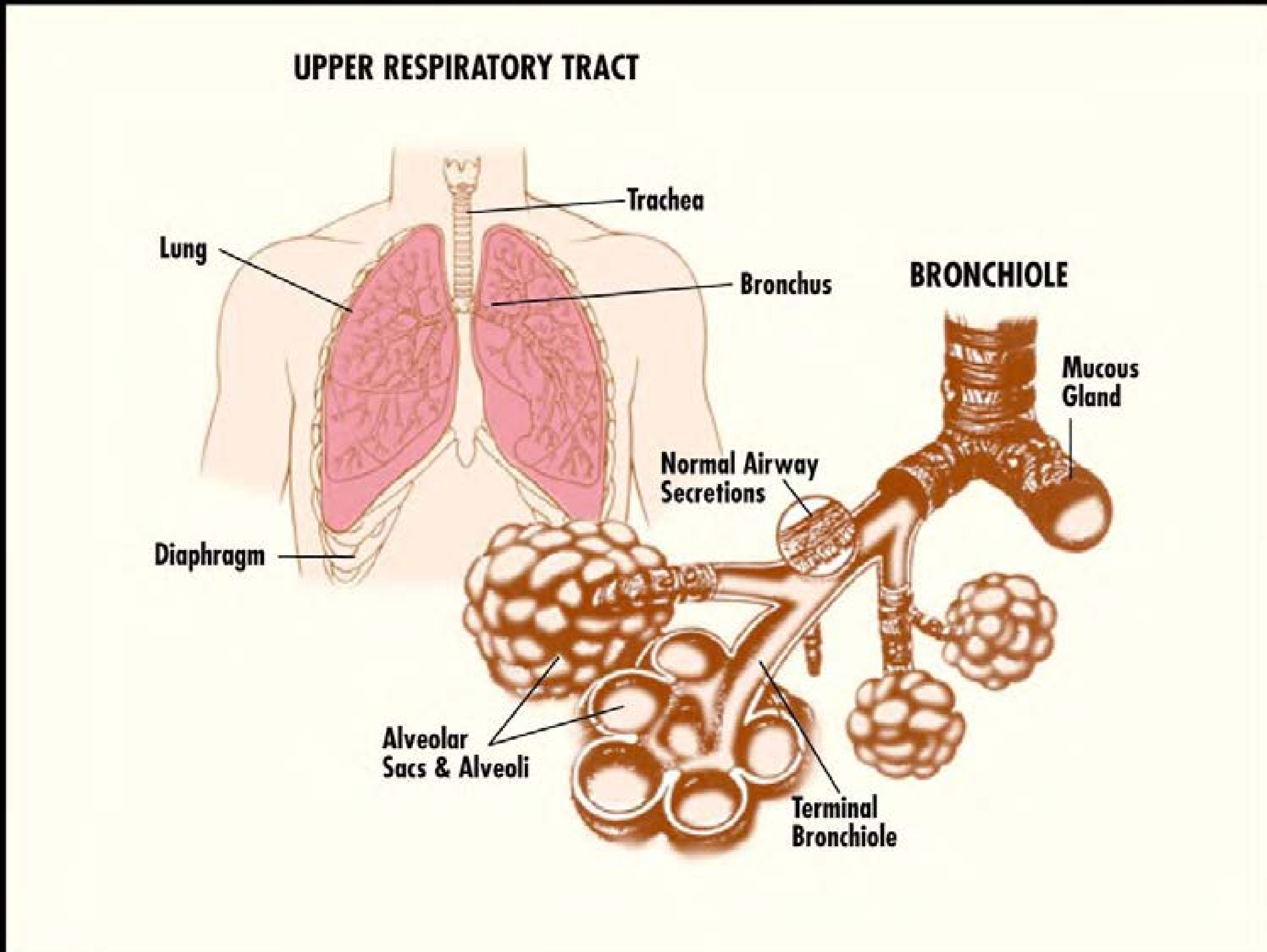
UPPER RESPIRATORY TRACT
Trachea
Lung
Bronchus
BRONCHIOLE
Mucous Gland
Normal Airway Secretions
Diaphragm
Alveolar Sacs & Alveoli
Terminal Bronchiole

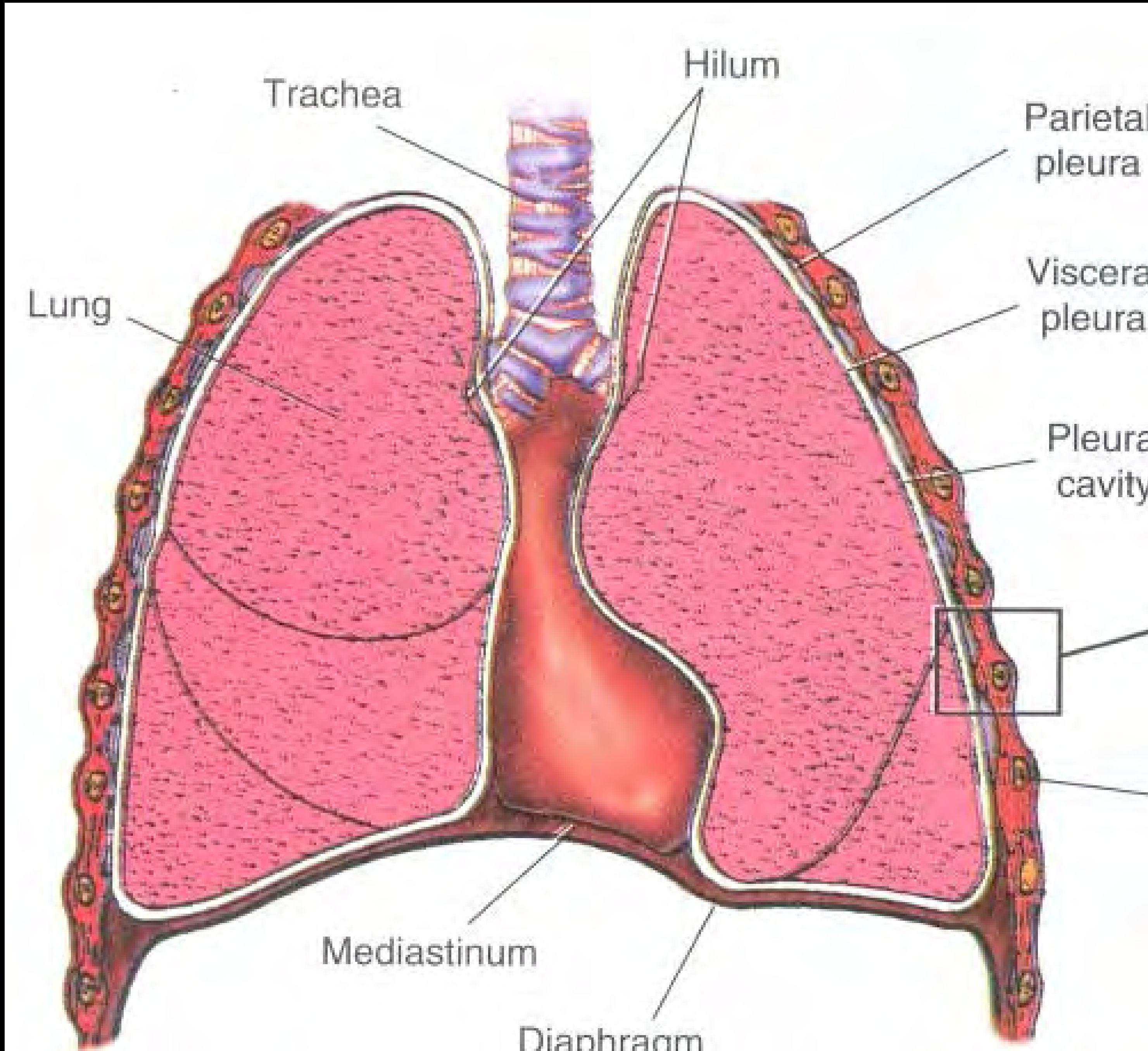

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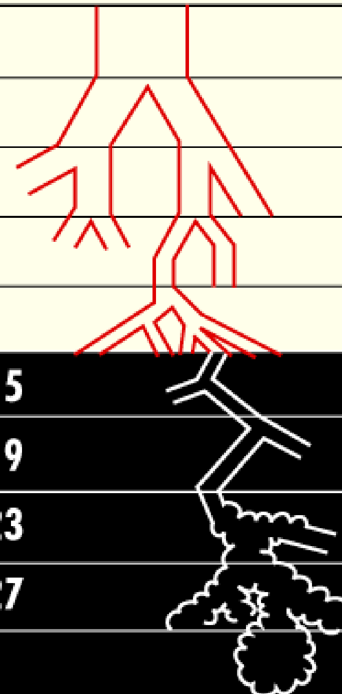
TABLE 1-1. Major Structures and Corresponding Generations of the Tracheobronchial Tree

Zone	Structures of the Lungs	Generations	
Conducting Zone	Trachea	0	Cartilaginous airways
Conducting Zone	Main stem bronchi	1	Cartilaginous airways
Conducting Zone	Lobar bronchi	2	Cartilaginous airways
Conducting Zone	Segmental bronchi	3	Cartilaginous airways
Conducting Zone	Subsegmental bronchi	4-9	Cartilaginous airways
Conducting Zone	Bronchioles	10-15	Noncartilaginous airways
Conducting Zone	Terminal bronchioles	16-19	Noncartilaginous airways
Respiratory Zone	Respiratory bronchioles	20-23	Sites of gas exchange
Respiratory Zone	Alveolar ducts	24-27	Sites of gas exchange
Respiratory Zone	Alveolar sacs	28	Sites of gas exchange



(Also called terminal respiratory units, primary lobule, lung parenchyma, acinus, and functional units)

NOTE: The precise number of generations between the subsegmental bronchi and the alveolar sacs is not known.

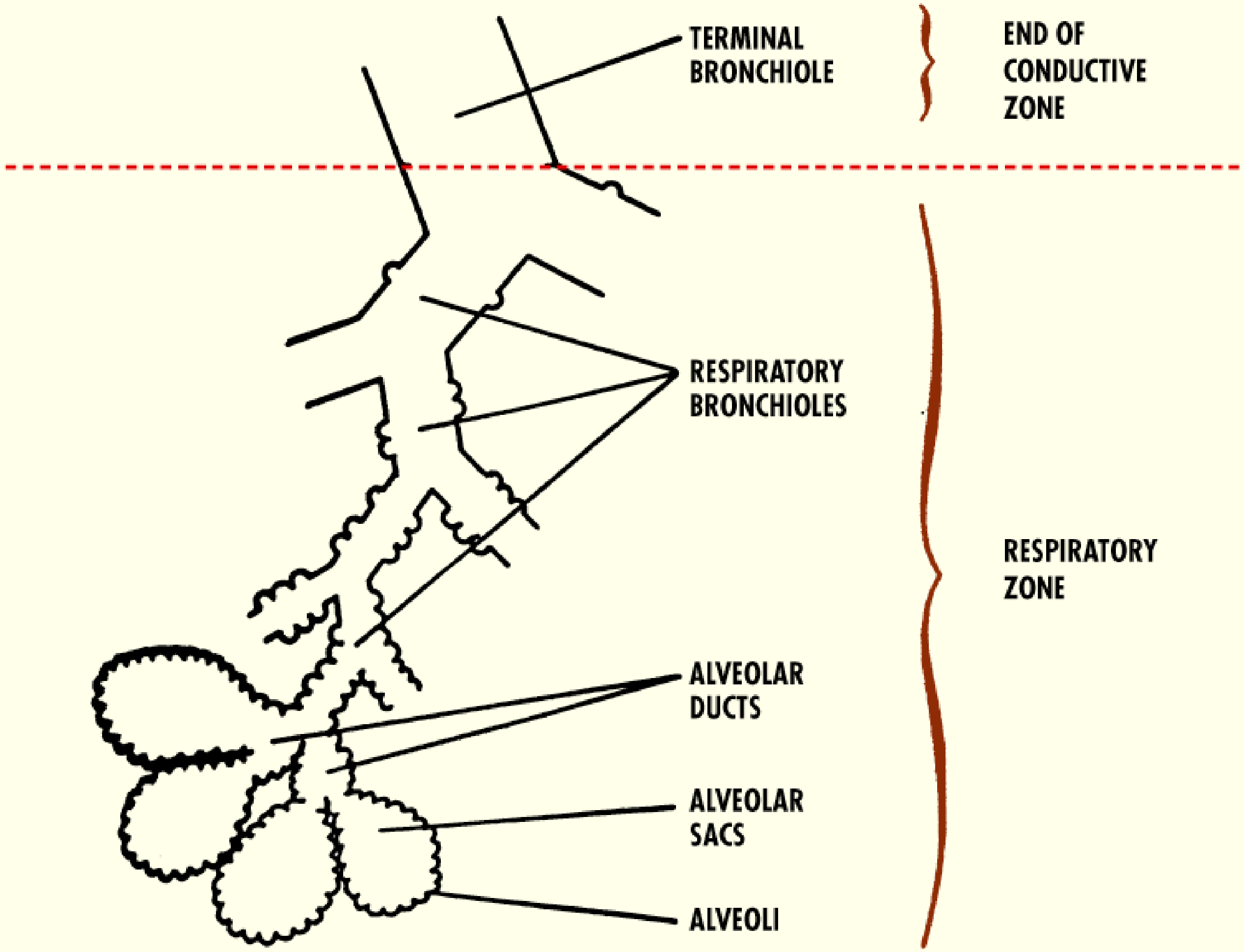
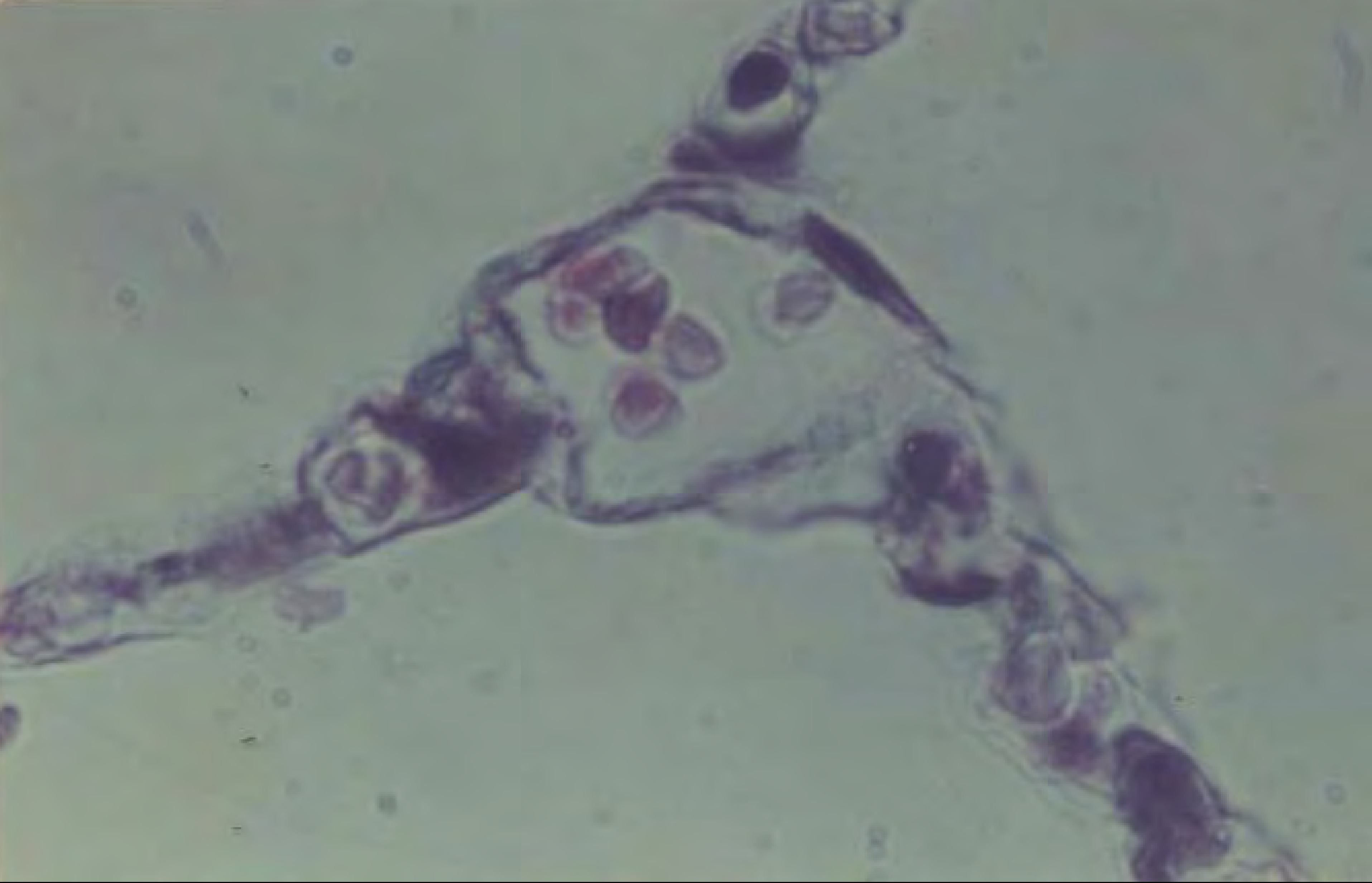


FIGURE 1-20 Schematic drawing of the anatomic structures distal to the terminal bronchioles; collectively, these are referred to as the primary lobule.

Schematic drawing of the anatomic structures distal to the terminal bronchioles; collectively, these are referred to as the primary lobule.



Alveolar unit

Functional Zones of Respiratory System

1. Conducting Zone

- Upper and lower airways
  - Filter, warm and humidify, and conduct gases
- Ventilation = movement of gases, O_2 and CO_2, in and out of the lungs
- Conducting zone = anatomical deadspace (1/3)

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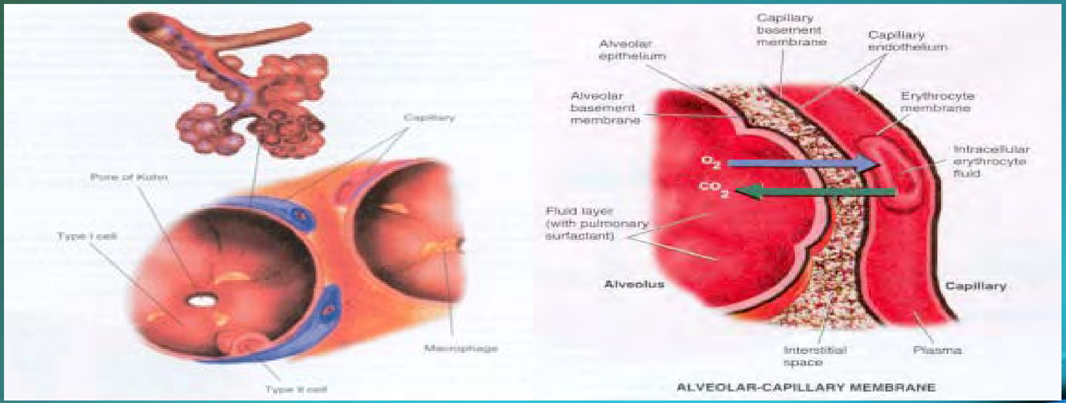
Functional Zones of Respiratory System

2. Respiratory Zone

- Bronchioles, alveolar ducts, and alveoli
- Alveoli = primary site for gas exchange
- Respiration = exchange of gases between the lungs and blood



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Quick Review

Although the respiratory system can be viewed as 3 main components, a functional description is more useful because it distinguishes the process of ventilation from that of respiration. The two functional areas are the *conducting and respiratory zones*. The conducting zone participates in ventilation. Inspired gas is filtered, warmed, and humidified as it is enters the lungs. Gas movement in the conducting zone is termed dead space ventilation. Increased levels of dead space can cause the patient to increase their rate and depth of breathing to compensate for the effect on ventilation and respiration.

Quick Review

The exchange of gases between the alveoli and blood is called respiration and occurs in the respiratory zone. This area is comprised of small airways, alveoli, and the pulmonary capillaries. Gas enters the respiratory zone from the conducting airways and blood circulates the alveoli from the pulmonary capillaries. In order to have affective respiration there must be adequate levels of ventilation and pulmonary blood flow.

Pulmonary Mechanics

Respiratory Mechanics

Pulmonary Mechanics

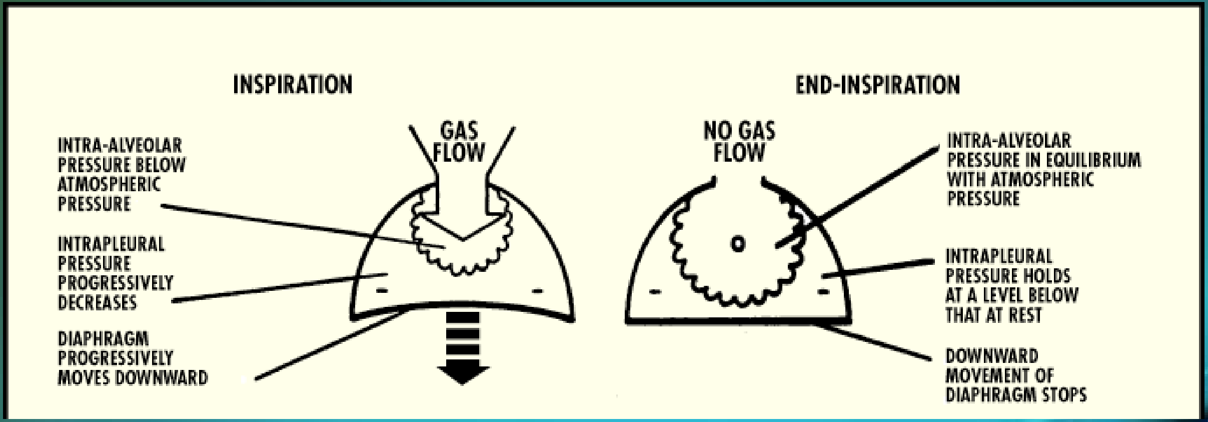
- Requires chest wall (thorax) and respiratory muscles
- Pleura (lining) - lubricant
- Opposing forces keep lungs inflated (thorax=out, lungs=in)
- Muscles provide force(work)
- Diaphragm = major muscle of ventilation

Inspiration (ACTIVE)

Diaphragm contracts - moves downward

Thoracic volume increases

Lung (pleural) pressure decreases - air moves in



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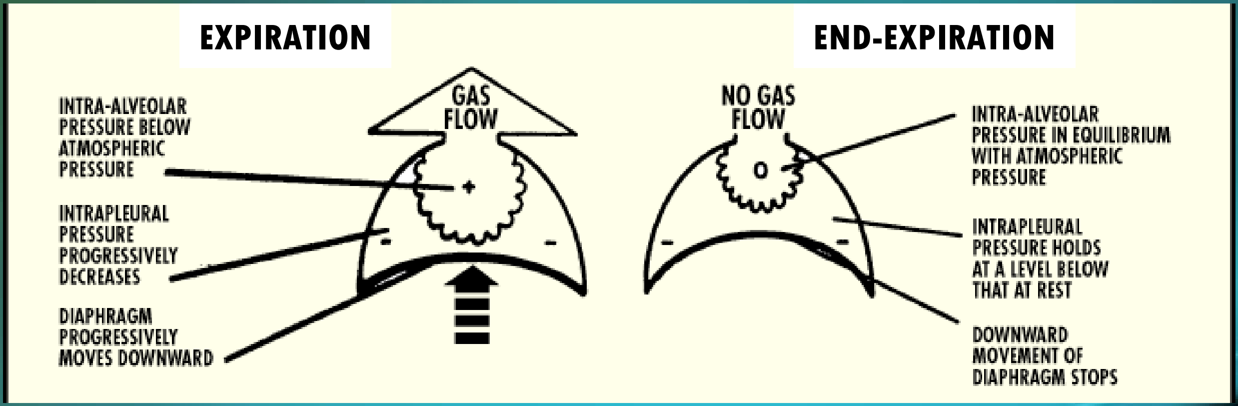
Expiration (PASSIVE)

Diaphragm relaxes - moves up

Thoracic volume decreases

Lung (pleural) pressure decreases air moves out



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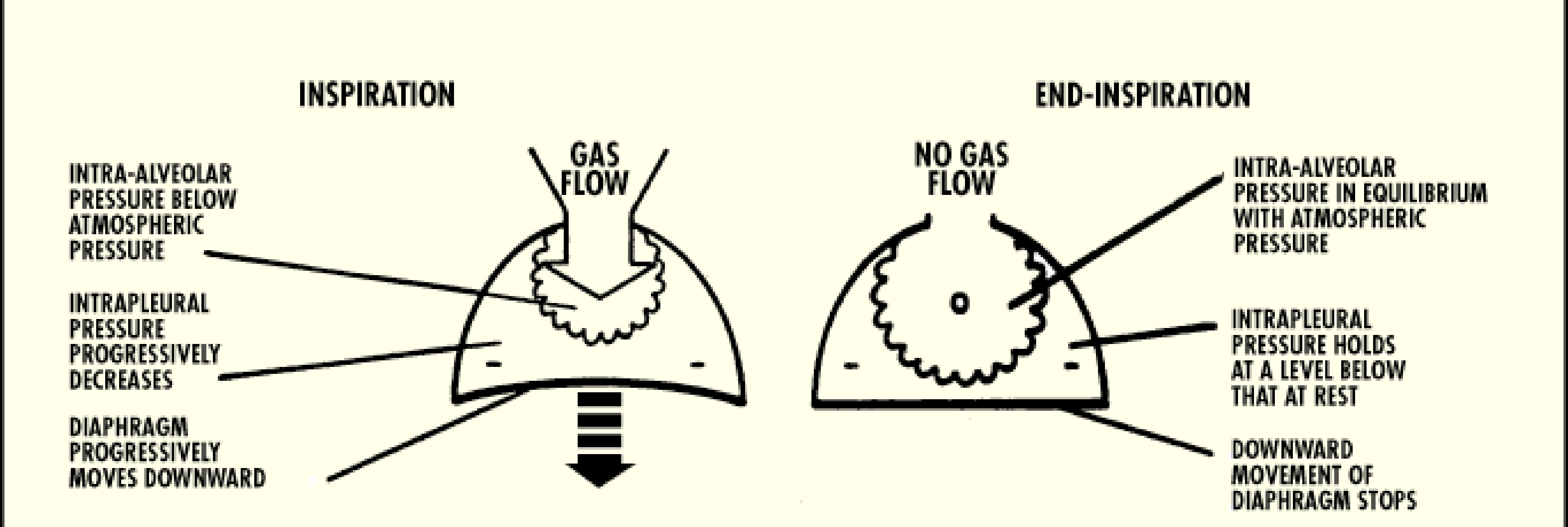
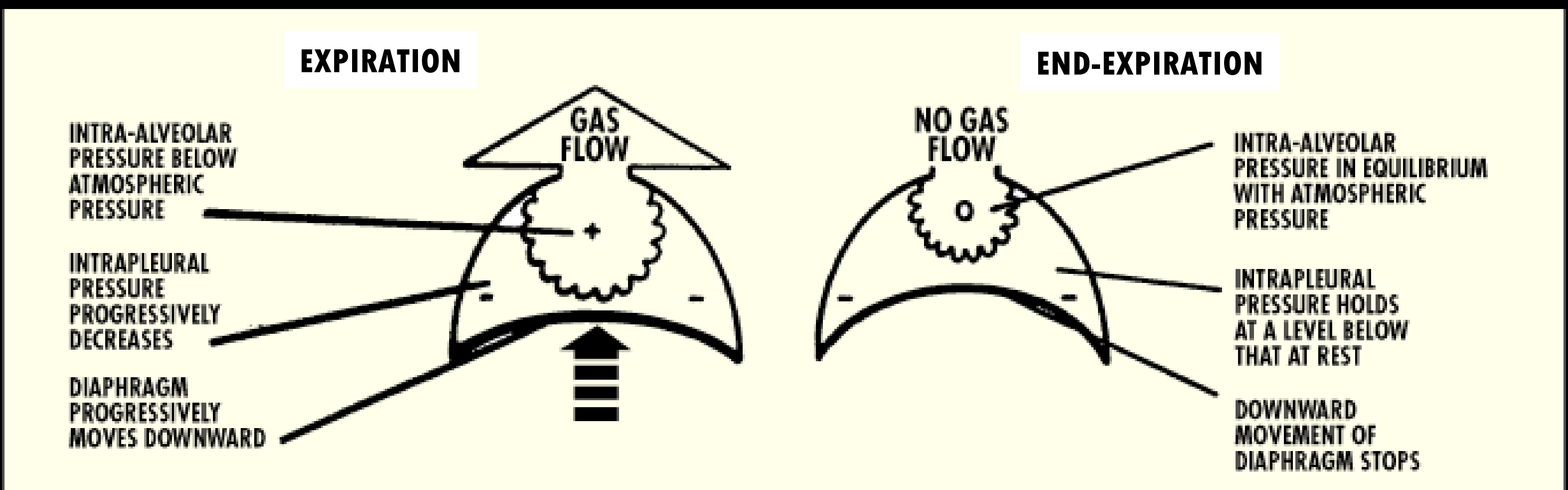
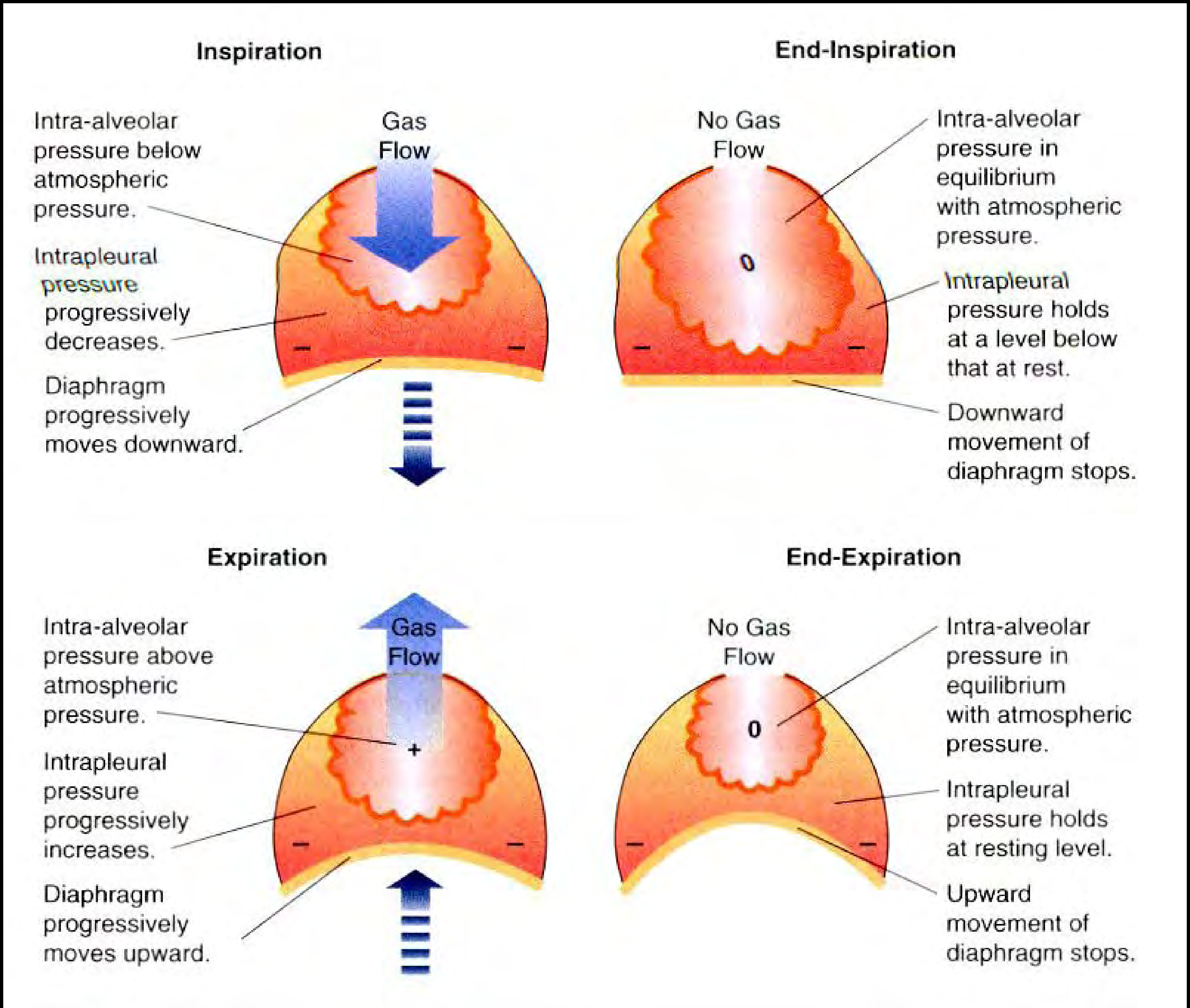


FIGURE 2-5. How the excursion of the diaphragm affects the intrapleural pressure, intra-alveolar pressure, and bronchial gas flow diring inspiration and expriation.





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Pulmonary Mechanics

Compliance

- Amount of work required to inflate lungs
  - "how stiff is the lung?"
- Compliance = $\frac{\Delta \text{Volume}}{\Delta \text{Pressure}}$ (L/cmH_20)
- Normal = 0. 1L/cmH_20 (100 ml/cmH_20)
- High compliance easier - to inflate
- Low compliance - harder to inflate

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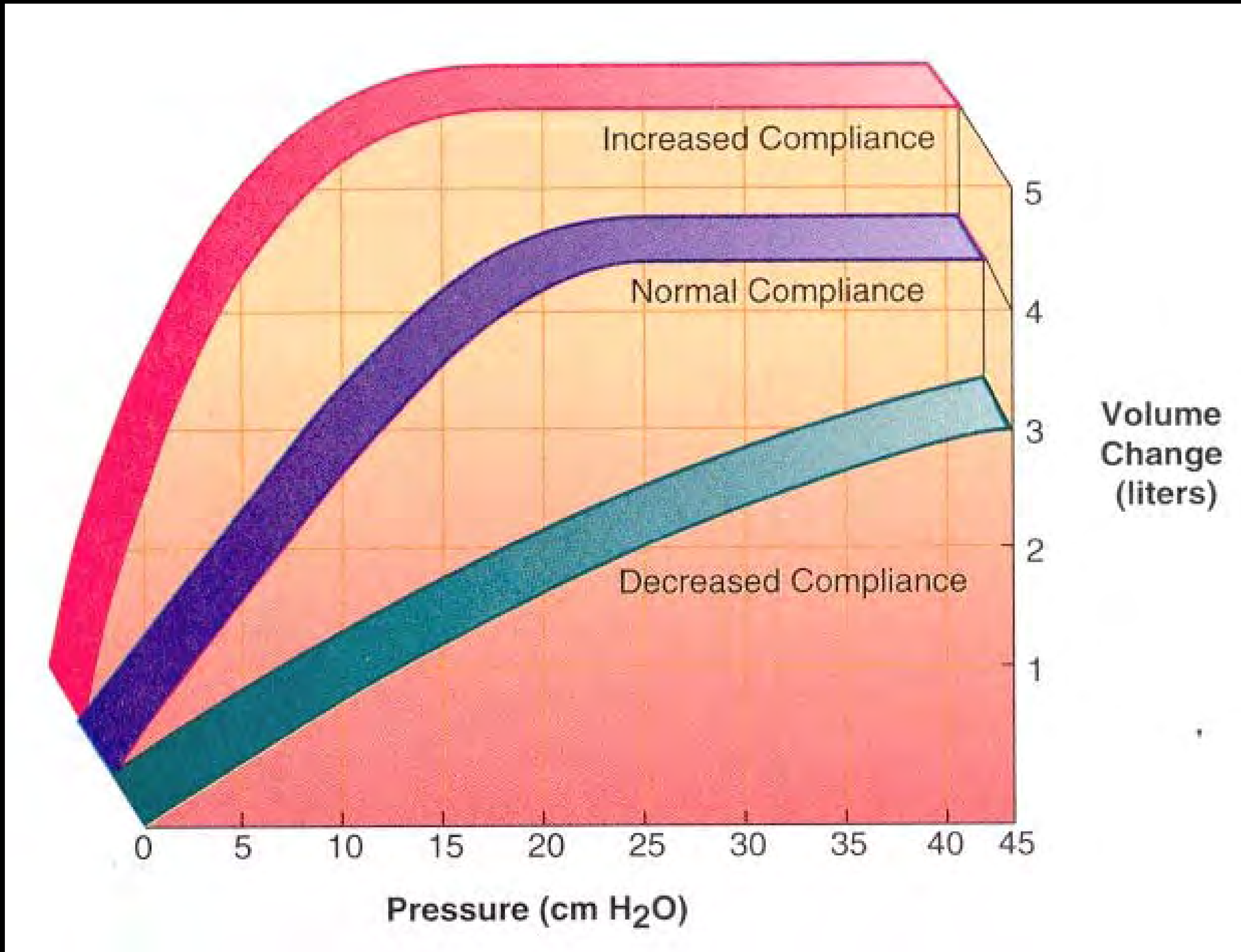

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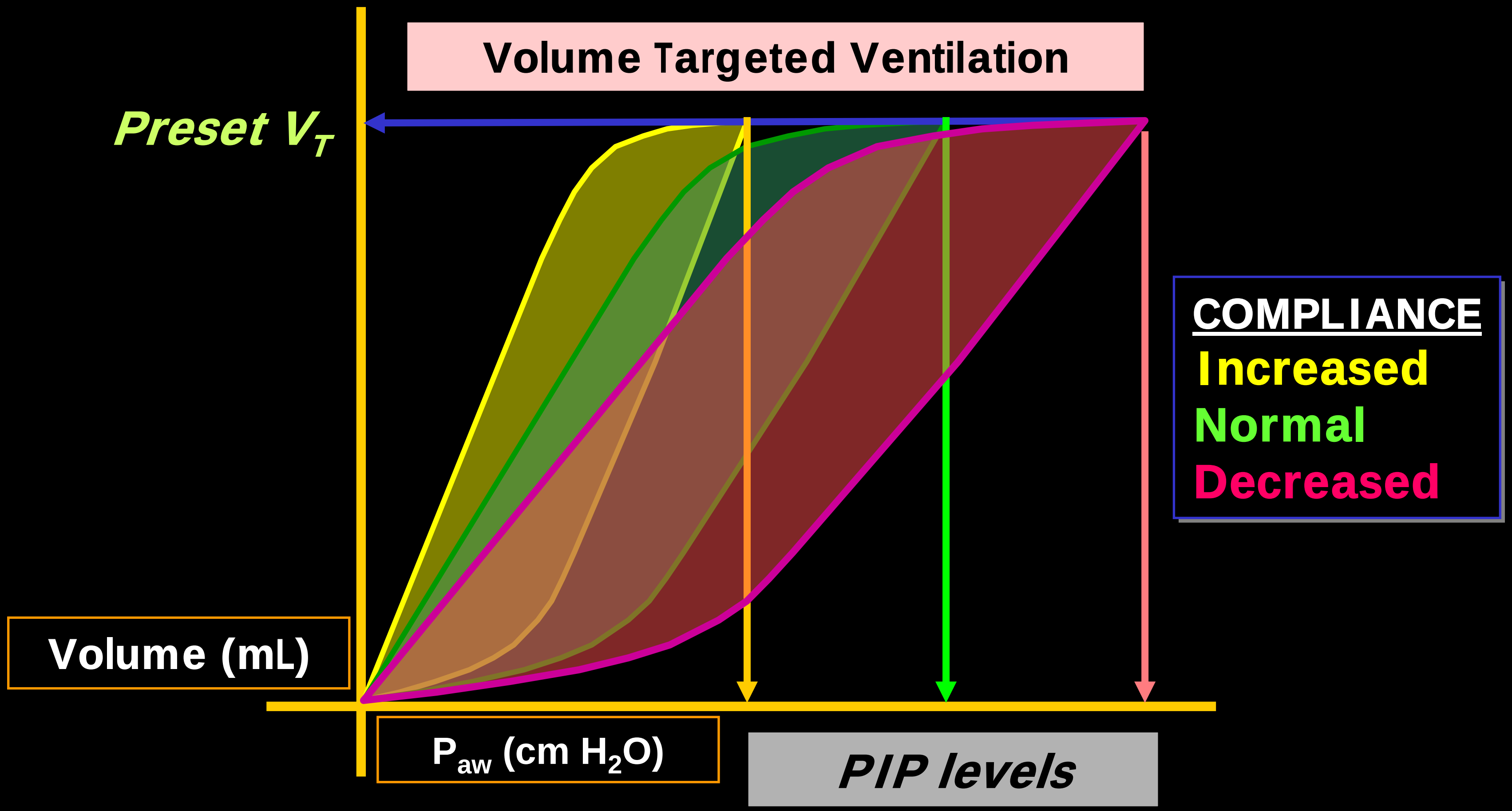
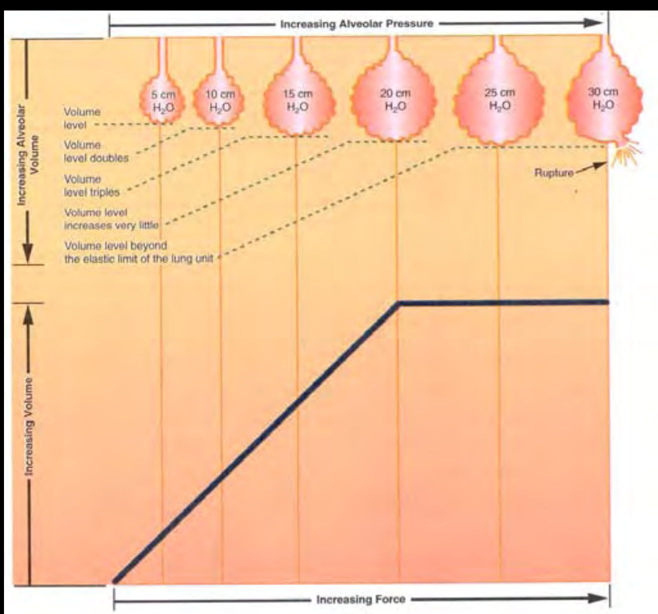
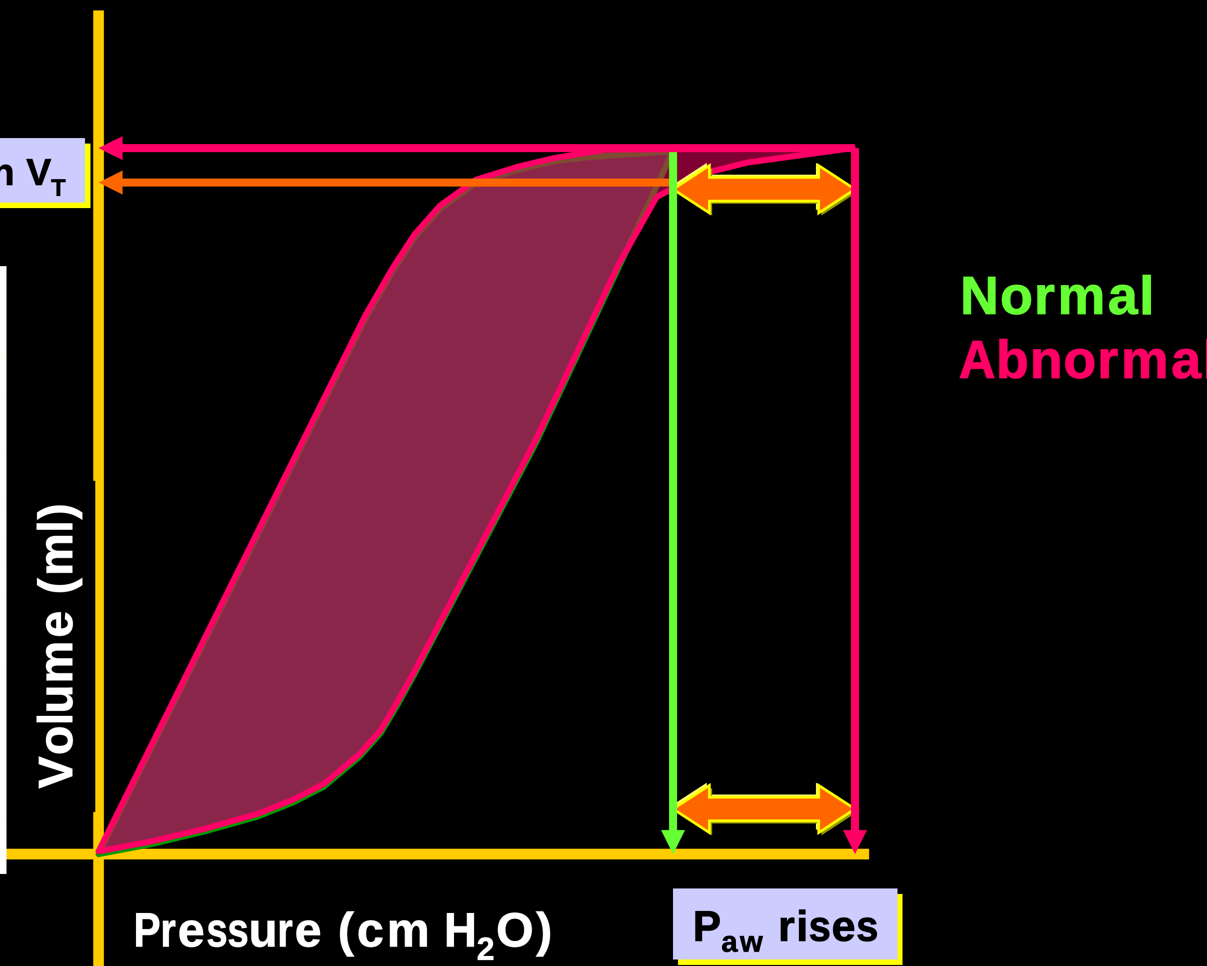
Lung Compliance Changes and the P-V Loop



Overdistension





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Pulmonary Mechanics

Elastance

- Amount of work required to exhale
- Elastance = $\dfrac{\Delta \text{Pressure}}{\Delta \text{Volume}}$ (cmH_20/L)
- Reciprocal of compliance
- Good compliance = bad elastance
- Bad compliance = good elastance

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Pulmonary Mechanics

Resistance

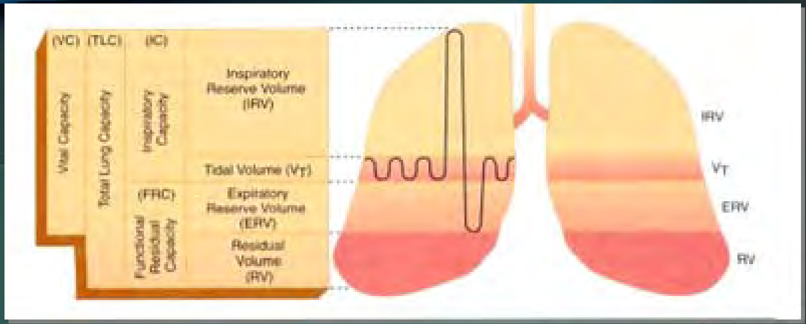
- Amount of work required to move air through the lungs
- Resistance = $\frac{\text{Pressure}}{\text{Flow}}$ ($cmH_20/L/sec$)
- Primarily influenced by airway diameter
- Normal = 0.6 - 2.4 $cmH_20/L/sec$

Quick Review

Ventilation occurs due to a pressure gradient between the lungs and mouth. Contraction of the respiratory muscles results in a pressure - volume change in the lungs. As pressure decreases air moves into the lungs during inspiration, and as lung pressure increases gas moves out of the lungs during expiration. The compliance of the pulmonary system influences the amount of pressure required to affect a volume change. Airway resistance also influences the effort needed to create a volume change.

Lung Volumes and Capacities

Pulmonary Function



Lung Volumes and Capacities

Volumes	Capacities
Tidal Volume (V_T)	Inspiratory Capacity (IC)
Inspiratory Reserve Volume (IRV)	Vital Capacity (VC)
Expiratory Reserve Volume (ERV)	Functional Residual Capacity (FRC)
Residual Volume (RV)	Total Lung Capacity (TLC)

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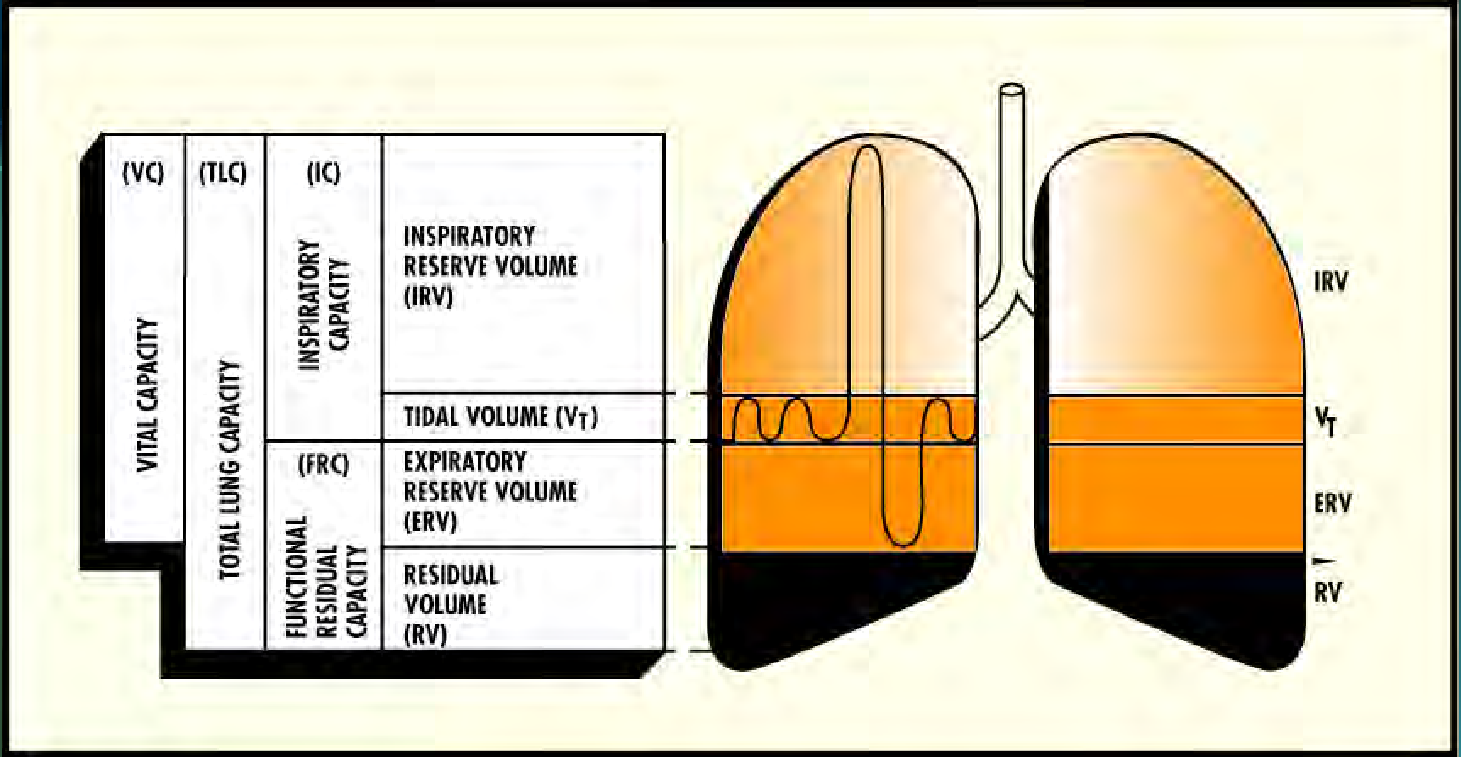
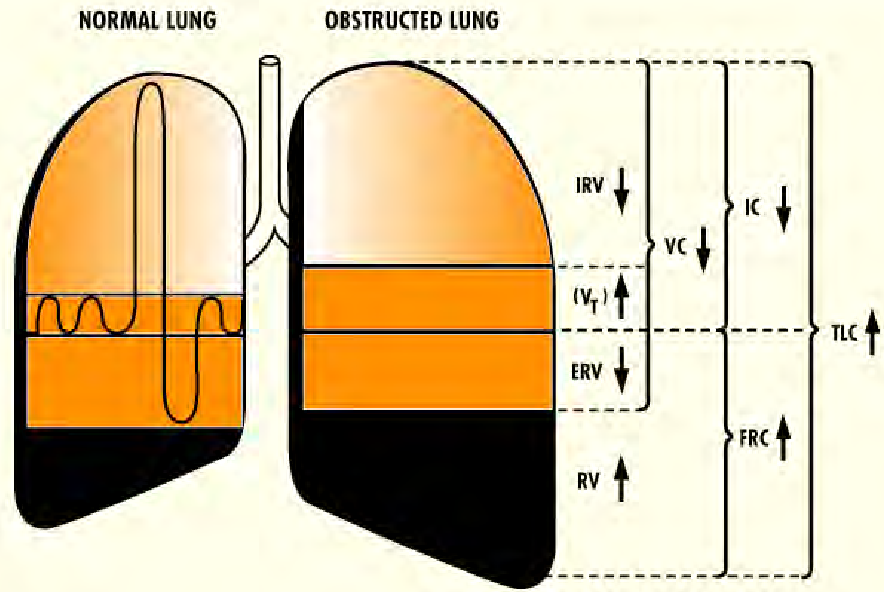
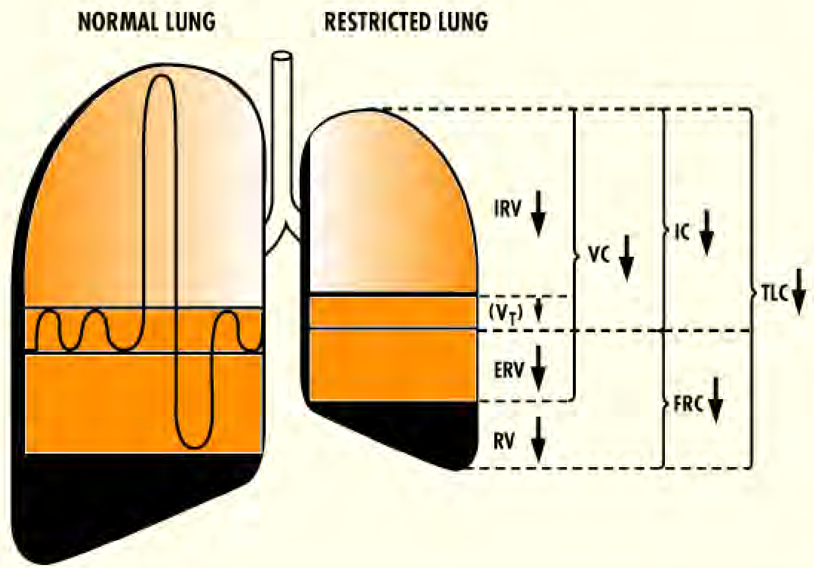


FIGURE 4-1. Normal lung volumes and capacities.
IRV = inspiratory reserve volume;
VT = tidal volume; RV = residual volume; ERV = expiratory reserve volume;
TLC = total lung capacity; VC = vital capacity; IC = inspiratory capacity;
FRC = functional residual capcity.


NORMAL LUNG
OBSTRUCTED LUNG
IRV
(VT)
ERV
RV
VC
IC
FRC
TLC


NORMAL LUNG
RESTRICTED LUNG
IRV
(VT)
ERV
RV
VC
IC
FRC
TLC

Assessment of Ventilation

Signs & Symptoms

Assessment of Ventilation

Qualitative

- Respiratory pattern
- Accessory muscle use
- Prolonged expiration
- Shortness of Breath (SOB)
- Cyanosis
- Minute ventilation ($VE = f \times V_T$)

Assessment of Ventilation

- *Quantitative*
- ABG's (primarily CO_2)
- Pulse oximetry
- Capnography
- Transcutaneous monitoring
- NICO

Control of Respiration

1. Chemical Stimulants

- Oxygen and carbon dioxide influence rate and depth of respiration
- CO_2 is the primary stimulus

↑ CO_2 = ↑ rate and/or depth

↓ CO_2 = ↓ rate and/or depth

↓ O_2 = ↑ ventilation

↑ O_2 = ↓ ventilation

Quick Review

Respiration is the exchange of gases between the lungs and pulmonary blood vessels (external respiration) and between the blood and tissues (internal respiration). Oxygen and carbon dioxide move from one area to the other due to pressure gradients. Systemic levels of CO_2 and O_2, influence the depth and rate of ventilation with carbon dioxide acting as the primary stimulus for ventilation.

Arterial Blood Gas Variables

- **pH** This indicates the relative acidity or alkalinity of the blood. The normal range is 7.35 - 7.45. Values less than 7.35 are acid, and those above 7.45 alkaline.
- **$PaCO_2$** The partial pressure (tension) of carbon dioxide in the arterial blood. The normal range is 35 - 45 torr. Values less than 35 indicate excessive levels of ventilation, and values above 45 indicate a drop in ventilation.

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Arterial Blood Gas Variables

- **PaO_2** The partial pressure (tension) of oxygen in the arterial blood. The normal range, breathing room air, is 80 - 100 torr, values less than 70 indicate a lack of oxygen.
- **SaO_2** This indicates the percentage of red blood cells that are combined with O_2. The normal range, breathing room air, is 90 - 100%. Levels below 90% indicate a lack of oxygen.

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FYI

Gas pressures, or tensions, are usually expressed in units of torr. One torr is equal to one mm Hg (millimeter of mercury pressure), similar to what your local weatherman uses. Torr is used to honor Evangelista Torricelli who invented the mercury barometer. Torr and mm Hg can be used interchangeably, however torr is the preferred unit.

Ventilation-Perfusion Relationships

- Perfusion(Q)
- Ventilation(V)
- Need V/Q matching to achieve effective gas exchange.
- Normal V/Q ratio = 0.8
- Increased V/Q ventilation>perfusion (deadspace)
- Decreased V/Q perfusion>ventilation (shunt)
- Abnormal V/Q ratios alter work of breathing

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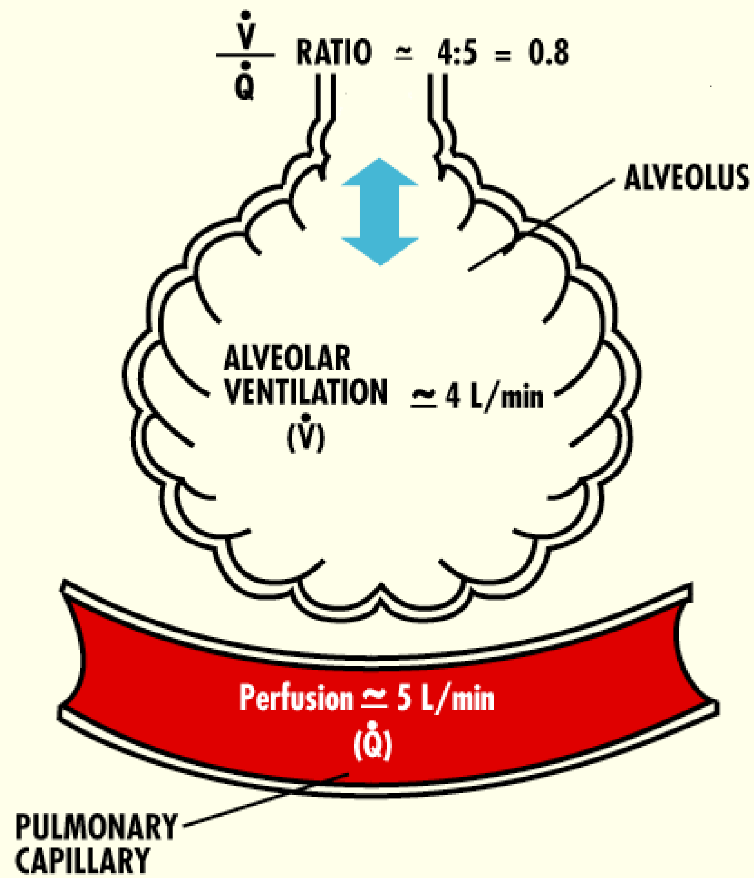
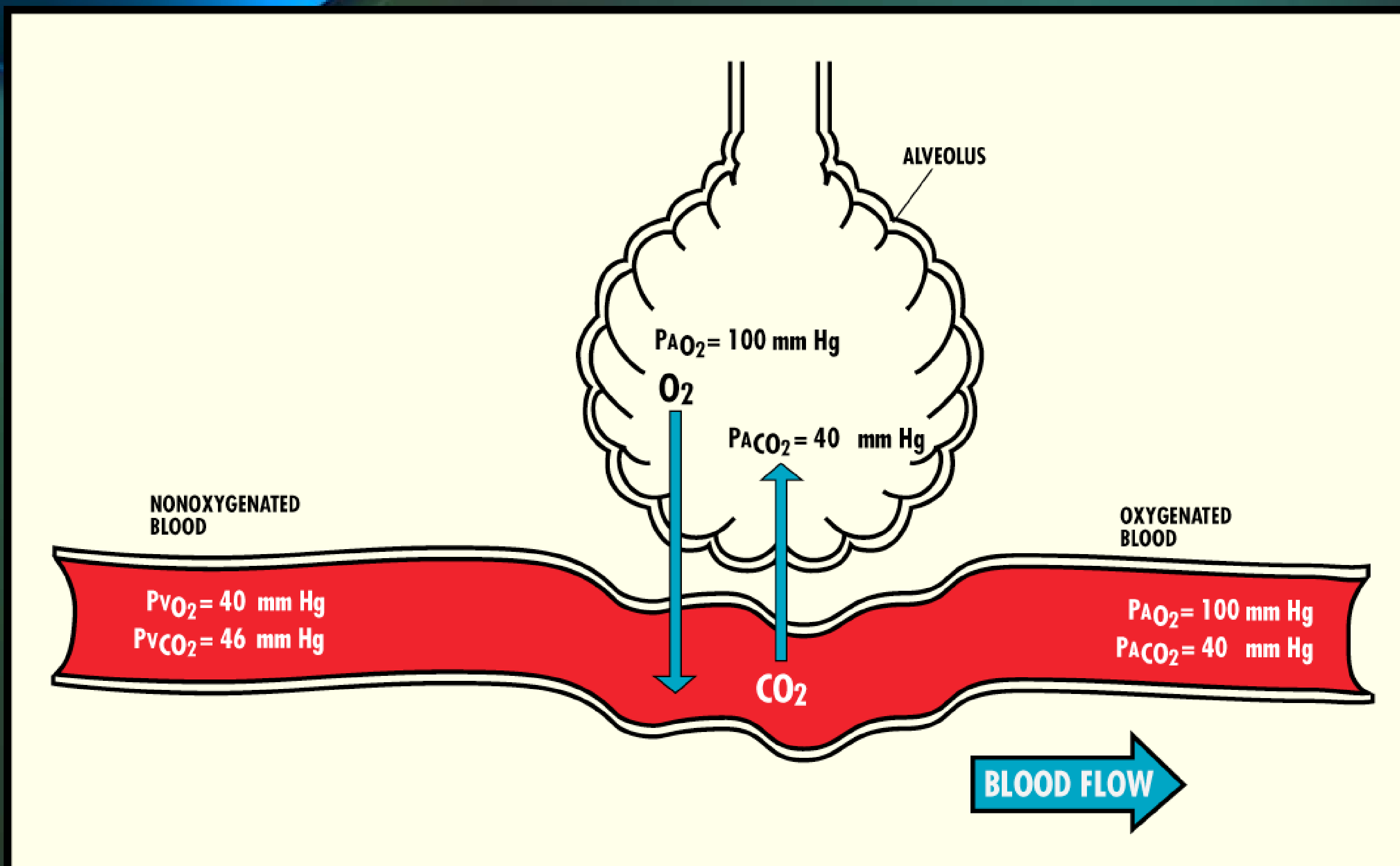
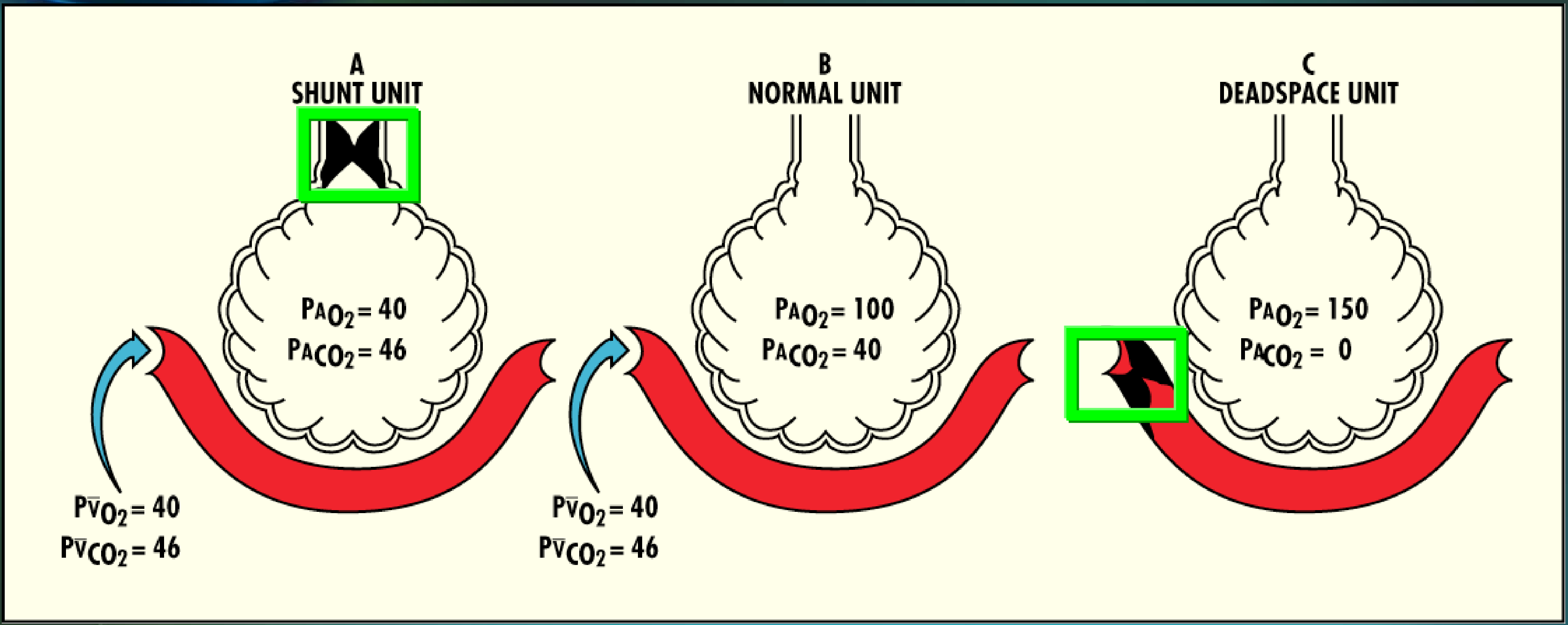
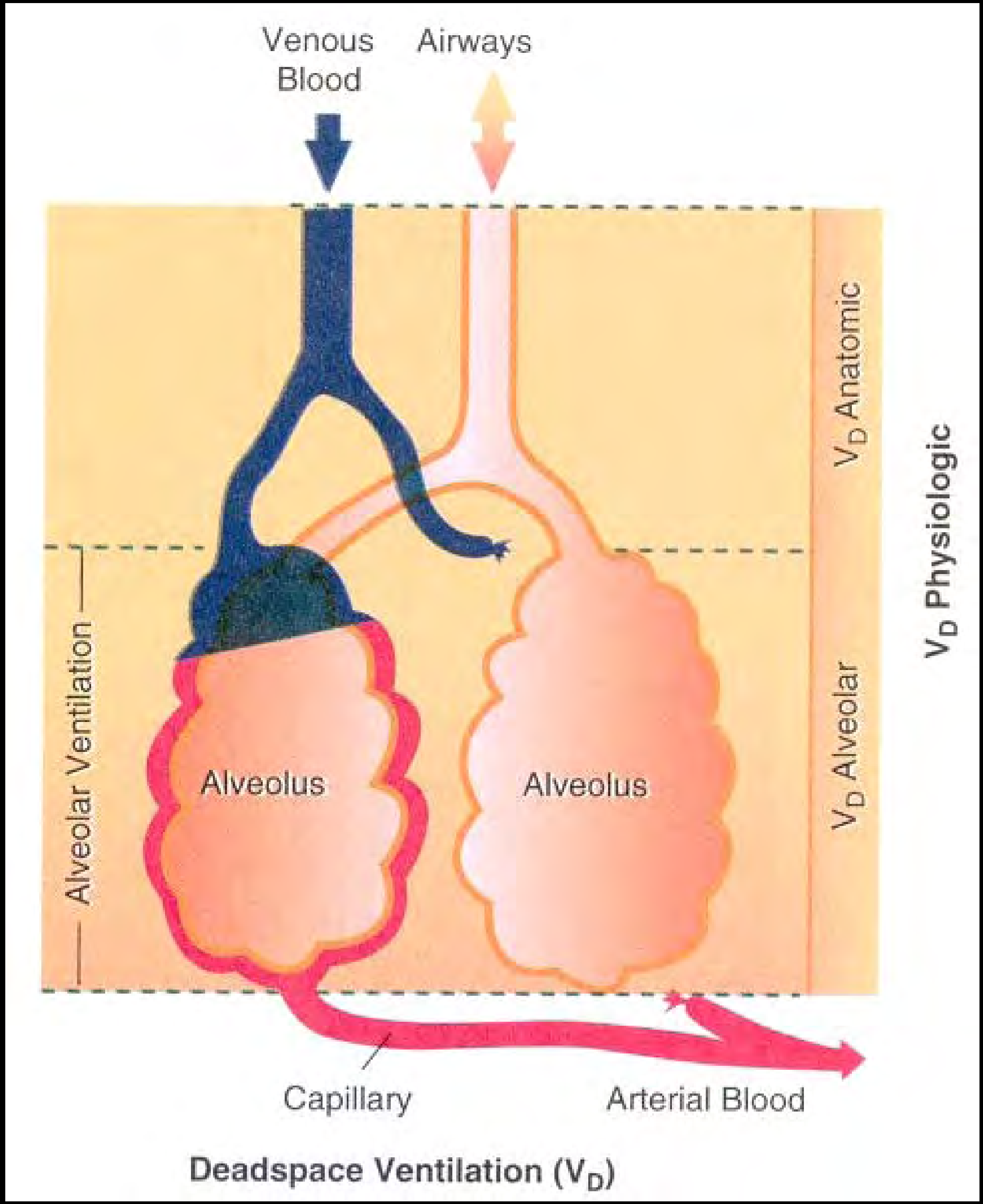


The normal ventilation perfusion ratio ($\dot{V}/\dot{Q}$ ratio) is about 0.8.


ALVEOLUS
P_{AO_2} = 100 mm Hg
O_2
P_{ACO_2} = 40 mm Hg
NONOXYGENATED BLOOD
P_{VO_2} = 40 mm Hg
P_{VCO_2} = 46 mm Hg
CO_2
OXYGENATED BLOOD
P_{AO_2} = 100 mm Hg
P_{ACO_2} = 40 mm Hg
BLOOD FLOW


A
SHUNT UNIT
PAO2 = 40
PACO2 = 46
PvO2 = 40
PvCO2 = 46
B
NORMAL UNIT
PAO2 = 100
PACO2 = 40
PvO2 = 40
PvCO2 = 46
C
DEADSPACE UNIT
PAO2 = 150
PACO2 = 0



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Balance Between External Respiration and Internal Respiration (supply and demand)

- Exercise increases O_2 consumption and CO_2 production.
- If body cannot maintain balance to hypoxia and hypercarbia is reflected by clinical and laboratory assessment.
- Need adequate respiratory and cardiac function in order to maintain acid-base and supply-demand balance.

Quick Review

ABG's are used to assess the effectiveness of respiration. Problems in external respiration occur from V/Q mismatches. Low V/Q areas produce oxygenation problems (shunting) and high V/Q ratios represent alveolar dead space ventilation. Internal respiration is the exchange of O_2 and CO_2 between the arterial blood and the tissues. Metabolic activity of the cells requires O_2 and produces CO_2 as a byproduct. ABGs are used to assess the level of O_2 available for metabolism and the effectiveness of lungs in removing CO_2.

Indications for Mechanical Ventilation

- Simply stated mechanical ventilation is indicated when a patient is unable to adequately remove CO_2 and maintain adequate levels of O_2 in the arterial blood.
- Ventilation may be short or long-term depending on underlying disorder.

Goals of Mechanical Ventilation

- Decrease work of breathing
- Increase alveolar ventilation
- Maintain ABG values within normal range
- Improve distribution of inspired gases

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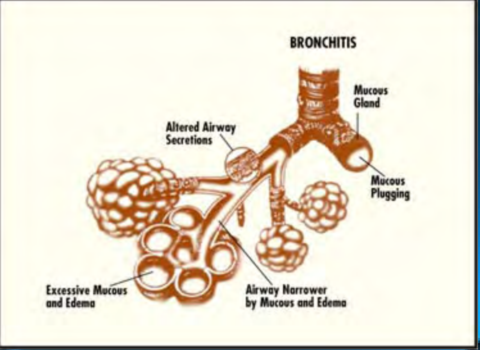
Obstructive Lung Disease

Goal of Ventilation:

Reduce work of breathing

1. Emphysema

- **Pathology:** Destruction of terminal airways and air sacs.
- **Concerns:** Must assure adequate time and pressure for exhalation. Low pressures desirable to reduce the likelihood of damage to the lung, additional high airway resistance; end stages will also have poor lung compliance.



Obstructive Lung Disease Goal of Ventilation :

Reduce work of breathing

2. Bronchitis

- **Pathology:** Chronic inflammation of mucous-producing cells. Hyper-reactive airways. Excessive abnormal secretions from irritation (infection, allergies, smoke, etc.).
- **Concerns:** Ventilation only supportive; must reduce volume of secretions and remove irritants.

Respiratory Dysfunction

Diagnosis confirmed via PFTs

Obstructive Lung Disease

- Decreased expiratory flowrates
- Increased RV, FRC, and TLC = air trapping "can't get air out"
- Exhibit increased airway resistance
- Decreased elastance; increased compliance
- Examples: (COPD)
  - a. asthma
  - b. emphysema
  - c. bronchitis
  - d. bronchiolitis

Respiratory Dysfunction

Restrictive Lung Disease

- Decreased volumes and capacities, normal flowrates
- “can’t get volume in”
- Exhibit decreased compliance, increased elastance
- Examples:
  - a. pulmonary fibrosis
  - b. pulmonary edema
  - c. pneumo/hemo thorax
  - d. ARDS/IRDS
  - e. chest wall deformities
  - f. obesity
  - g. neuromuscular disorders

Work of Breathing

Work = Force (pressure) x Distance (volume)

- Pressure generated must overcome:
  - a. resistance of airways
  - b. compliance of lung and chest wall
- Muscles of respiration are very inefficient
  - – can fatigue and lead to respiratory failure
- Signs of fatigue:
  - a. increased respiratory rate
  - b. increased arterial CO_2
  - c. paradoxical breathing

Mechanical Ventilation

1. Negative Pressure Ventilators

- Iron lung
- Cuirass

2. Positive Pressure Ventilators

- Volume ventilators
- Pressure ventilators

Negative Pressure Ventilation

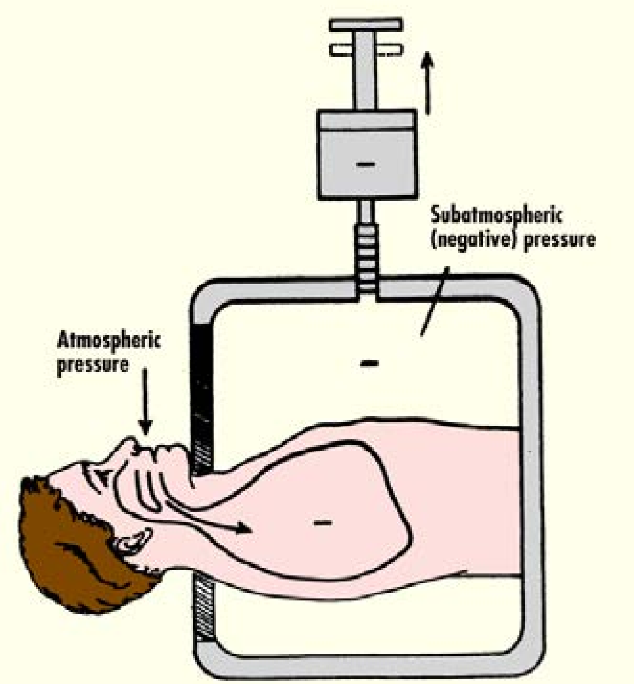


FIGURE 8-1 By applying subatmospheric pressure around the chest wall you can produce a drop in pressure in the airway and gas flow into the lungs.

- Creates a negative (subatmospheric) extrathoracic pressure to provide a pressure gradient.
- Mouth (atmospheric), Lungs (subatmospheric) = Inspiration
- Problems?

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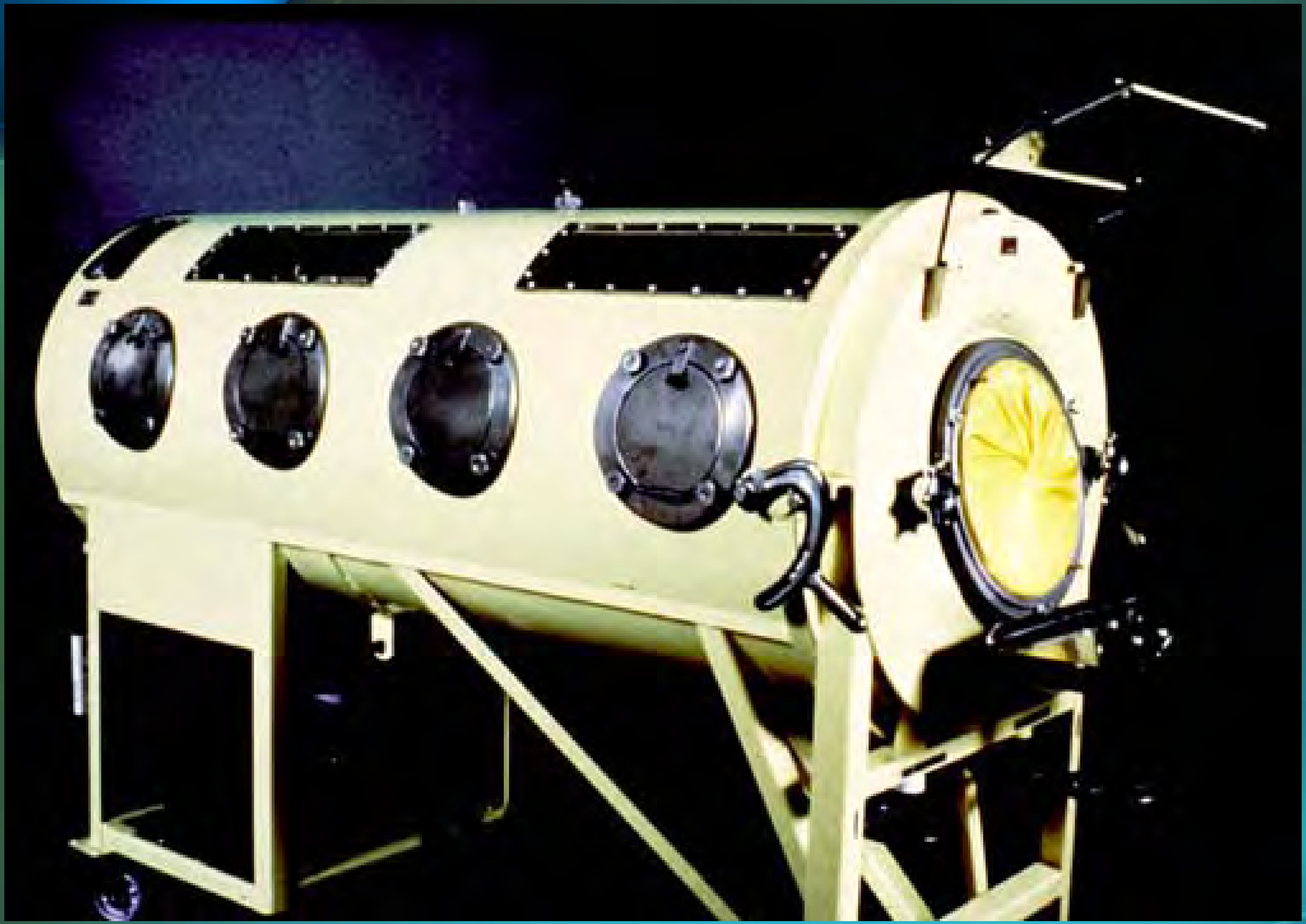

Emerson Iron Lung

NEV 100 + Neumo suit

Positive Pressure Ventilation

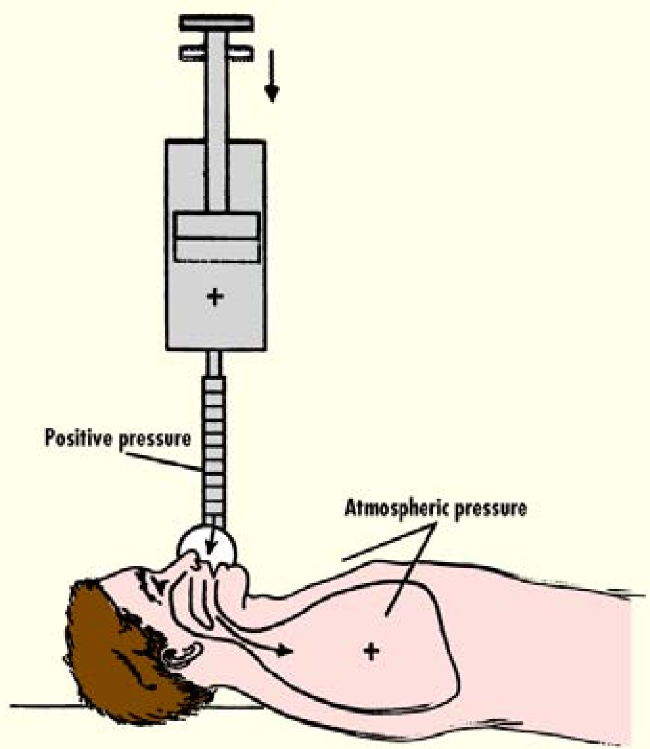

FIGURE 8-2 Application of positive pressure at the airway provides a pressure gradient and therefore gas flows into the lungs.

- Creates a positive intrapleural pressure in presence of atmospheric extrathoracic pressure.
- Mouth (atmospheric), Lungs (atmospheric) = Instpiration
- Problems?

Negative vs. Positive Pressure Ventilation

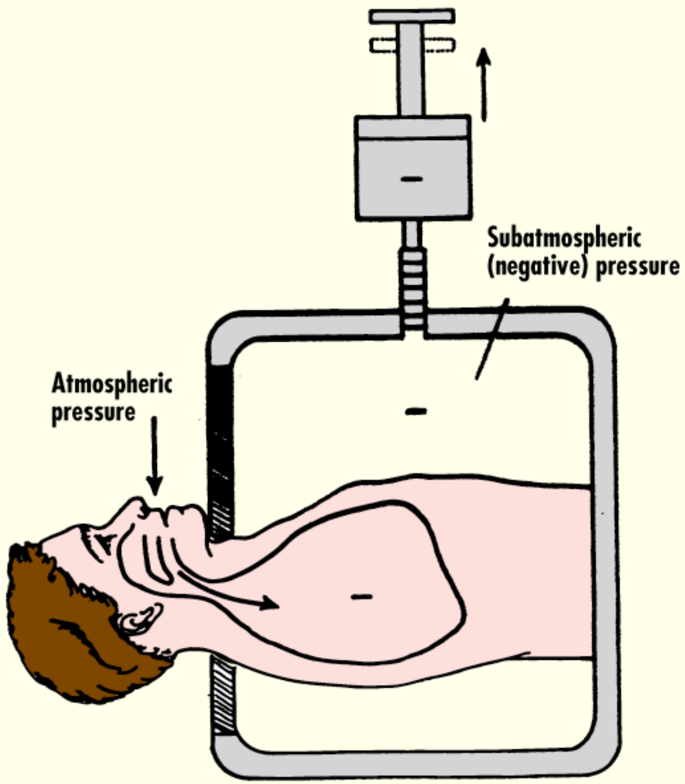

FIGURE 8-1 By applying subatmospheric pressure around the chest wall you can produce a drop in pressure in the airway and gas flow into the lungs.

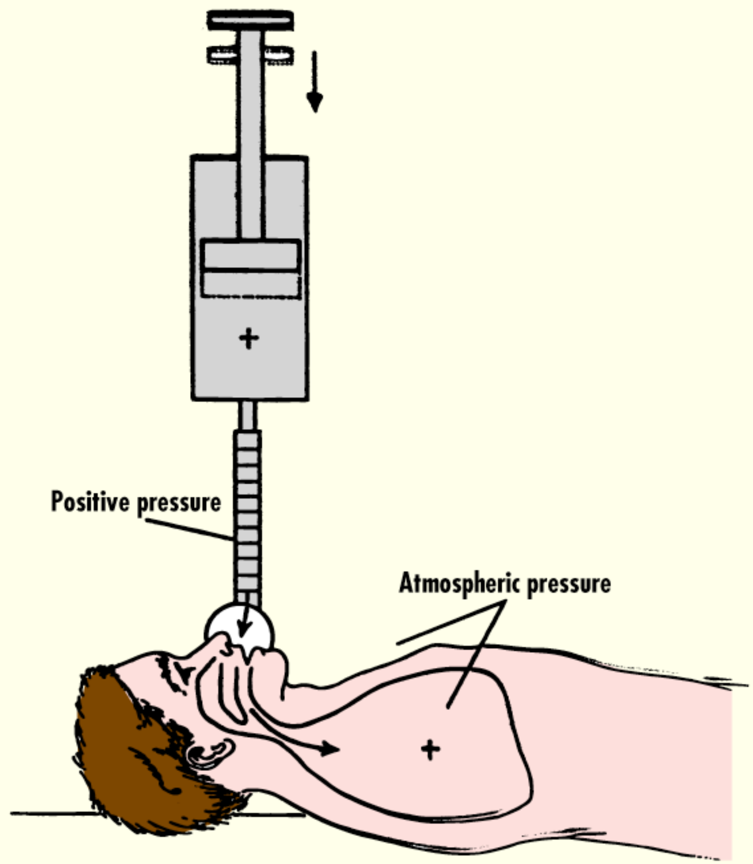

FIGURE 8-2 Application of positive pressure at the airway provides a pressure gradient and therefore gas flows into the lungs.

Positive Pressure Ventilation

Volume-Targeted Ventilation

- Preset volume is delivered to patient.
- Inspiration ends once volume is delivered.
- Volume constant, pressure variable.
- Ensures proper amount of air is delivered to lungs regardless of lung condition
- May generate undesirable(high) airway pressures.

Positive Pressure Ventilation

Pressure-Targeted Ventilation

- Preset inspiratory pressure is delivered to patient.
- Pressure constant, volume variable.
- Clinician determines ventilating pressures.
- Volumes may increase or decrease in response to changing lung conditions.

(TRIGGERING) Starting Inspiration

1. Manual Trigger
2. Patient (Flow/Pressure)Trigger -(assist)
3. Time-Trigger- (control)
4. Patient/Time-Trigger (assist/control)

(CYCLING) Ending Expiration

1. Pressure
2. Volume
3. Time
4. Flow
5. Manual

Ventilator Parameters

Settings

Volume-Targeted Ventilation

Tidal Volume

- **Definition:** How much air movement is needed to adequately remove CO_2 from the blood.
- **Setting:** Usually 8-10mL/kg or adjusted as indicated by arterial CO_2 levels.

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Respiratory Rate

- **Definition:** The frequency that the tidal volume must be delivered to adequately remove CO_2.
- **Setting:** Usually 12-14/min may be increased or decreased as indicated by arterial CO_2 levels.

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Peak Inspiratory Pressure

- **Definition:** Reflects airway resistance and lung compliance (work required to move air through the airways and into the alveoli).

  Elevated with either increased resistance (tracheal tube, ventilator circuitry) or decreased compliance.

Inspiratory Time

- **Definition:** Part of the ventilatory cycle necessary for inspiration
- **Setting:** Maintain an I:E of 1:2 or greater (1:3, 1:4, etc.)

Pressure-Targeted Ventilation

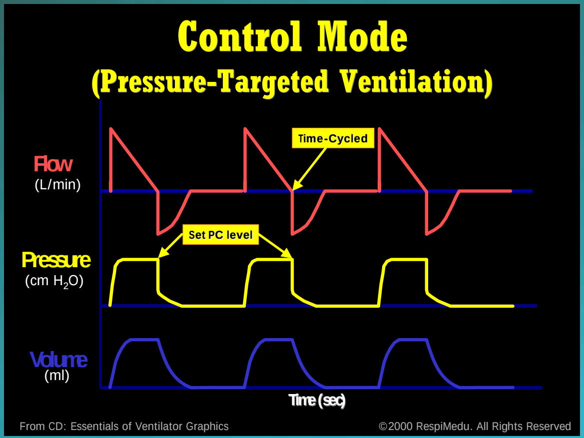
Peak Inspiratory Pressure

- **Definition:** Reflects airway resistance and/or lung compliance.
- **Setting:** Set to allow the delivery of an adequate tidal volume.

Modes of Ventilation

Control

- Indicated when patient cannot initiate inspiration.
- Inspiration is initiated by timing device.
- Machine controlled breath.



Click on the graphic to see details

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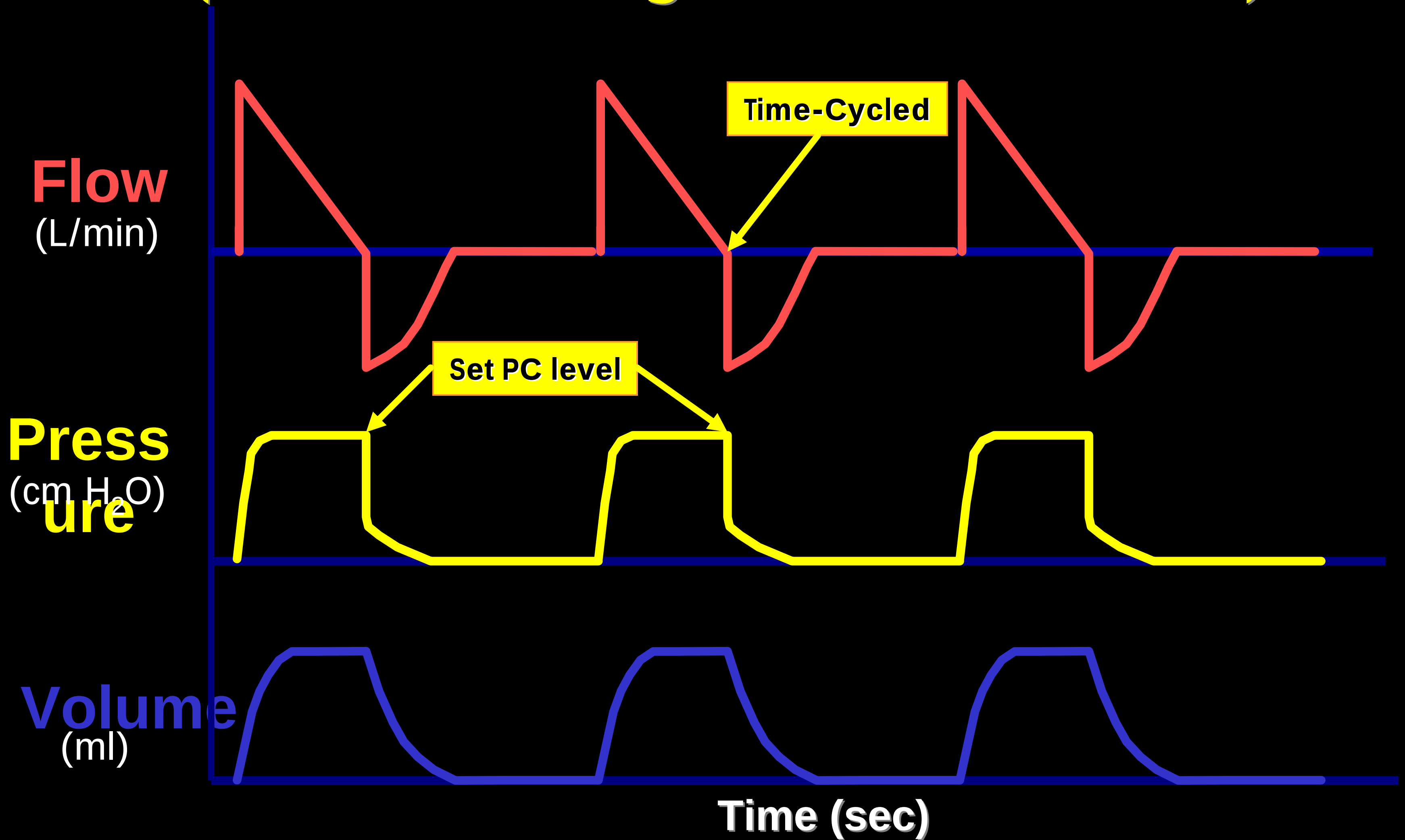
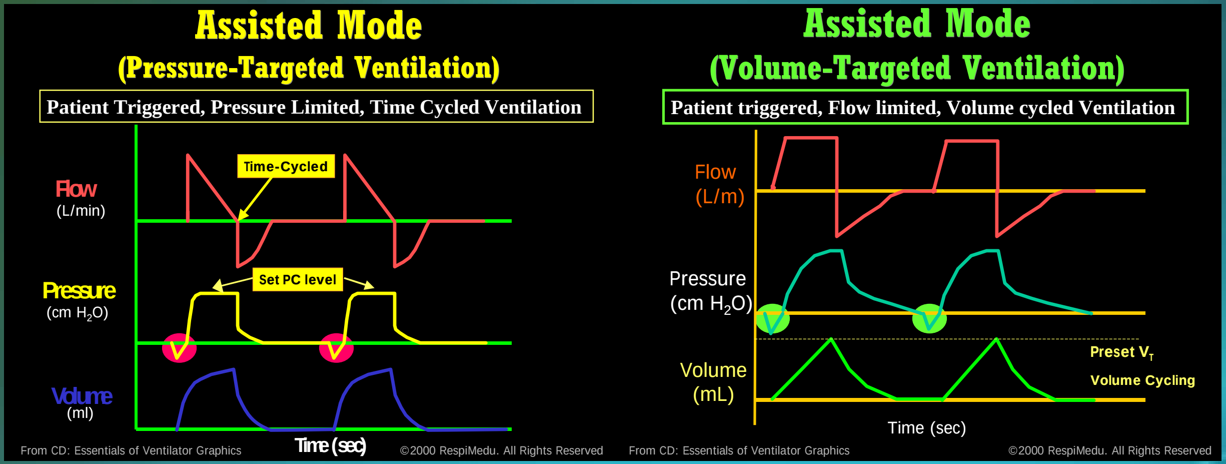
Control Mode

(Pressure-Targeted Ventilation)



Assist-Control

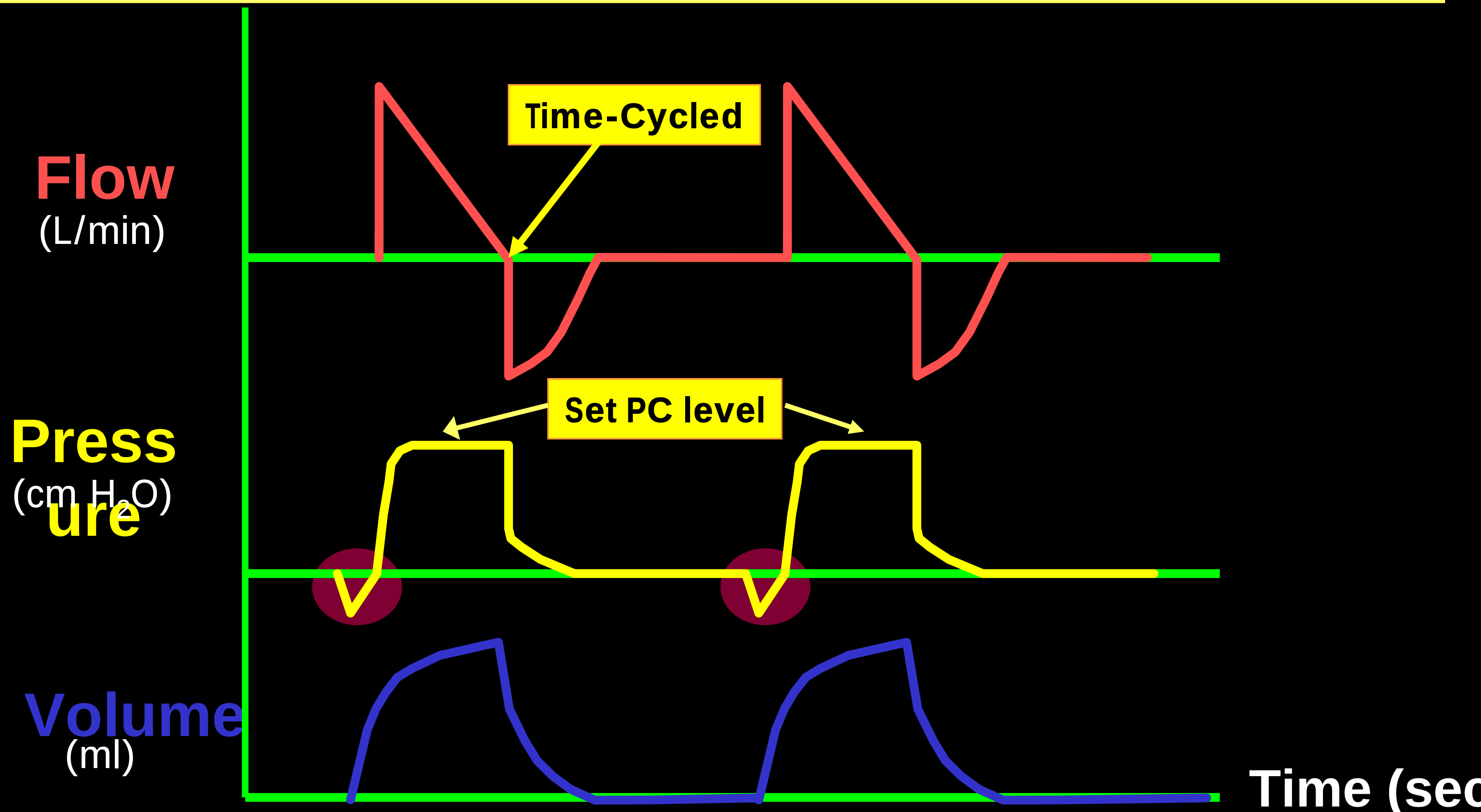
- Breath initiated by patient unless rate falls below selected respiratory rate.
- Each breath's pressure or volume is preset.



Click on the graphics to see details

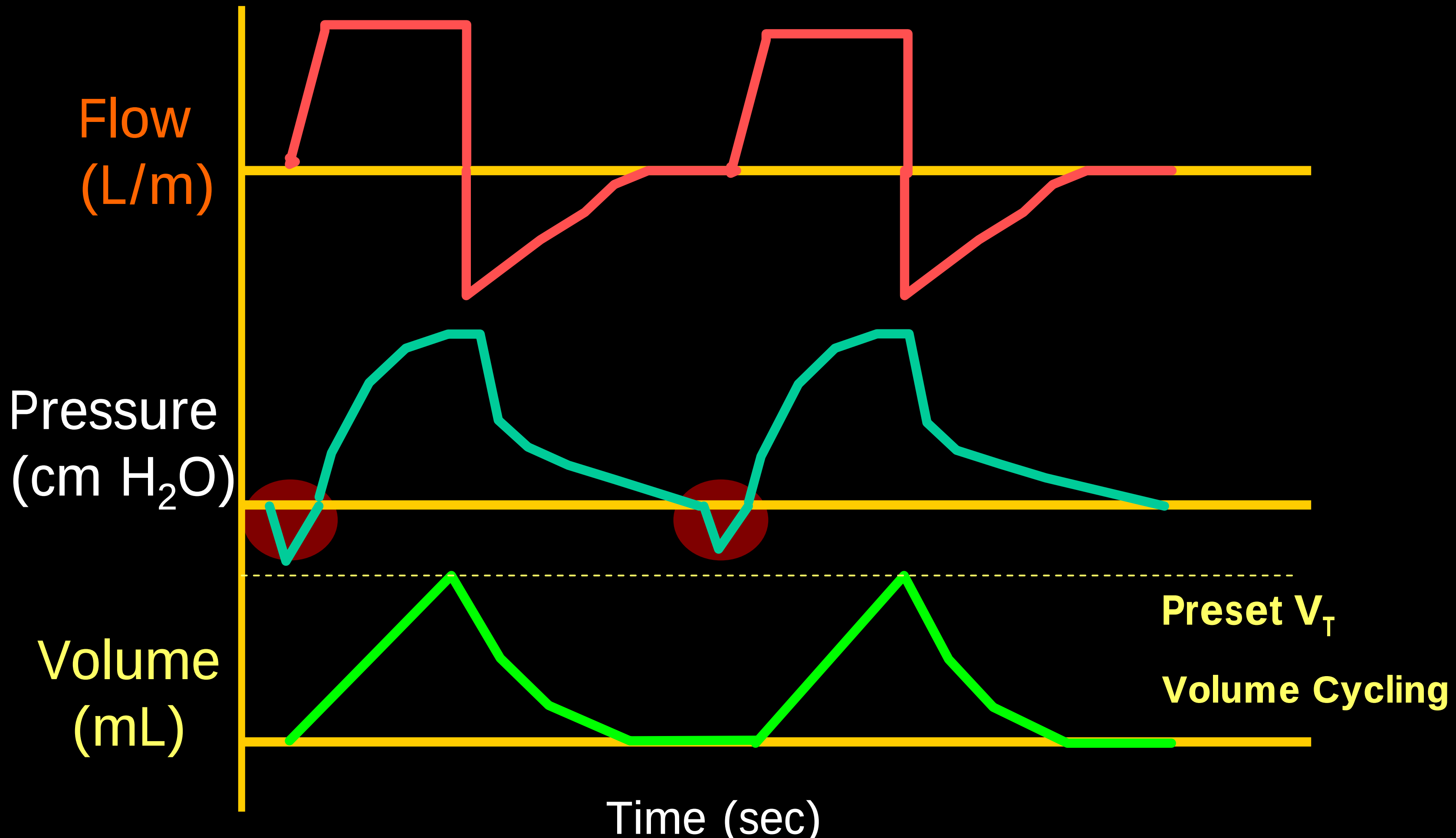
Assist-Control Mode
(Pressure-Targeted Ventilation)

Patient Triggered, Pressure Limited, Time Cycled Ventilation



Assist-Control Mode
(Volume-Targeted Ventilation)

Patient triggered, Flow limited, Volume cycled Ventilation



Flow-Trak™

VCV made easy!

What Is Flow-Trak

- It's an enhancement to standard VCV
- Doesn't punish the patient if Peak Flow setting is inappropriately low
- If the peak flow or tidal volume does not meet the patient's demand, Flow-Trak will give additional flow to satisfy patient need

Flow-Trak

Features	Benefits
It's always on No additional settings	Easy to use
Allows unrestricted access to flow/volume within a VCV breath without increasing driving pressure	Enhances patient-to-ventilator synchrony
Maintains the same expiratory time	Reduces the likelihood of breath-stacking and Auto-PEEP

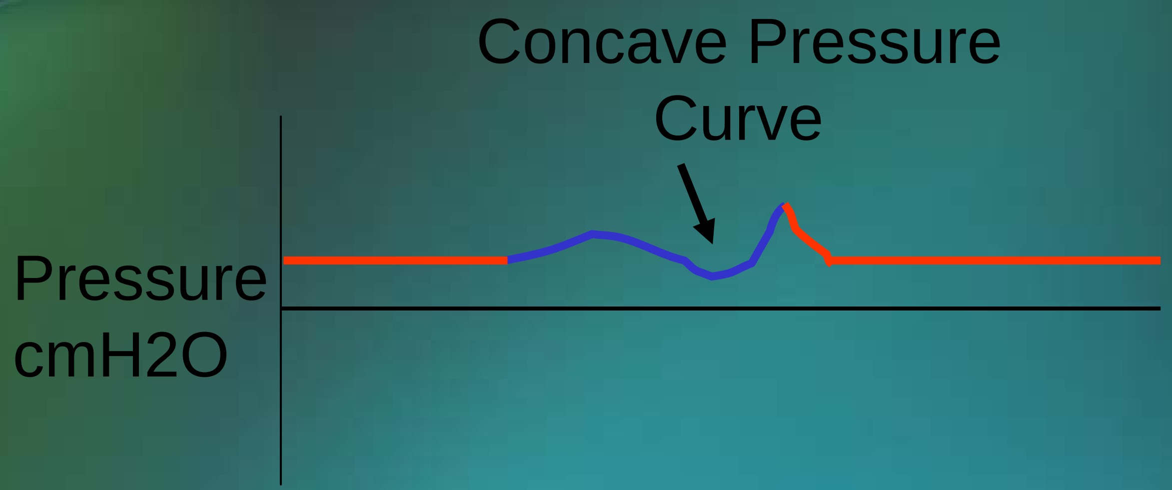
Flow-Trak

Features	Benefits
High Ve alarm	Alerts clinician to consistent increased ventilatory demands
Switches back to VCV if initial flow demand decreases before set Vt is delivered	Ensures the preset Vt is always delivered
Patient controls insp time on Flow-Trak breaths	Patient-to ventilator synchrony

Flow-Trak – Simple Version

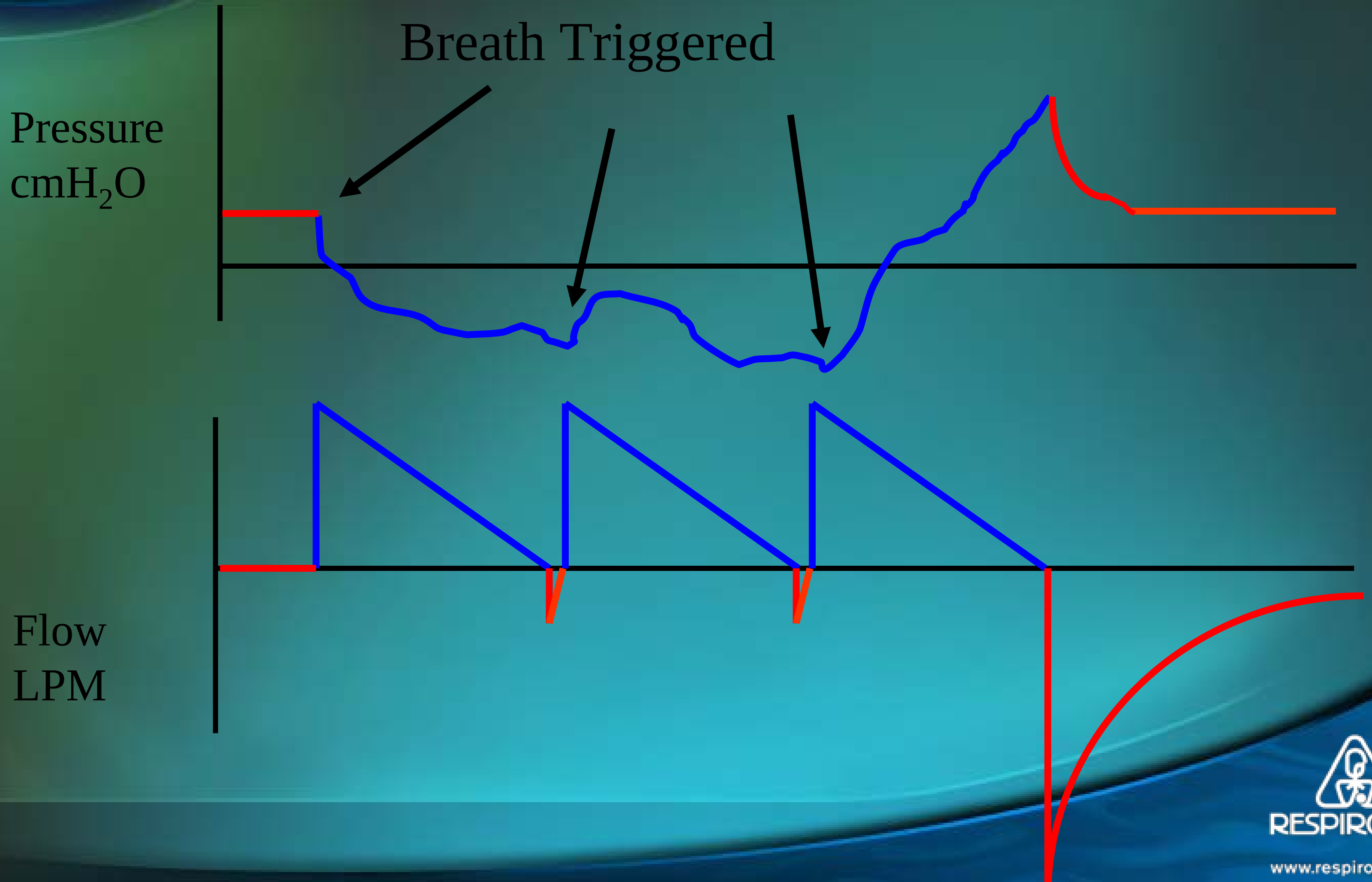
- Inspiration
  - Starts off as standard VCV breath either with square or decelerating flow pattern
  - If circuit pressure drops to PEEP minus 2cm H_20 (patient outdraws set flow), Flow-Trak is initiated.
- Once Flow-Trak is triggered it will pressure control to a target of 2 cmH_2O above baseline.

Without FlowTrak

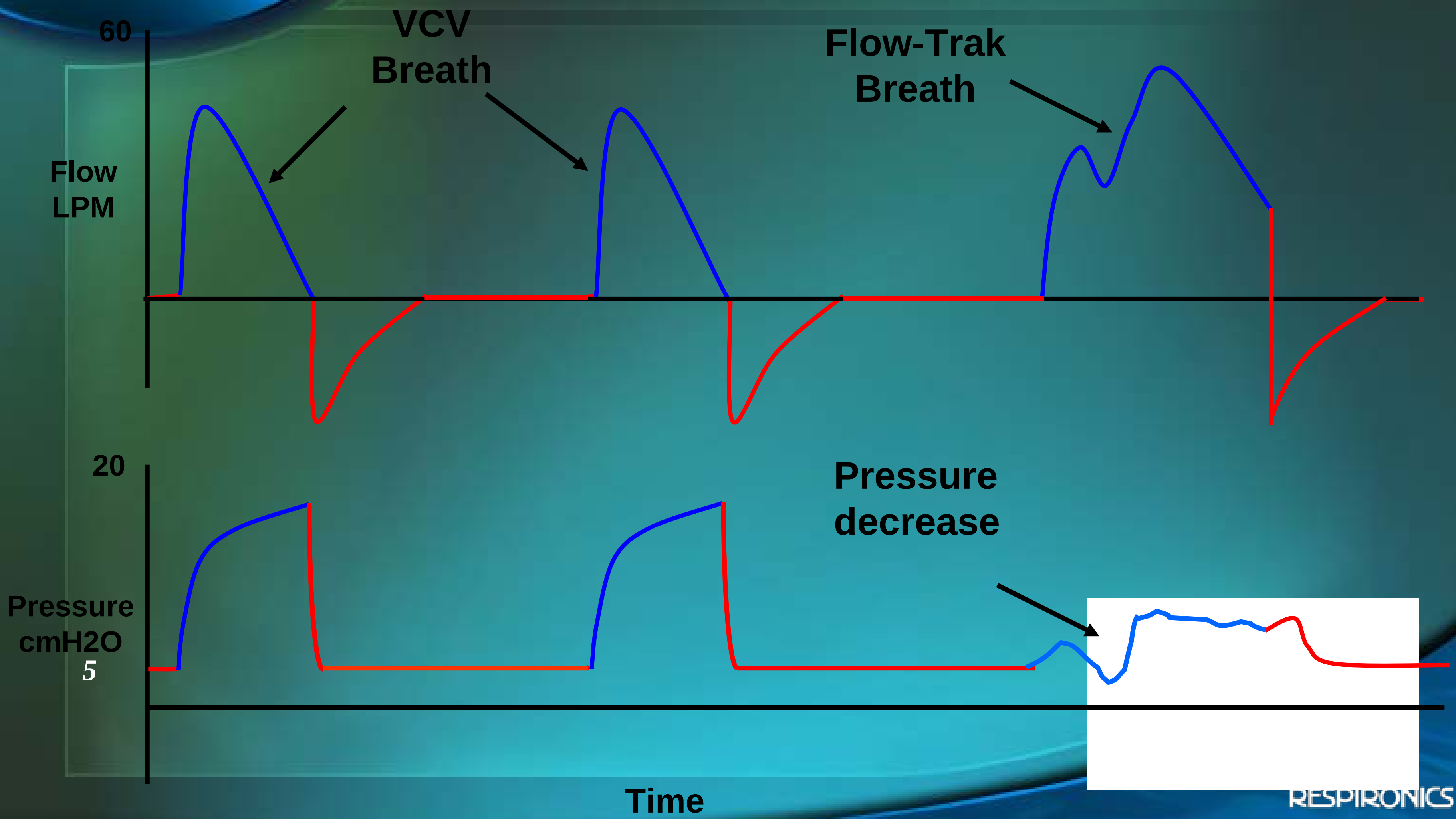


Profound Patient-to-ventilator dysynchrony ensues

Without FlowTrak



Flow-Trak



60
VCV Breath
Flow-Trak Breath
Flow LPM
20
Pressure decrease
Pressure cmH2O
5
Time

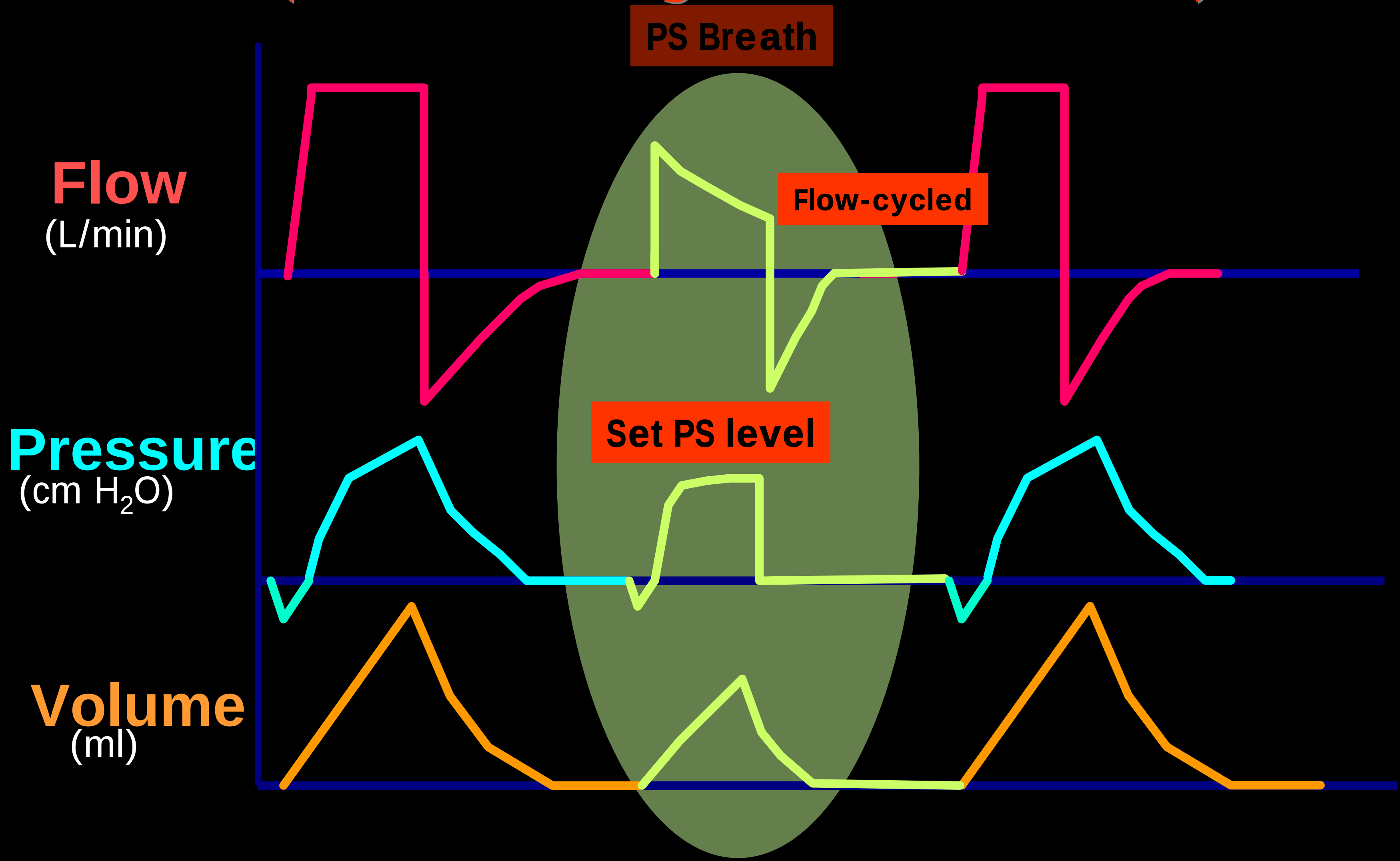
Intermittent Mandatory Ventilation (IMV)

- Machine delivers a set number of machine breaths, patient can breathe spontaneously between machine breaths.

Synchronized Intermittent Mandatory Ventilation (IMV)

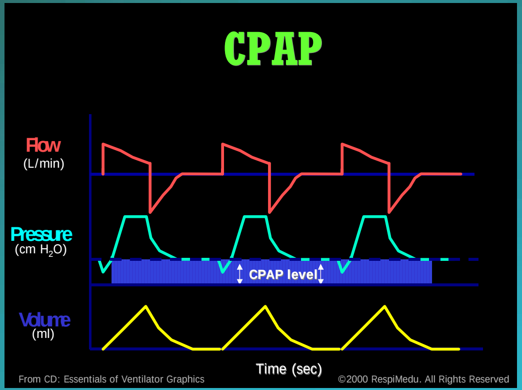
•Patient-initiated breath.
•Prevents breath stacking.

SIMV+PS
(Volume-Targeted Ventilation)



Continuous Positive Airway Pressure (CPAP)

- Preset pressure is maintained in the airway.
- Patient must breathe spontaneously - no mechanical breaths delivered.
- "breathing at an elevated baseline"
- Increases lung volumes, improves oxygenation.



Click on the graphic to see details

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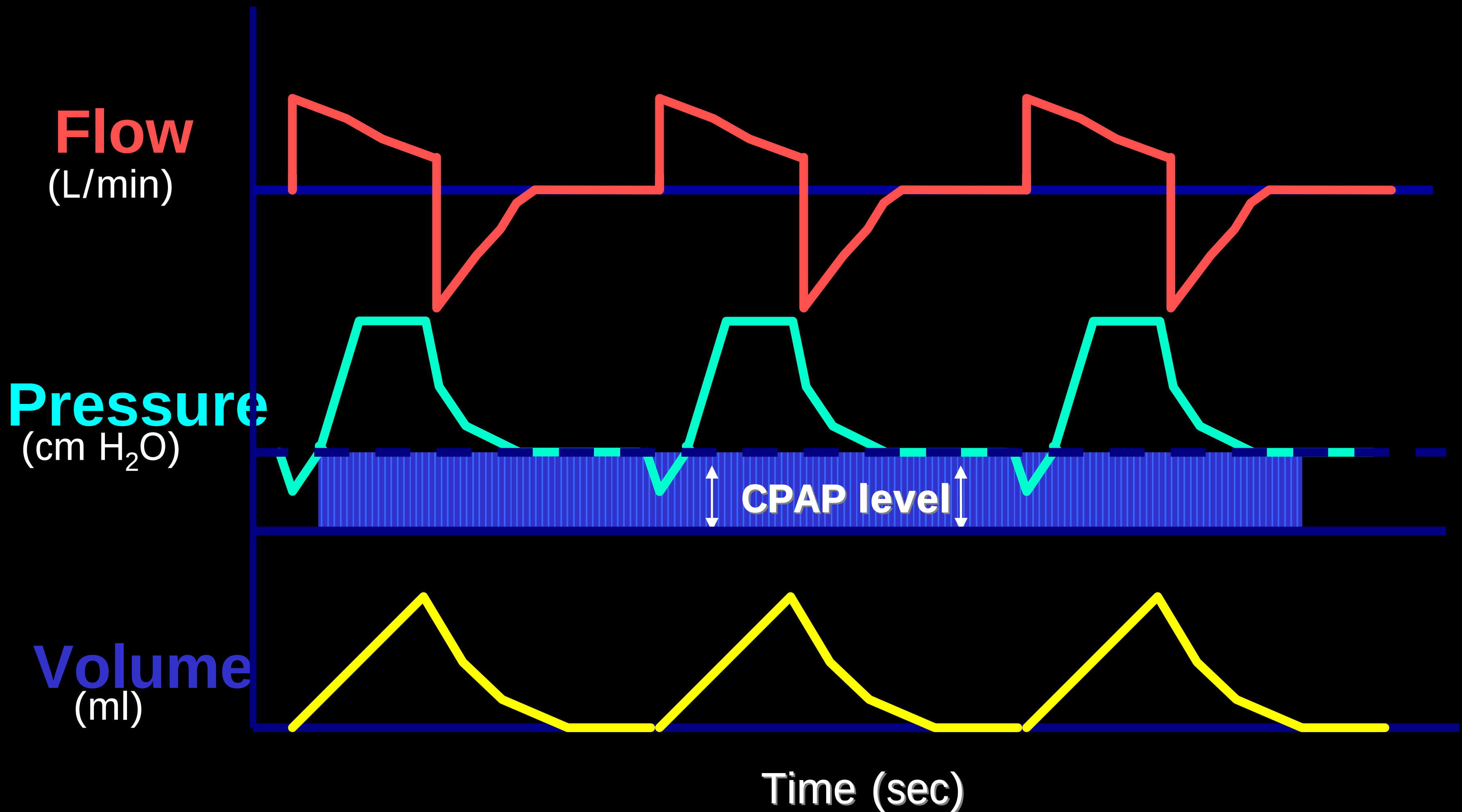
CPAP

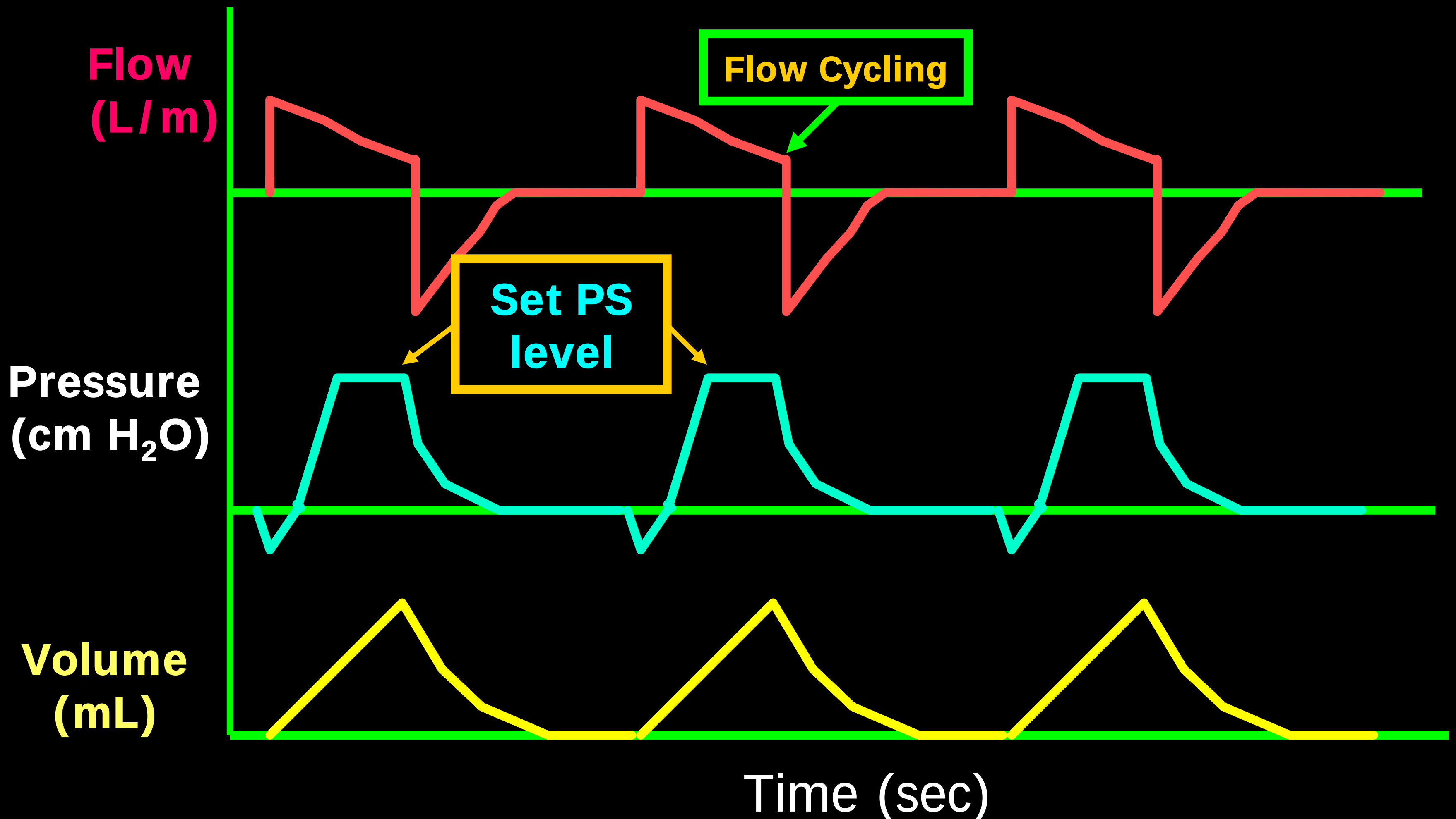


Pressure Support Ventilation (PSV)

- Patient-triggered, pressure-limited, flow-cycled breath.
- Augments spontaneous ventilation.
- Commonly used as a weaning mode.
- Pressure plateaus at set pressure until inspiration ends (flow).

PSV

Patient Triggered, Flow Cycled, Pressure limited Mode

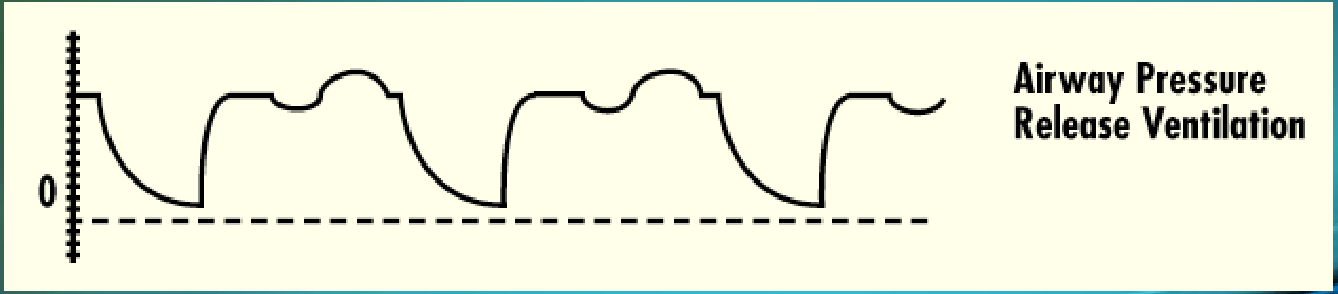


Pressure Control Ventilation

- Mechanical breath delivered at a preset peak inspiratory pressure.
- Can be used with inverse ratios.
- Mode of choice in management of patients with ARDS.

Airway Pressure Release Ventilation (APRV)

- Similar to CPAP, except at a predetermined time, system pressure will drop to a lower CPAP level or ambient pressure.
- Aids in CO_2 removal.
- Drop is short in duration.
- Allows patient to breathe spontaneously at two levels of CPAP.



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Bi-Level Positive Airway Pressure (BiPAP)

- Non-invasive ventilation.
- Set IPAP to obtain level of pressure support.
  - Improve ventilation.
- Set EPAP to obtain level of CPAP.
  - Improve oxygenation.

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High Frequency Ventilation

- Small tidal volumes < deadspace breaths at high rates.
- Different modalities:
  - High Frequency Jet Ventilation
  - High Frequency Flow Interruption
  - High Frequency Positive Pressure Ventilation
  - High Frequency Oscillatory Ventilation

Ventilator Controls

Ventilator Controls

1. **Mode**
2. **Tidal Volume (volume ventilator)**
   - -6-10 mL/Kg ideal body weight
   - -measured at ventilator outlet
3. **Respiratory Rate**
   - -normally 12-15 bpm
   - -alters E time, I:E ratio, CO_2

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Ventilator Controls

4. Flowrate

-normal setting is 40-60 Lpm

-alters inspiratory time

5. I: E ratio

-normal is 1: 2(adult); 1: 1 (infant)

-volume, flowrate, and rate control alter I:E ratio

6. FiO2

-Titrate to keep SpO_2 > 90%

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Ventilator Controls

7. Sensitivity

-normally -0.5 to -2 cmH20

8. Inflation hold

-used to improve oxygenation, calculate static compliance

9. PEEP

-used to increase FRC - improve oxygenation

10. Alarms

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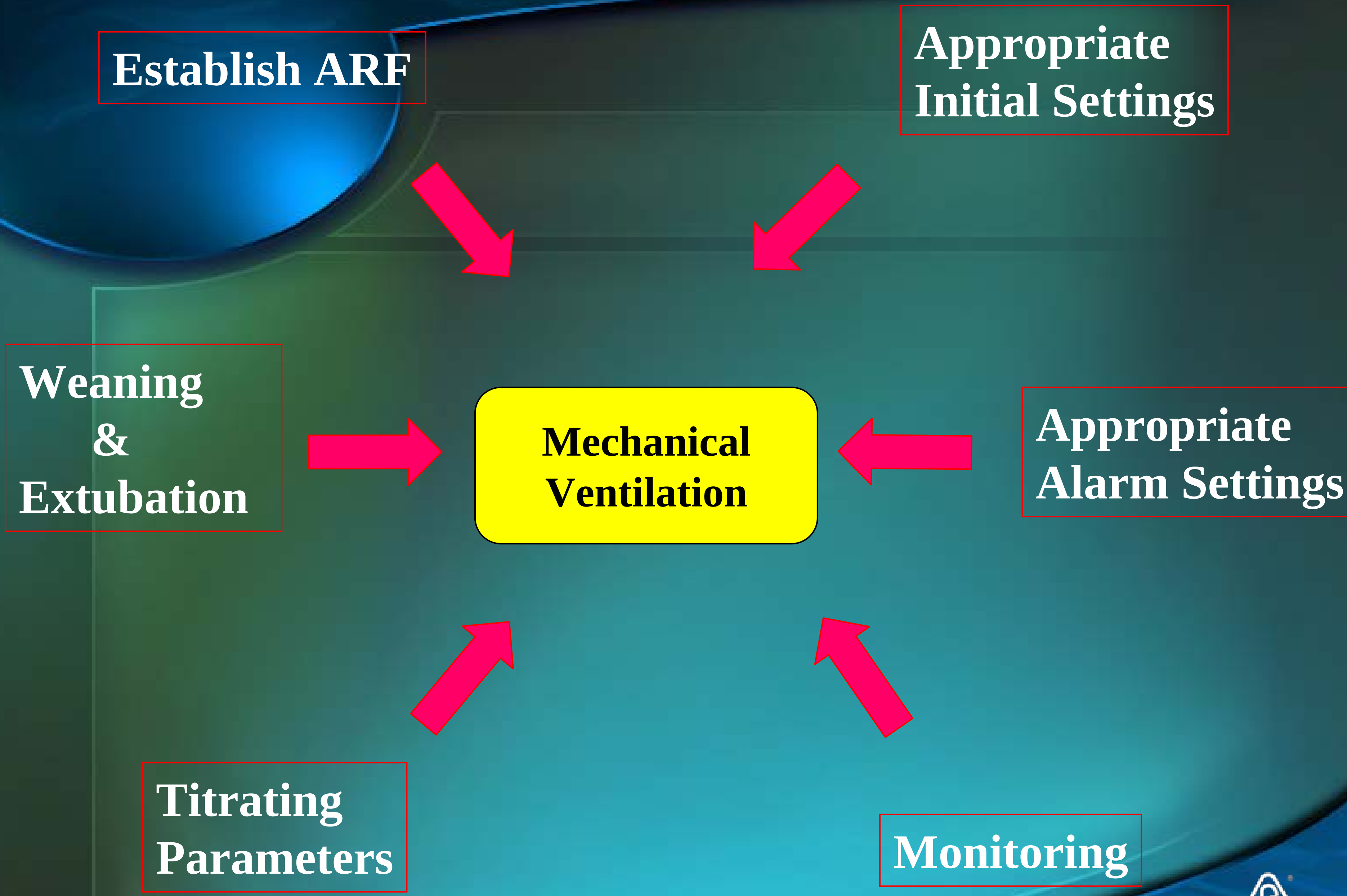
Ventilatory Management



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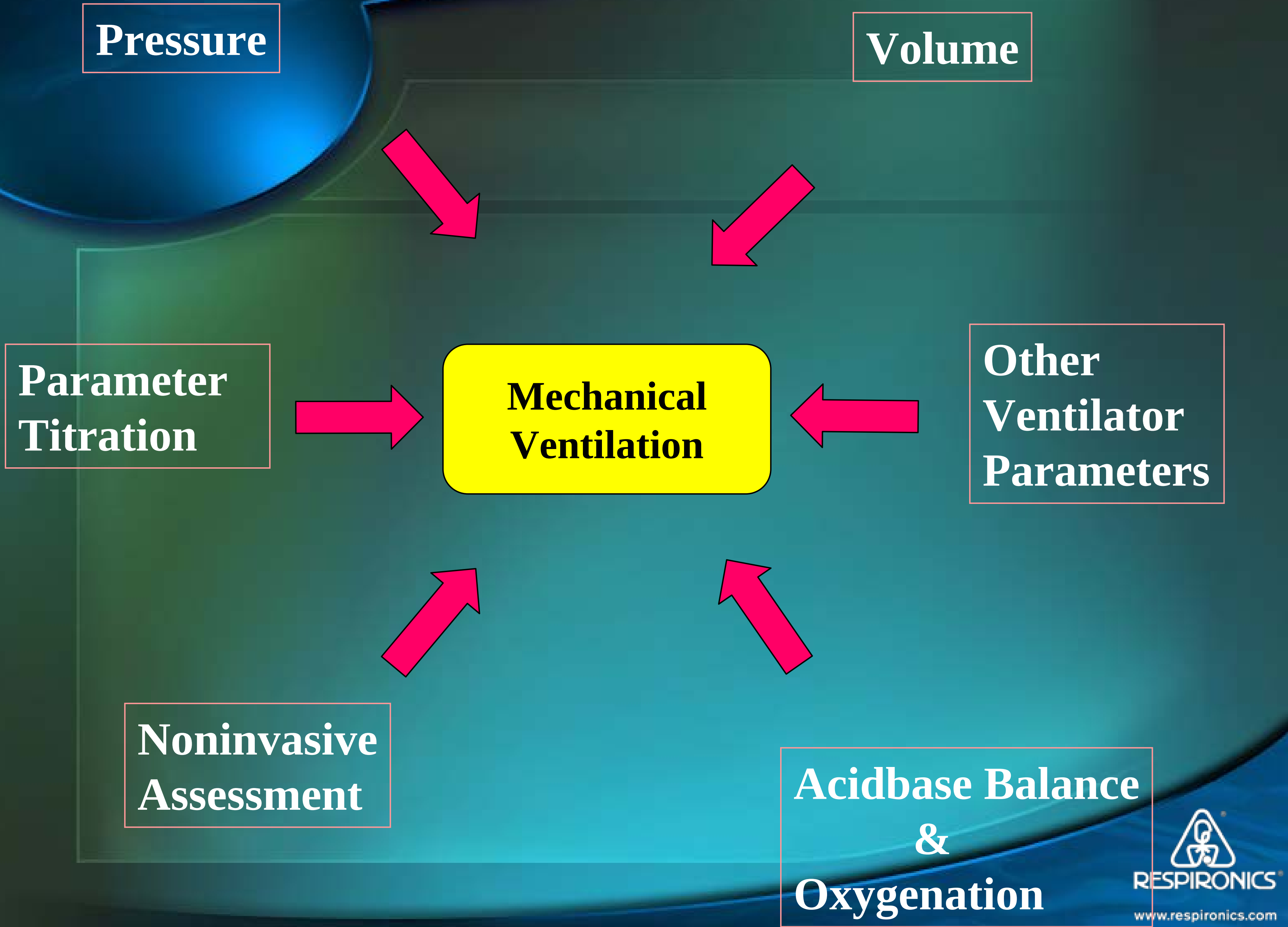
Pressure
Volume
Parameter Titration
Mechanical Ventilation
Other Ventilator Parameters
Noninvasive Assessment
Acidbase Balance & Oxygenation
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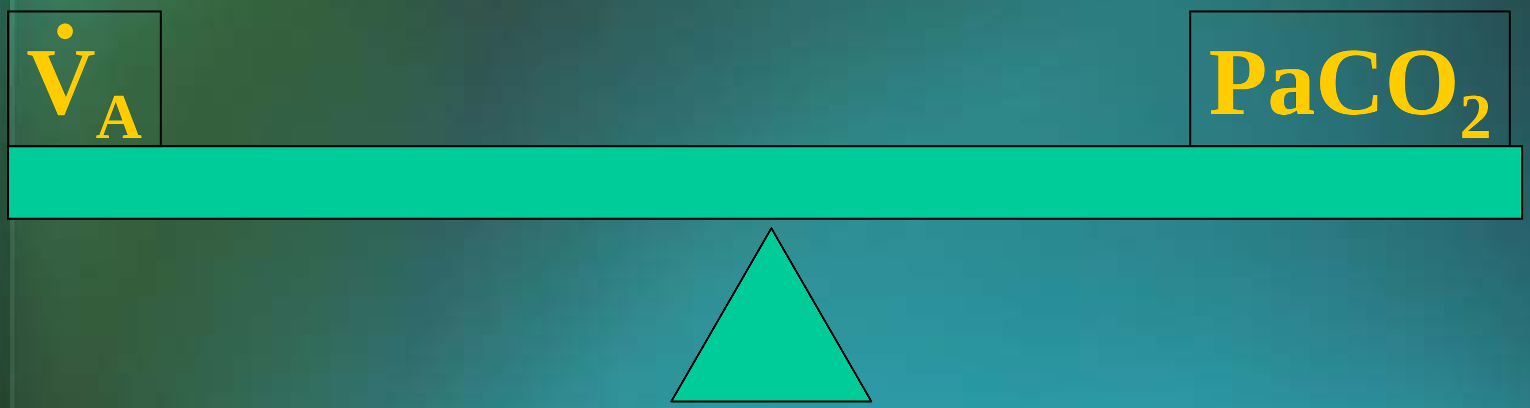
Modes of Ventilation

FULL SUPPORT	Control	Assist	Assist/control	
SPONTANEOUS	Spontaneous	CPAP	PSV	CPAP + PSV
PARTIAL SUPPORT	SIMV	SIMV + CPAP	SIMV + PSV	SIMV + PSV + CPAP

$\dot{V}_A$ and $PaCO_2$

Tidal Volume (V_T)
x
Frequency (f)

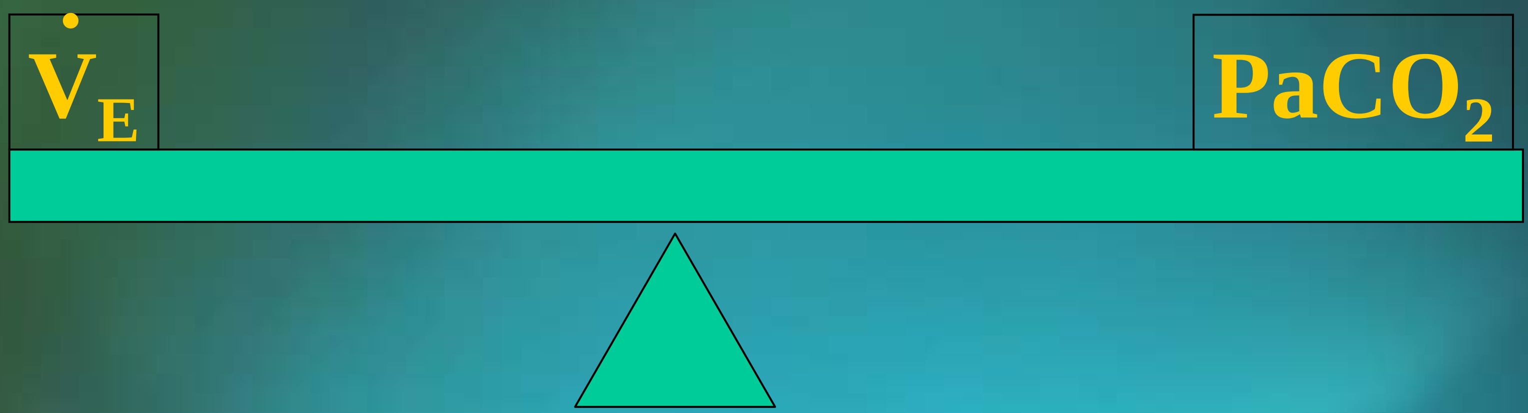


$$\dot{V}_A = \dot{V}_E - \dot{V}_D$$
$$= (V_T - V_D)\, f$$

Titration of Parameters

$\dot{V}E$ and $PaCO_2$

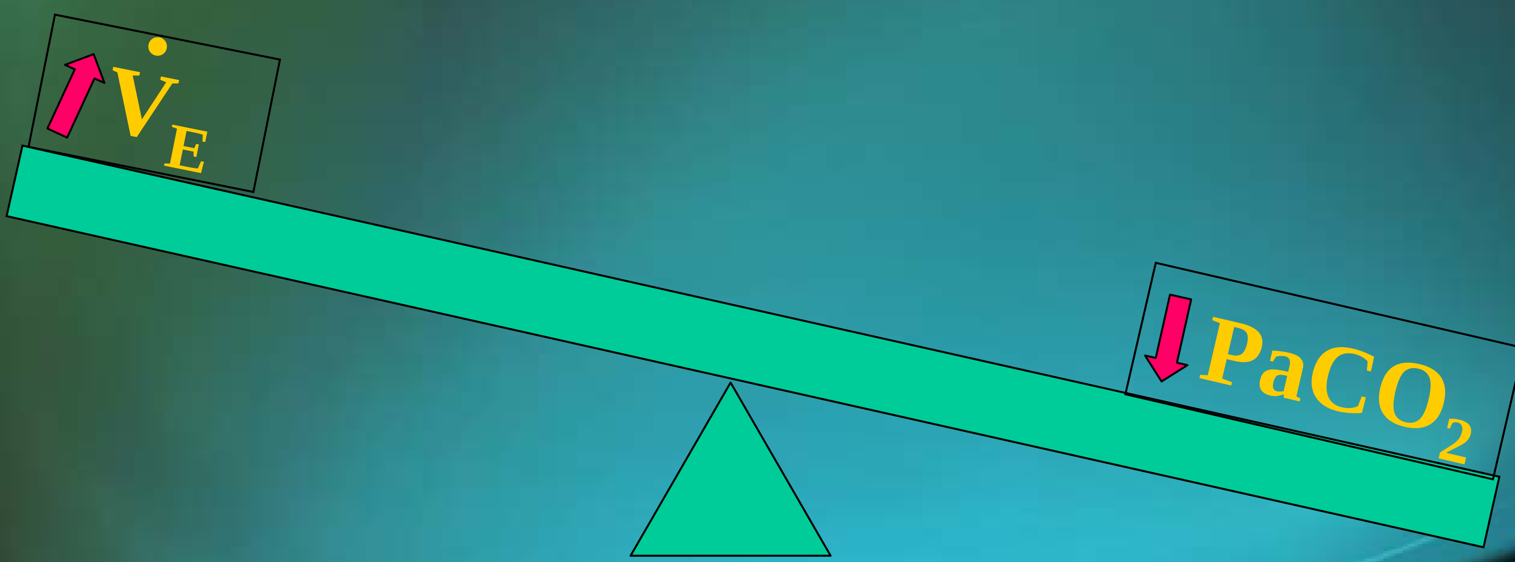
Tidal Volume (V_T)
x
Frequency (f)



Titration of Parameters

$\dot{V}E$ and $PaCO_2$

↑ Tidal Volume (V_T)
x
Frequency (f)



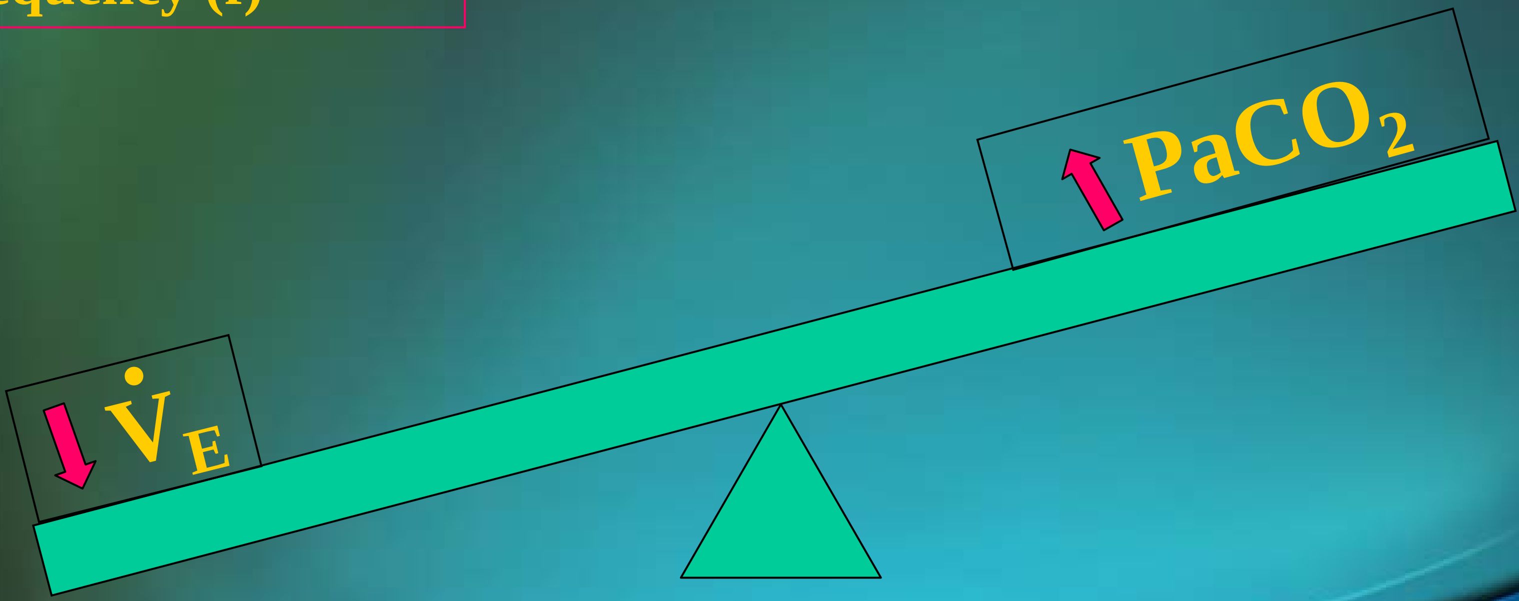
Titration of Parameters

$\dot{V}E$ and $PaCO_2$

↓ Tidal Volume (V_T)

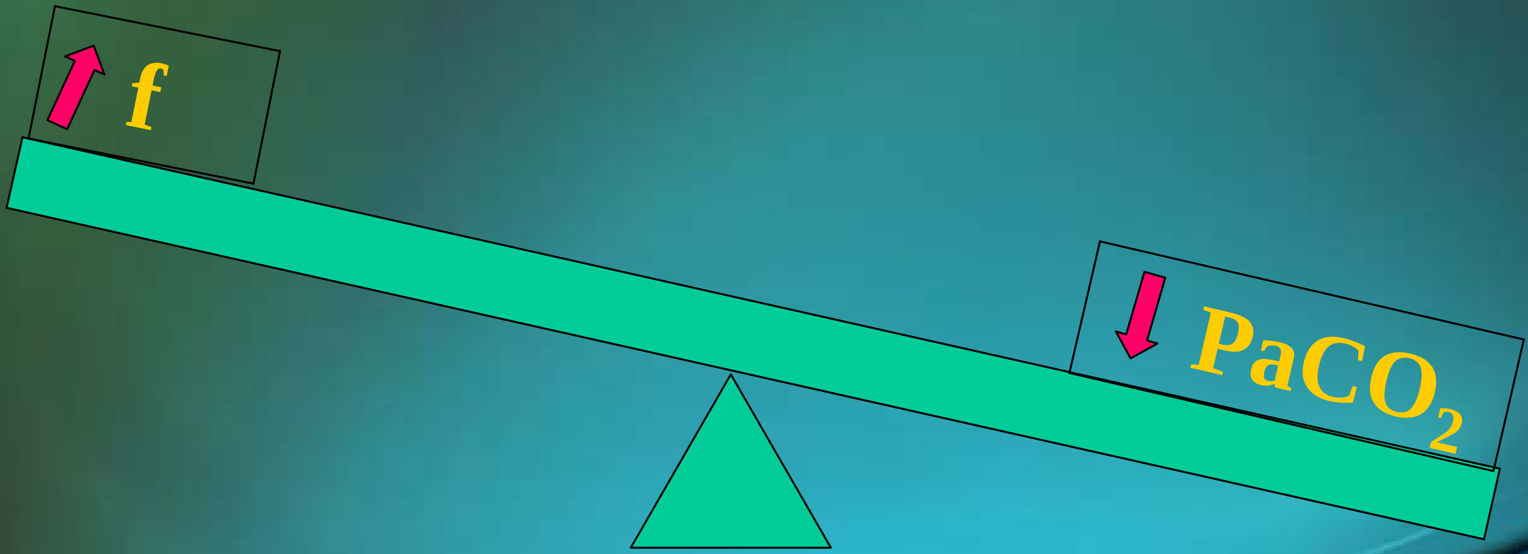
x

Frequency (f)



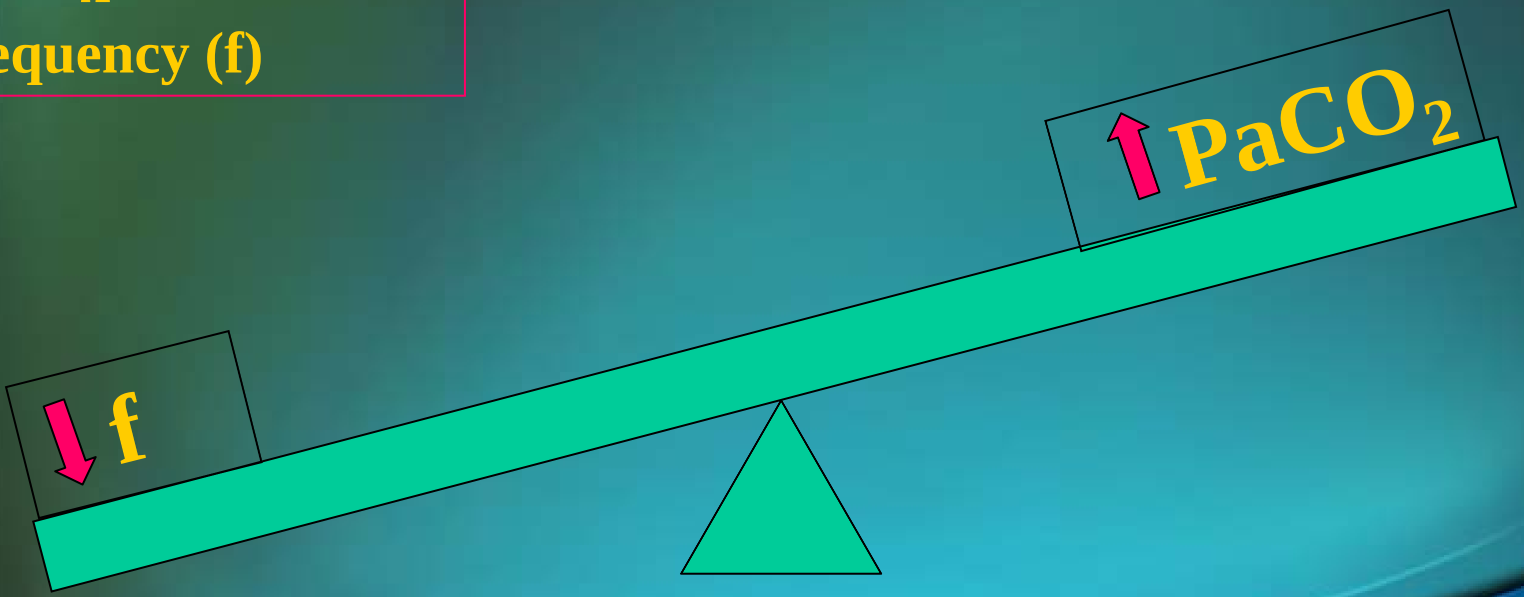
Titration of Parameters f and $PaCO_2$

↑ Tidal Volume (V_T)
x
Frequency (f)



Titration of Parameters
f and $PaCO_2$

Tidal Volume (V_T)
x
↓ Frequency (f)



Parameter Titration
PaO_2 and FiO_2

Increased FiO_2 increases PaO_2

FiO_2 ↑ ↓ PaO_2 ↑ ↓

Decreased FiO_2 decreases PaO_2

Capnography

- $EtCO_2$
- Capnogram
- Respiratory Rate

Volumetric CO_2

- CO_2 Elimination
- Deadspace
- Alveolar Ventilation
- Physiologic Vd/Vt

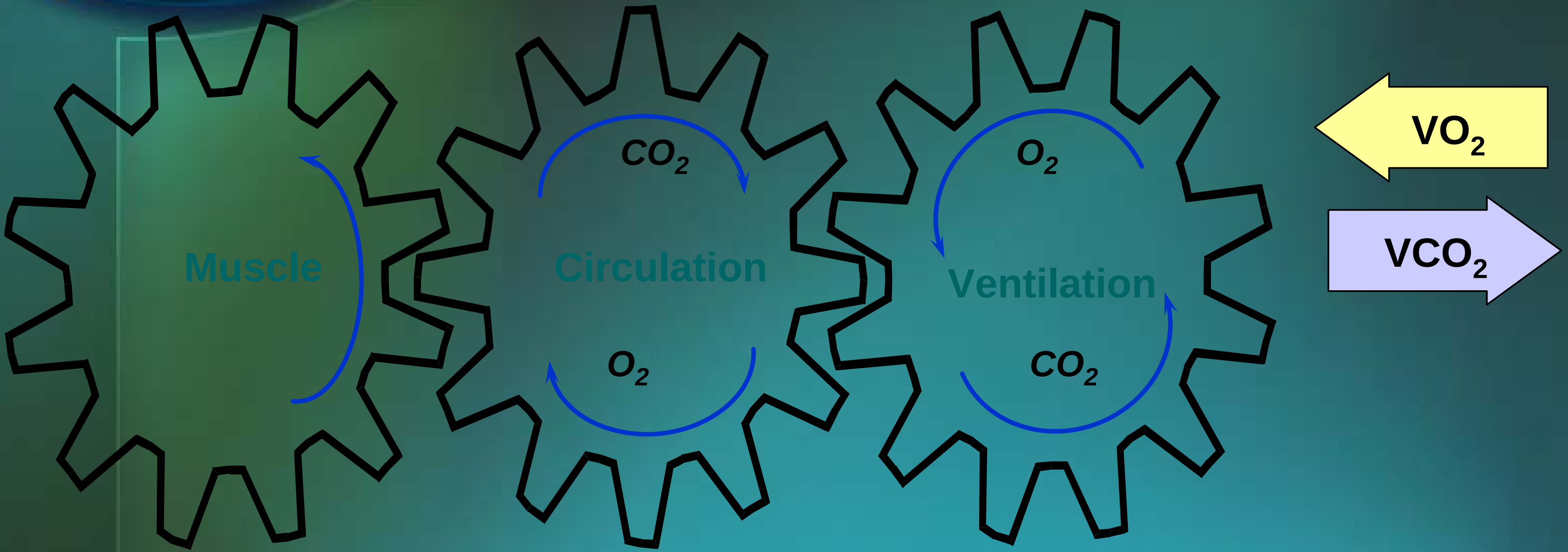
Integration of Flow & CO_2

The integration of CO_2 and Flow provides an easy method to obtain previously difficult to obtain parameters

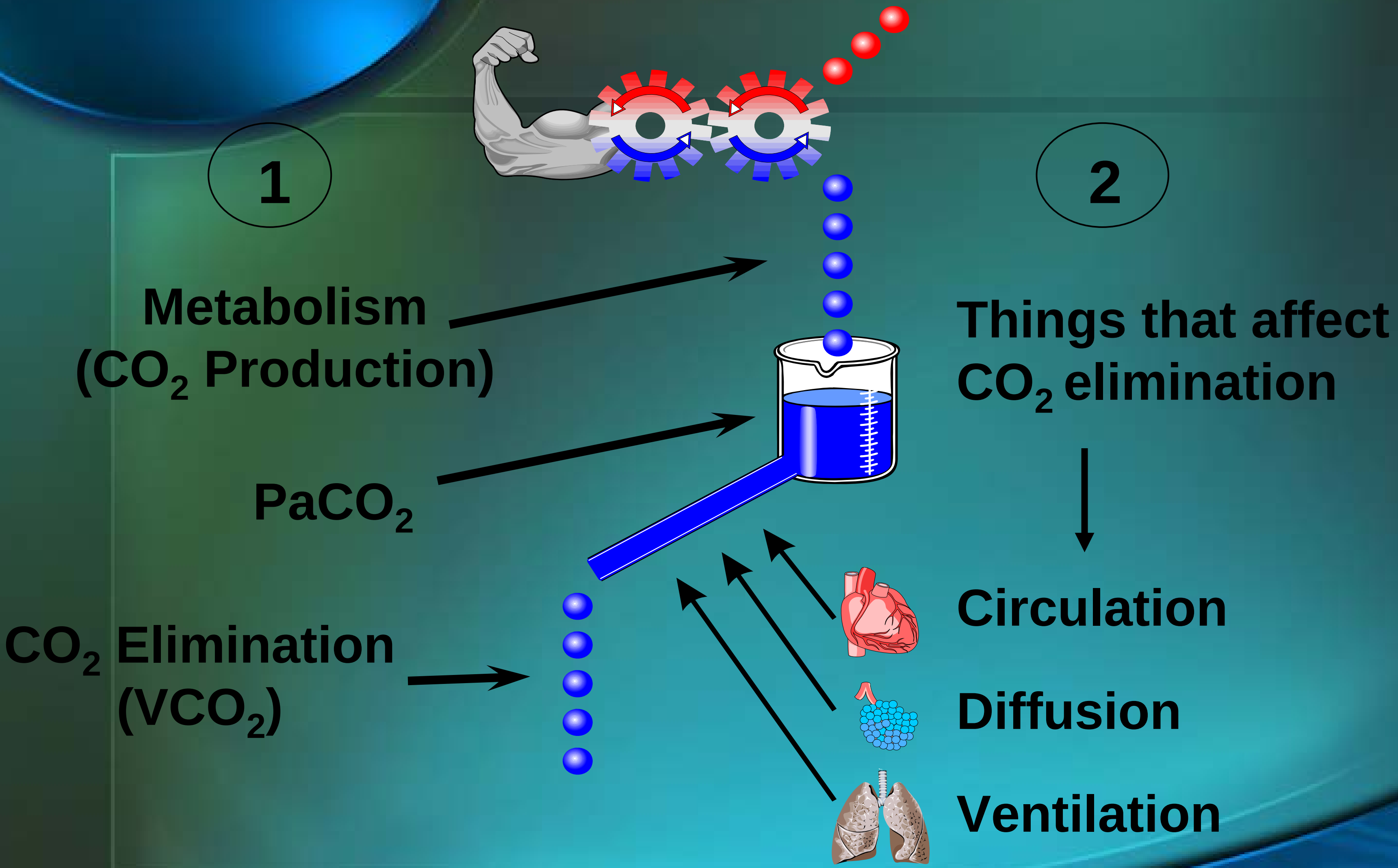
- $VCO_2 = CO_2$ Elimination
- Airway Deadspace, Physiologic V_D/V_T
- Alveolar Ventilation
- Cardiac Output

Capnography	Volumetric CO_2
• $EtCO_2$ • Capnogram • Respiratory Rate	• CO_2 Elimination • Airway Deadspace • Alveolar Ventilation • Physiologic Vd/Vt • Cardiac Output

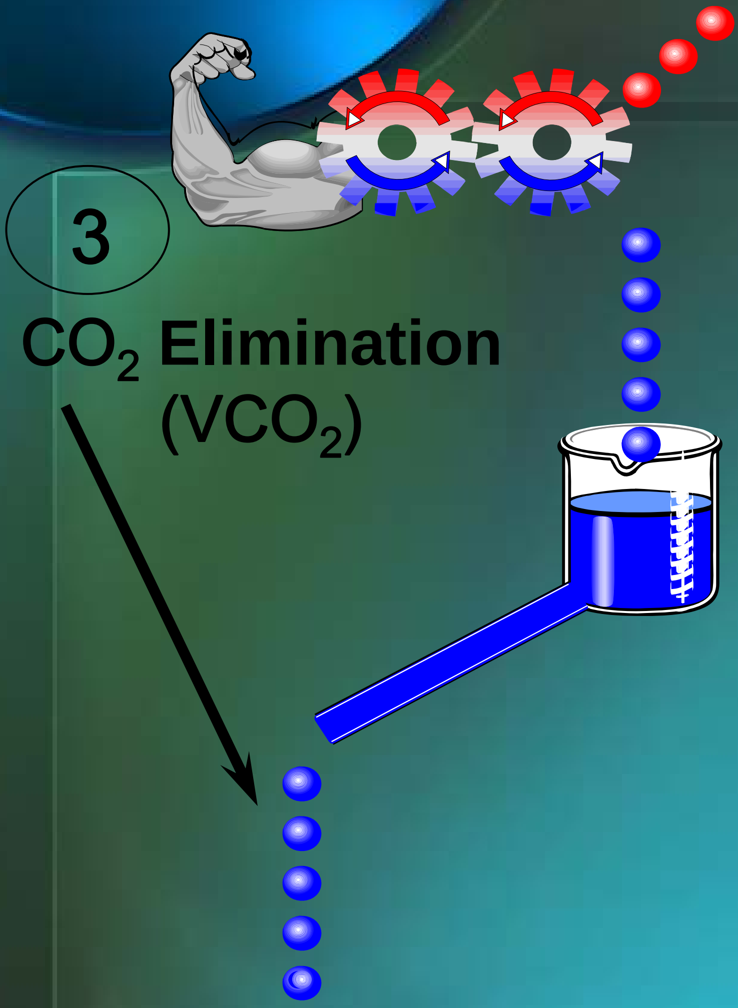
CO_2 Metabolism



VCO_2 - A Few Basics



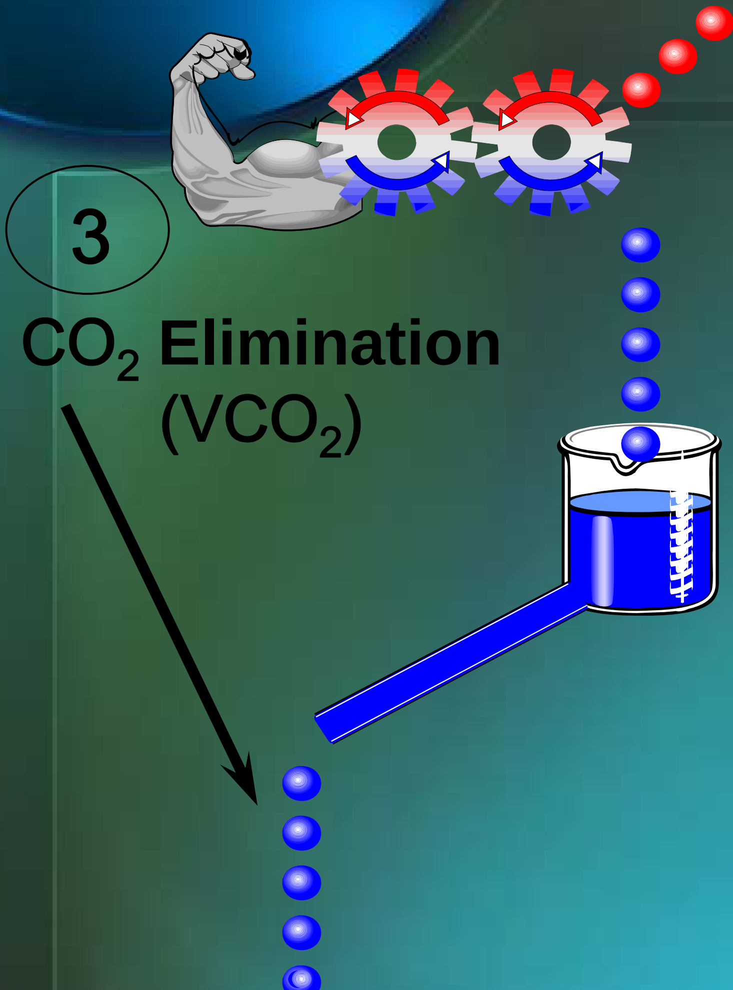
VCO_2 - A Few Basics



Why Measure VCO_2?

- Very Sensitive Indicator of PATIENT STATUS CHANGE
- Signals Future Changes in $PaCO_2$
- Defines When to Draw a Blood Gas ➔Reduces the # of ABGs

VCO_2 - A Few Basics



Why Measure VCO_2?

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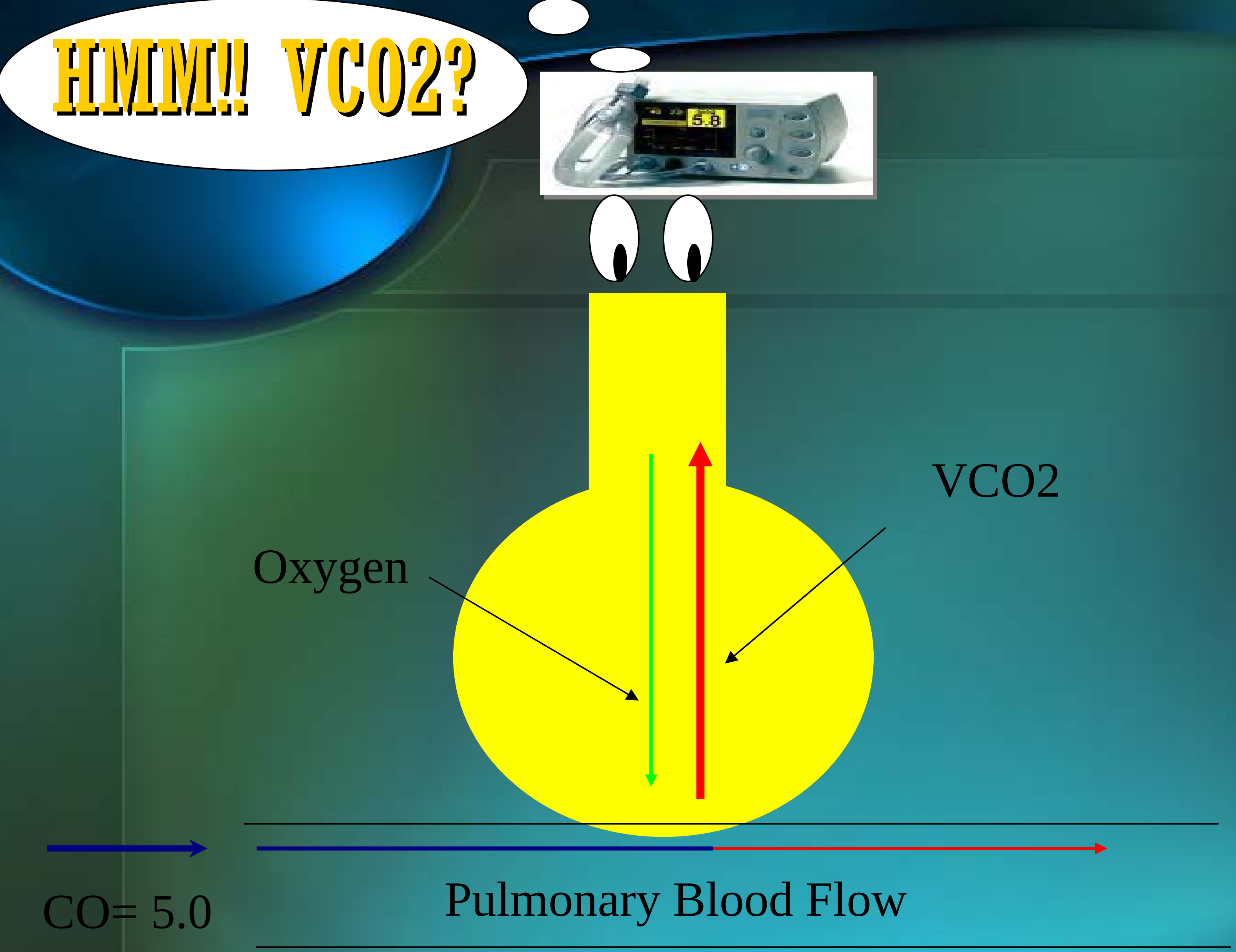

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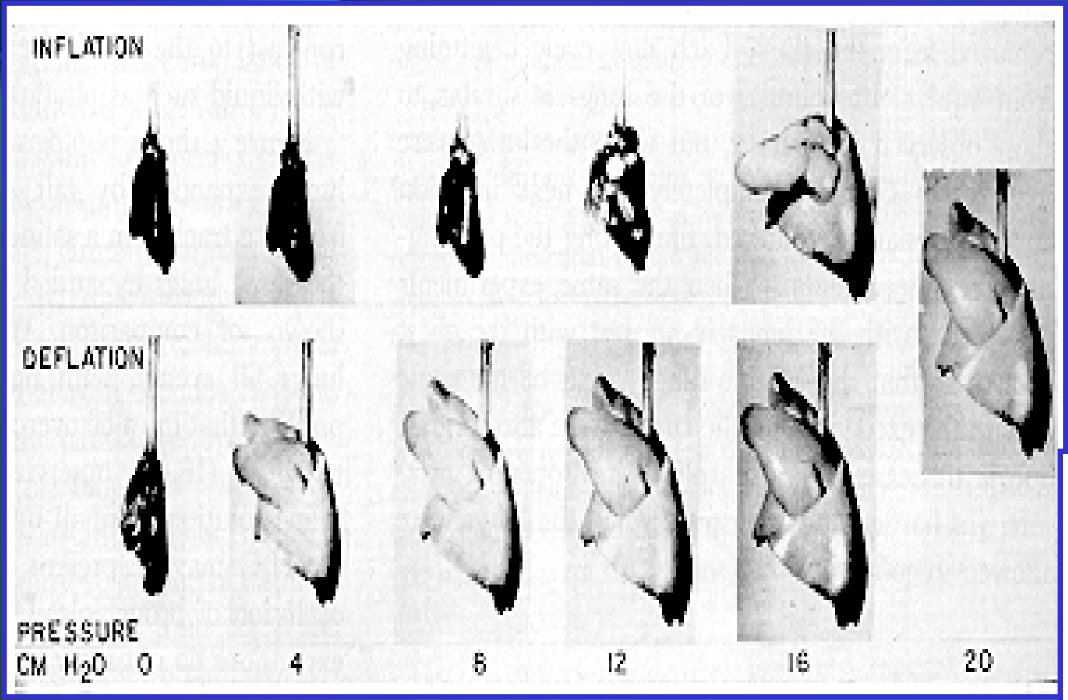
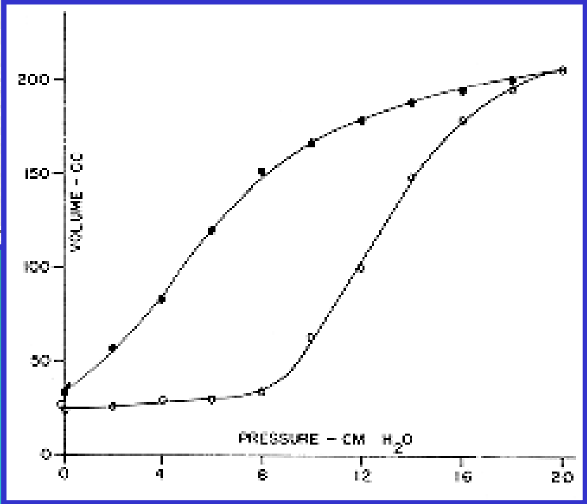
Open Lungs

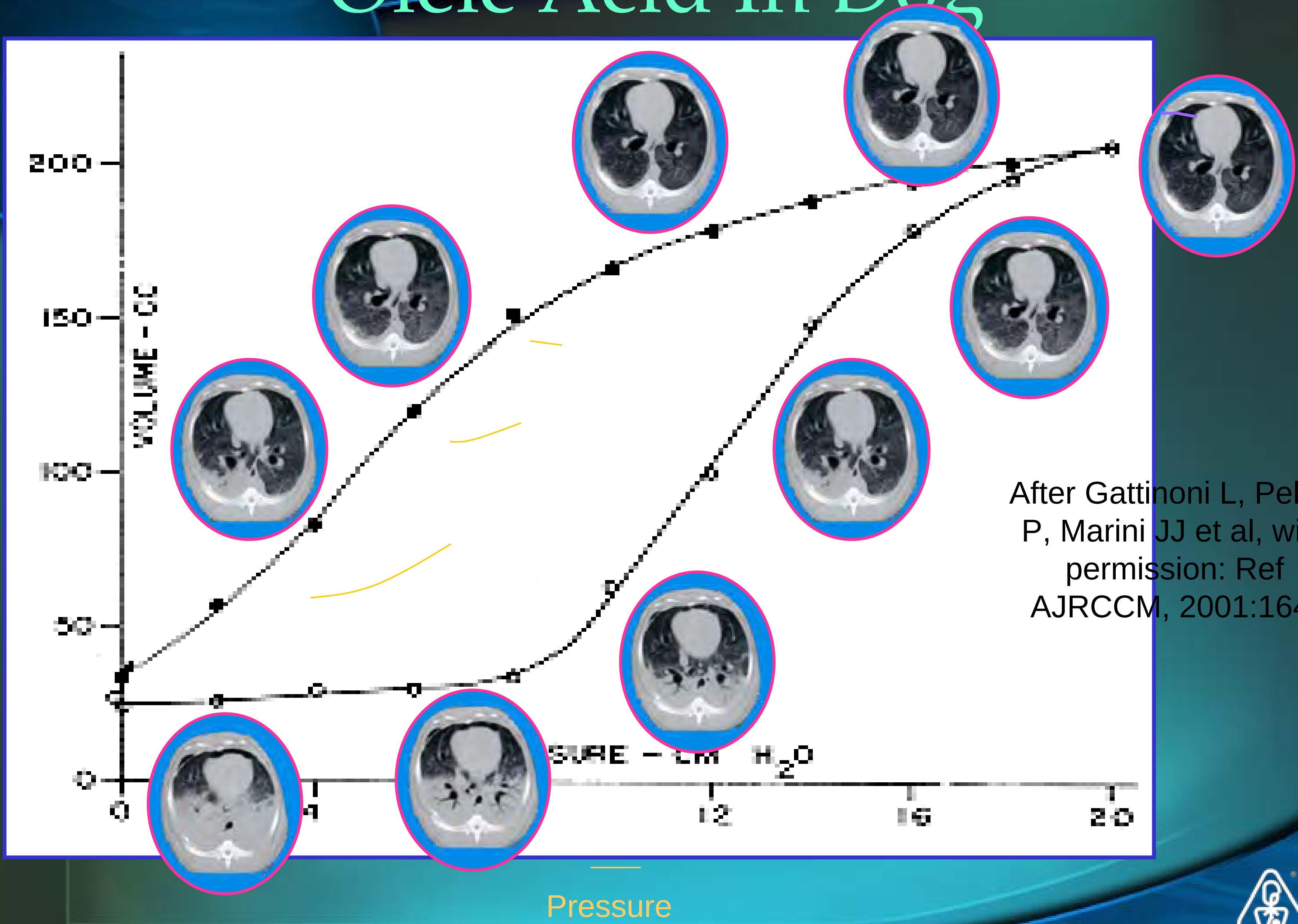


INFLATION
DEFLATION
PRESSURE
CM H2O 0
4
8
12
16
20



VOLUME - CC
200
150
100
50
0
PRESSURE - CM H2O
0
4
8
12
16
20

Oleic Acid In Dog



After Gattinoni L, Pelosi P, Marini JJ et al, with permission: Ref AJRCCM, 2001:164.

If Graphics are the Headlights on the Ventilator,

Then RUNNING NICO,

is Turning on the HIGH BEAMS!!!

Principles and Application of NPPV

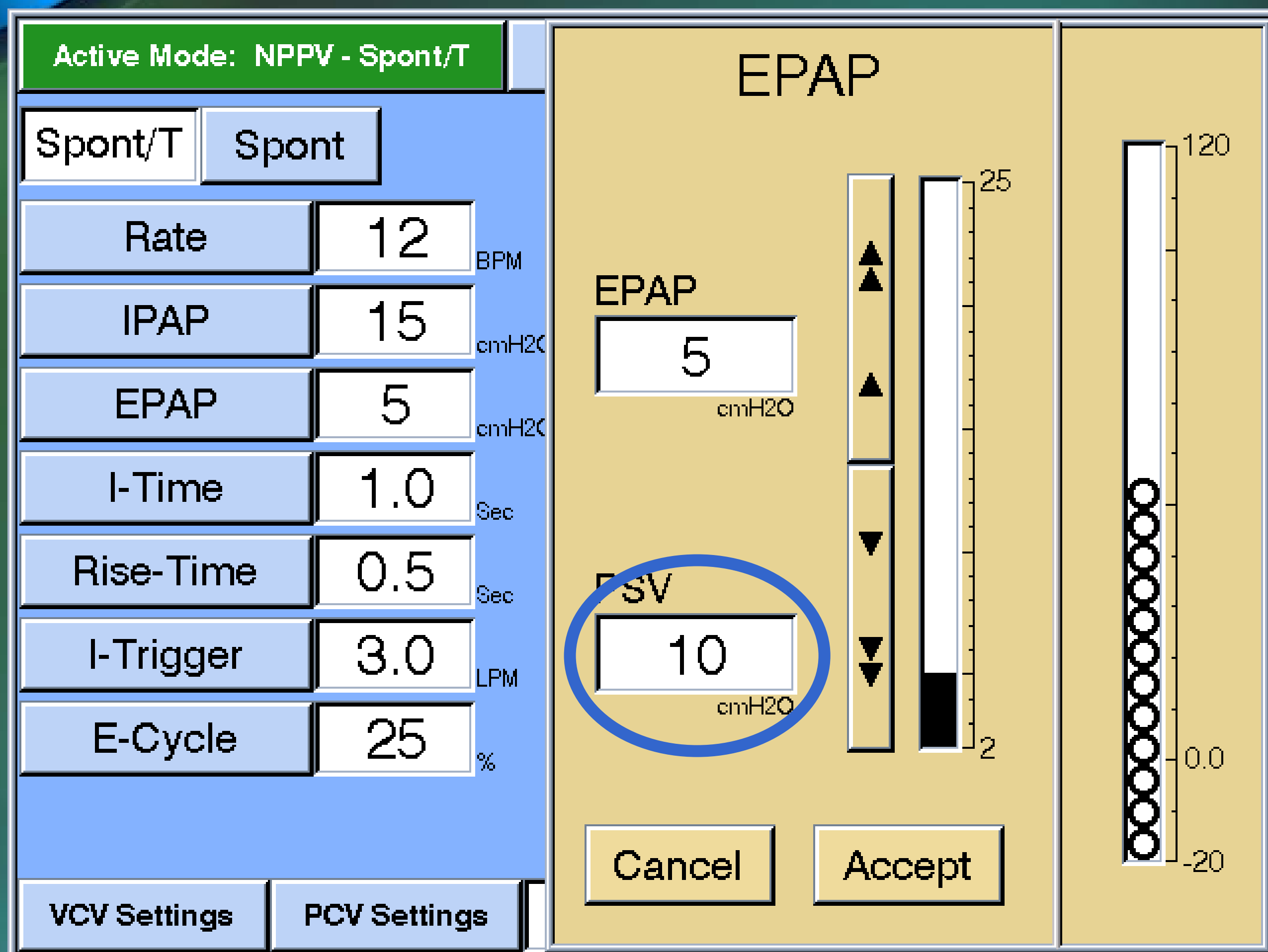
Performa Trak SE

For use with critical care ventilators with dual limb circuits and internal safety valves

Standard Elbow

Blue Packaging

Esprit Makes It Easy



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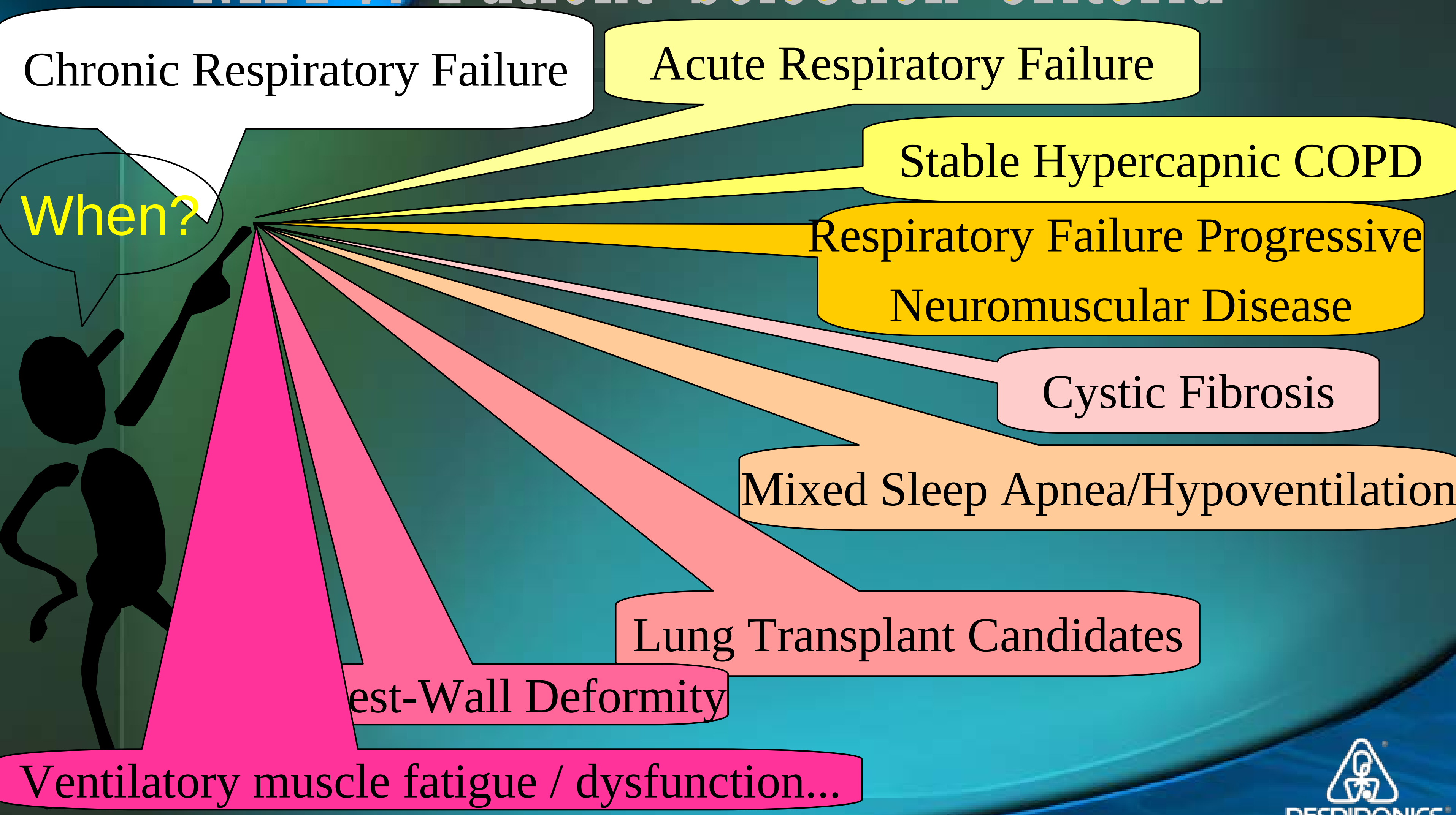
Auto-Trak Sensitivity
This is what we do.

NIPPV: Patient Selection Criteria



NIPPV Goal 1:

Resting the respiratory muscles

Increasing in Lung Compliance

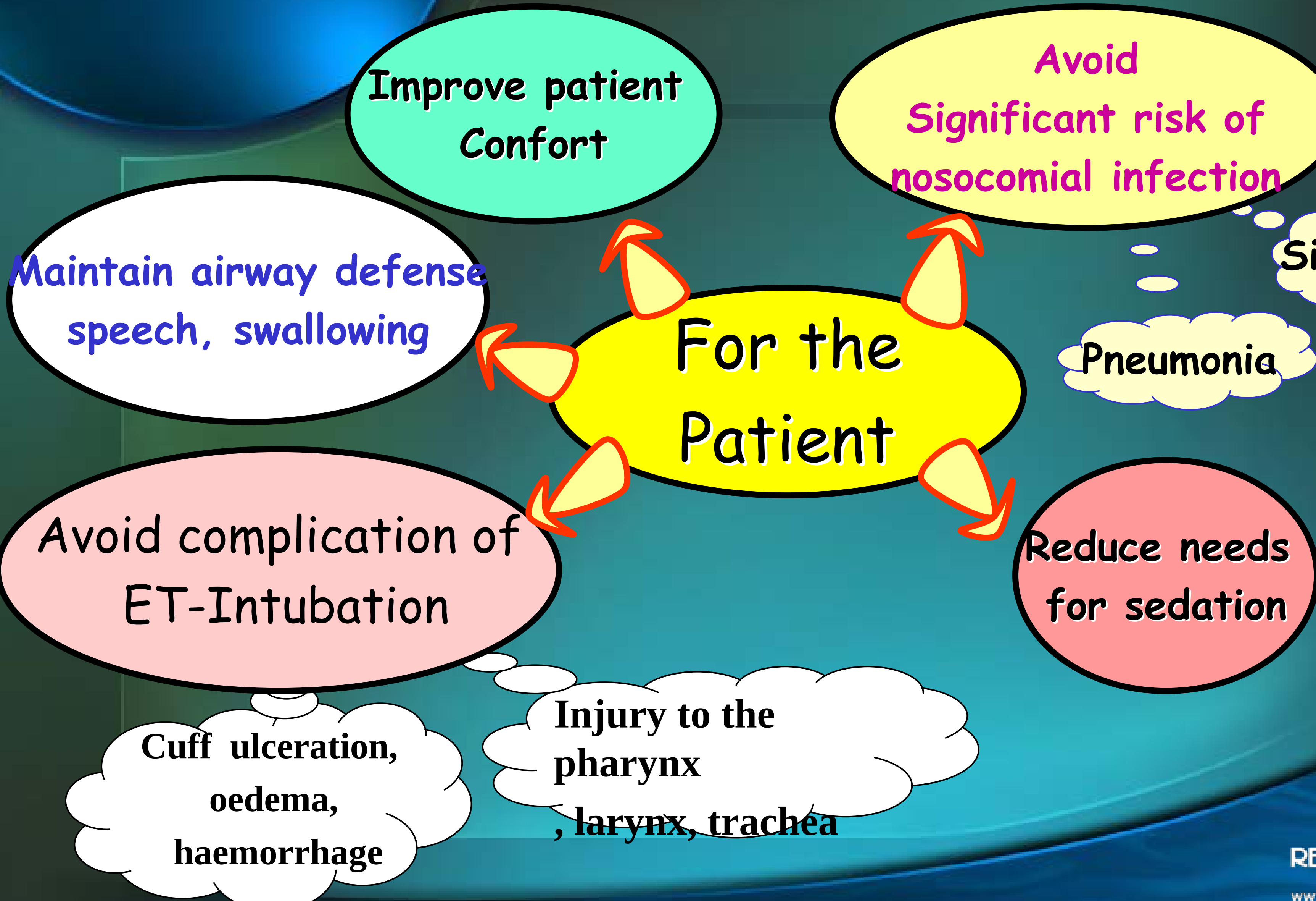
Mechanisms for Improvement

Resetting Central Chemoreceptors

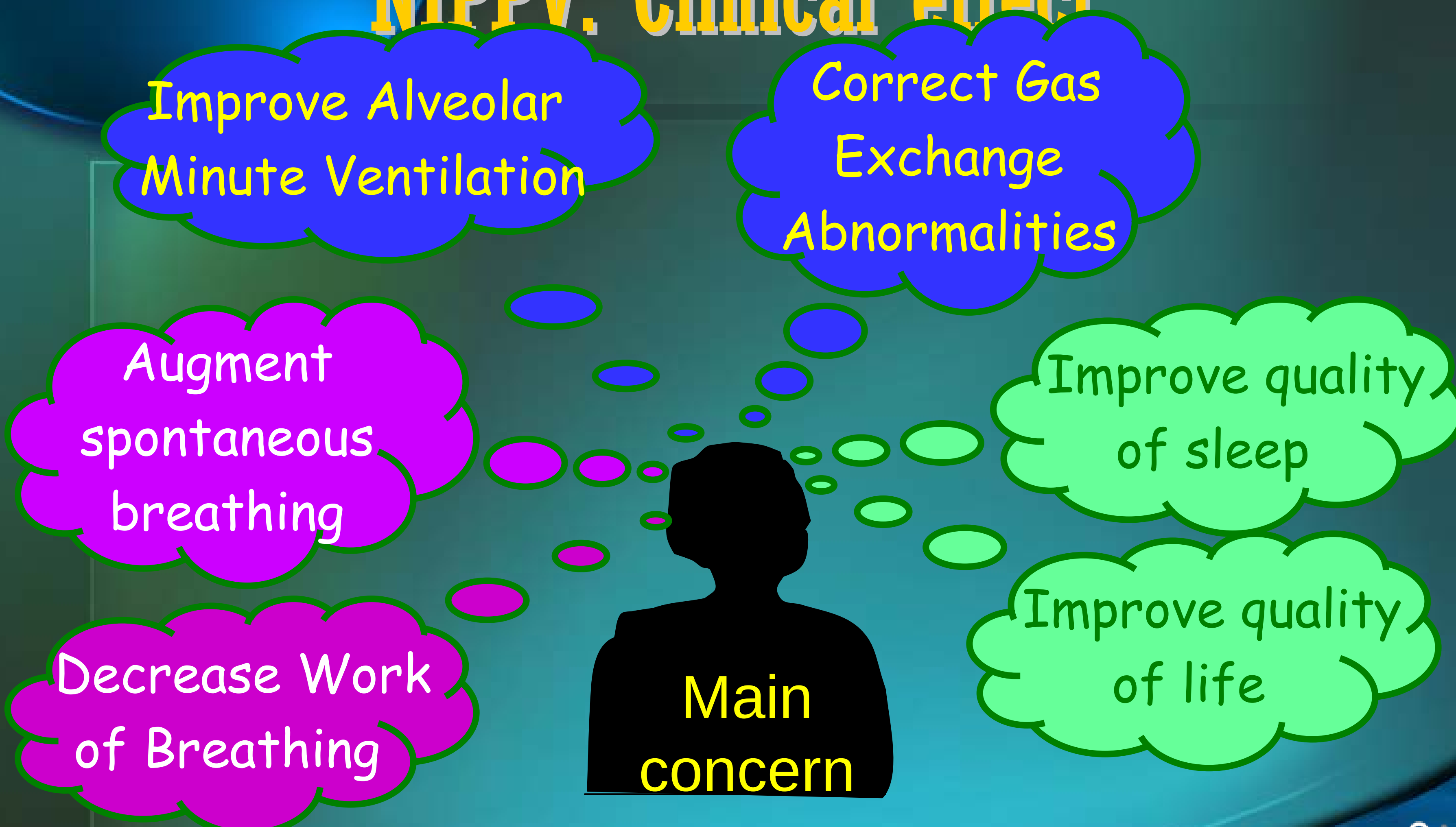
Augment patient's ability to breathe on a spontaneous basis

CO_2 sensitivity is blunted during failure

NIPPV Goal 2: For the patient



NIPPV: Clinical effect



NIPPV

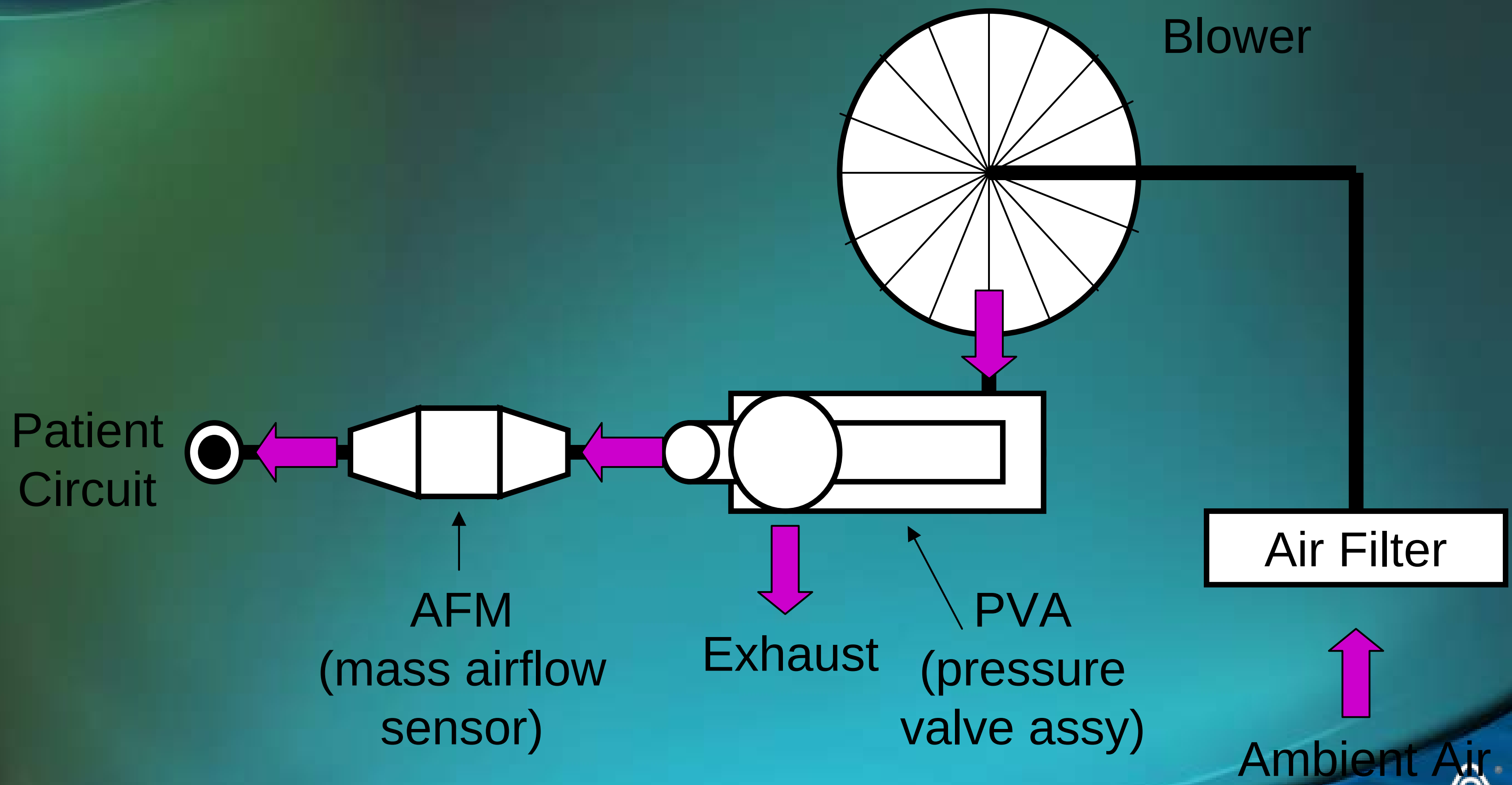
Mechanisms for improvement

For the patient

Clinical effect

Source: Kramer , Clinical Pulmonary Medicine 1996; 3: 336-342

General Overview NIV Pneumatic Design



Respironics is the inventor of the BiPAP® Systems

The Concept

Two pressure levels:

PS = IPAP - EPAP

PEEP = EPAP

Pressure Support with PEEP (Especially suited for Non Invasive Ventilation)

Continuous flow circuit

Our Know How

Detects and learns leaks

> To maintain automatic trigger sensibility

> Optimise performance

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BECAUSE:
It is virtually impossible for preset sensitivity settings to keep pace with

- *Wide variation in breath to breath effort*
- *Constantly changing breathing patterns*
- *Ventilation difference between Night & Day*

BECAUSE:
It is difficult to maintain proper patient ventilator synchrony in the presence:

- *Of unpredictable leaks*
- *Ongoing circuit leaks*

To meet the demands of NIV problems

The solution by RESPIRONICS is

Auto-Trak Sensitivity™

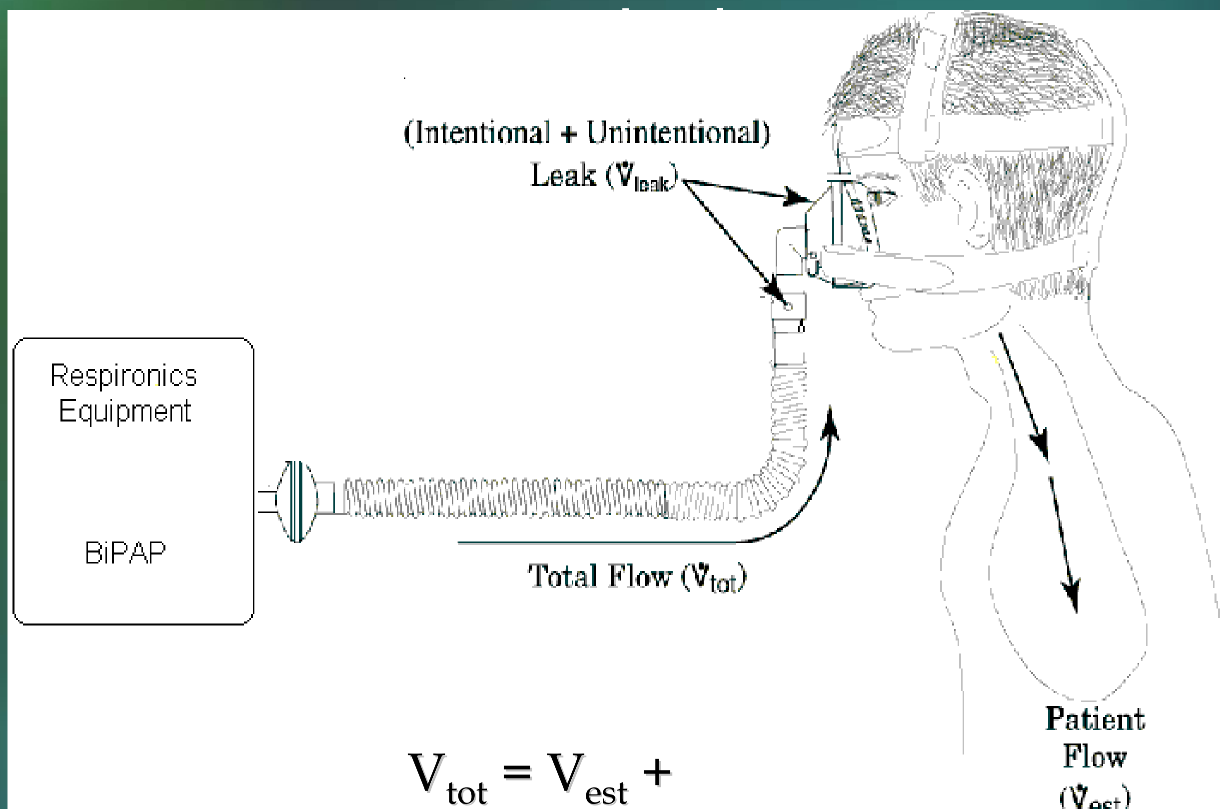
RESPIRONICS®
www.respironics.com

Two main topics of the Auto-Trak Sensitivity™

- **1- Leak tolerance** **Automatically adjusts sensitivity to changing breathing patterns and leak conditions**
  - Tidal Volume adjustment
  - Expiratory flow rate adjustment
- **2 - Sensitivity**
  - *Variable Trigger Thresholds (EPAP to IPap*
  - **Variable Cycle Thresholds (IPAP to EPap**

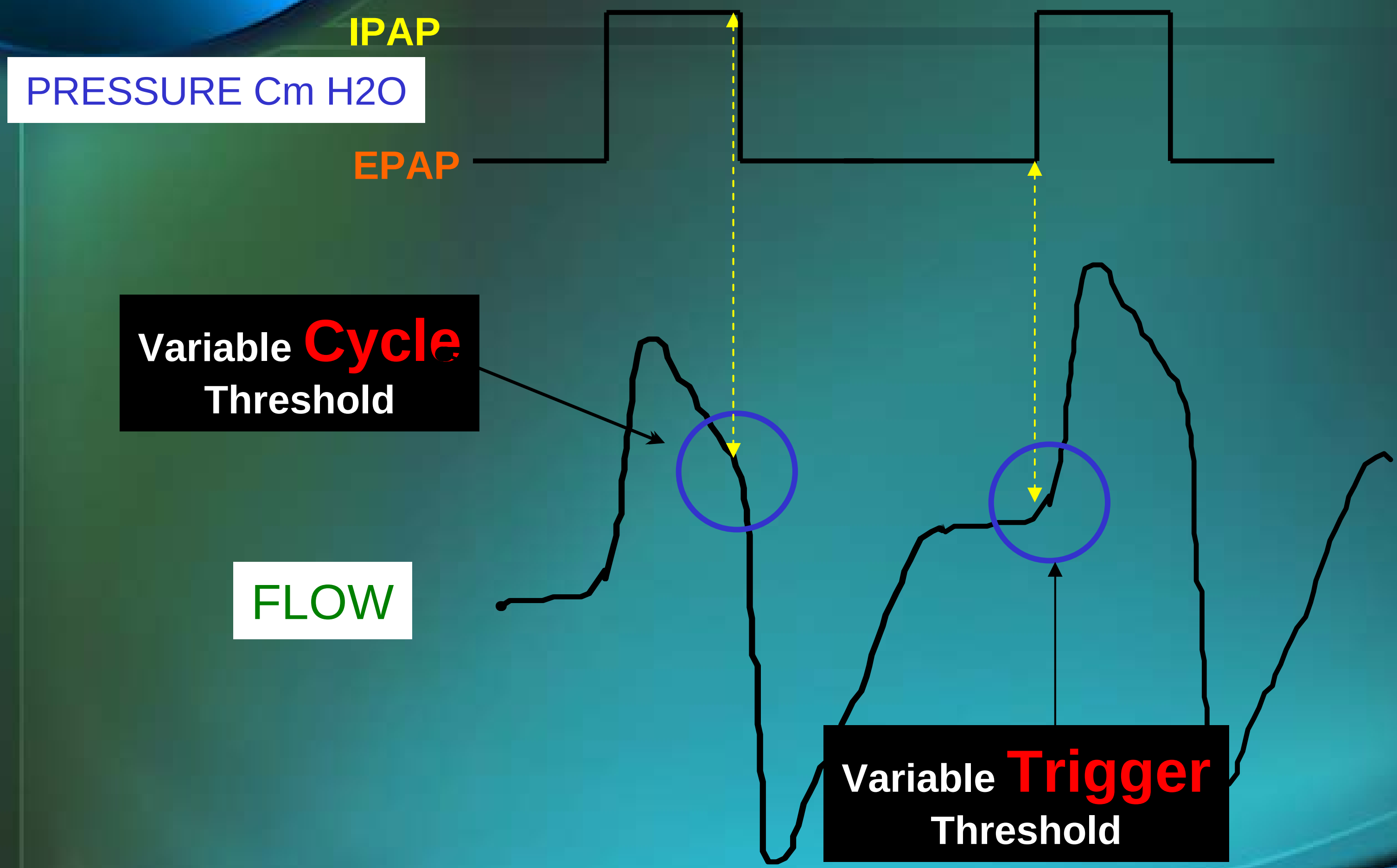
Leak Ventilation =>Flow Analysis

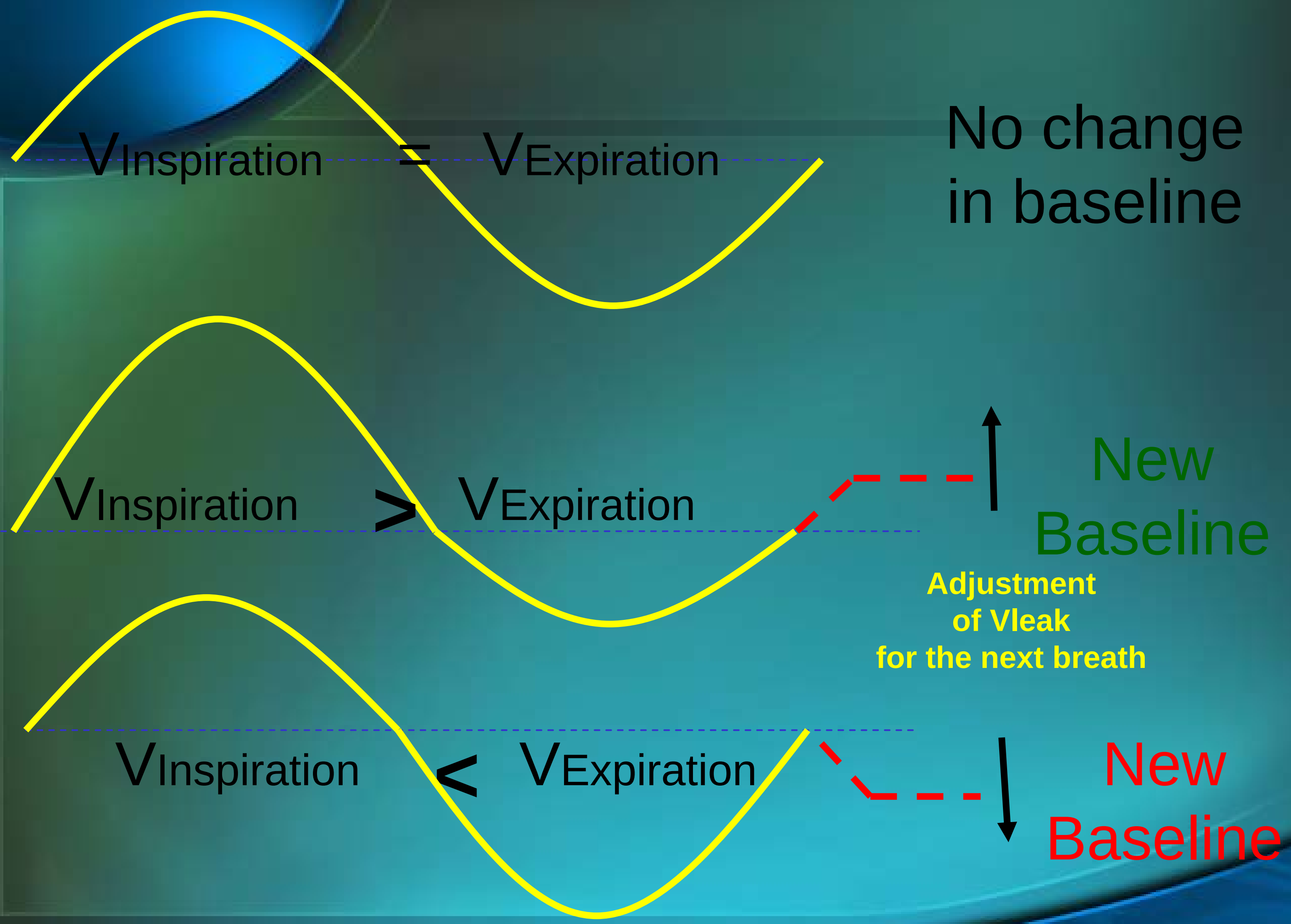
Total Flow = Estimated Patient Flow + Estimated



$$V_{tot} = V_{est} + V_{leak}$$

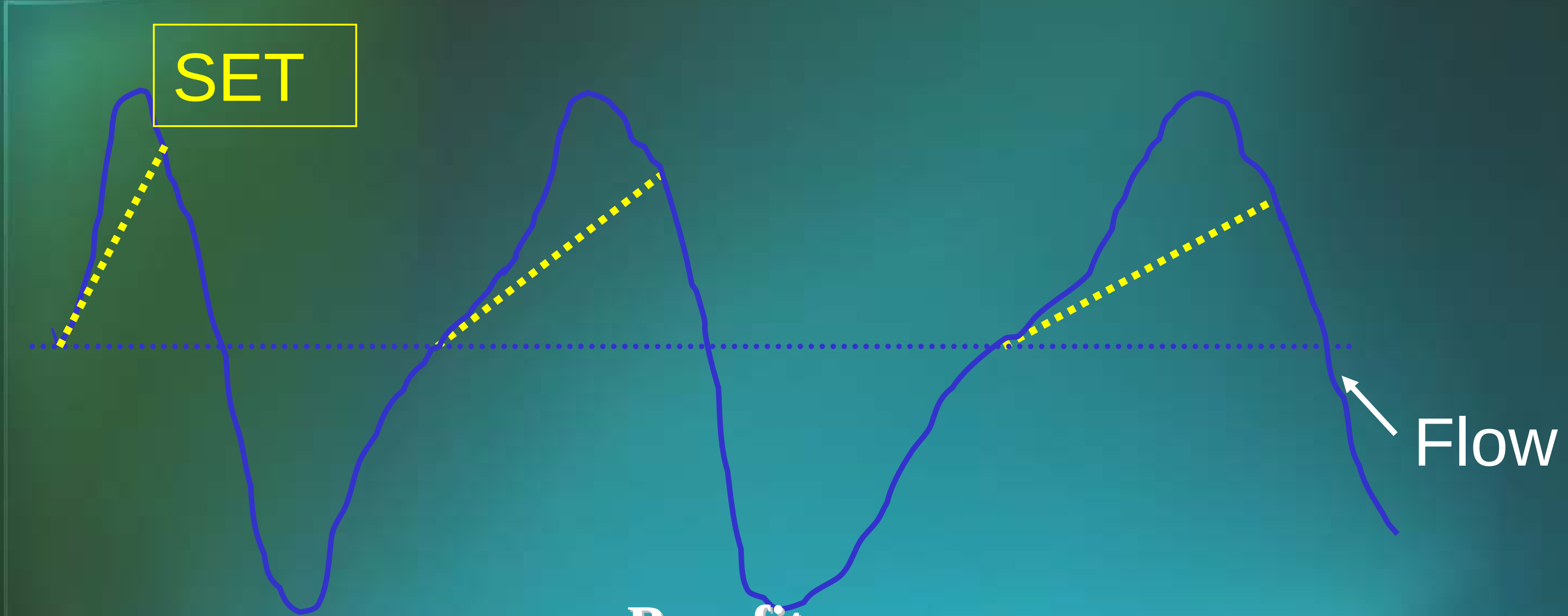
From EPAP to IPAP and IPAP to EPAP : Definitions




VInspiration = VExpiration
No change in baseline
VInspiration > VExpiration
New Baseline
Adjustment of Vleak for the next breath
VInspiration < VExpiration
New Baseline

Cycle Variables

SET (Spontaneous Expiratory Threshold)



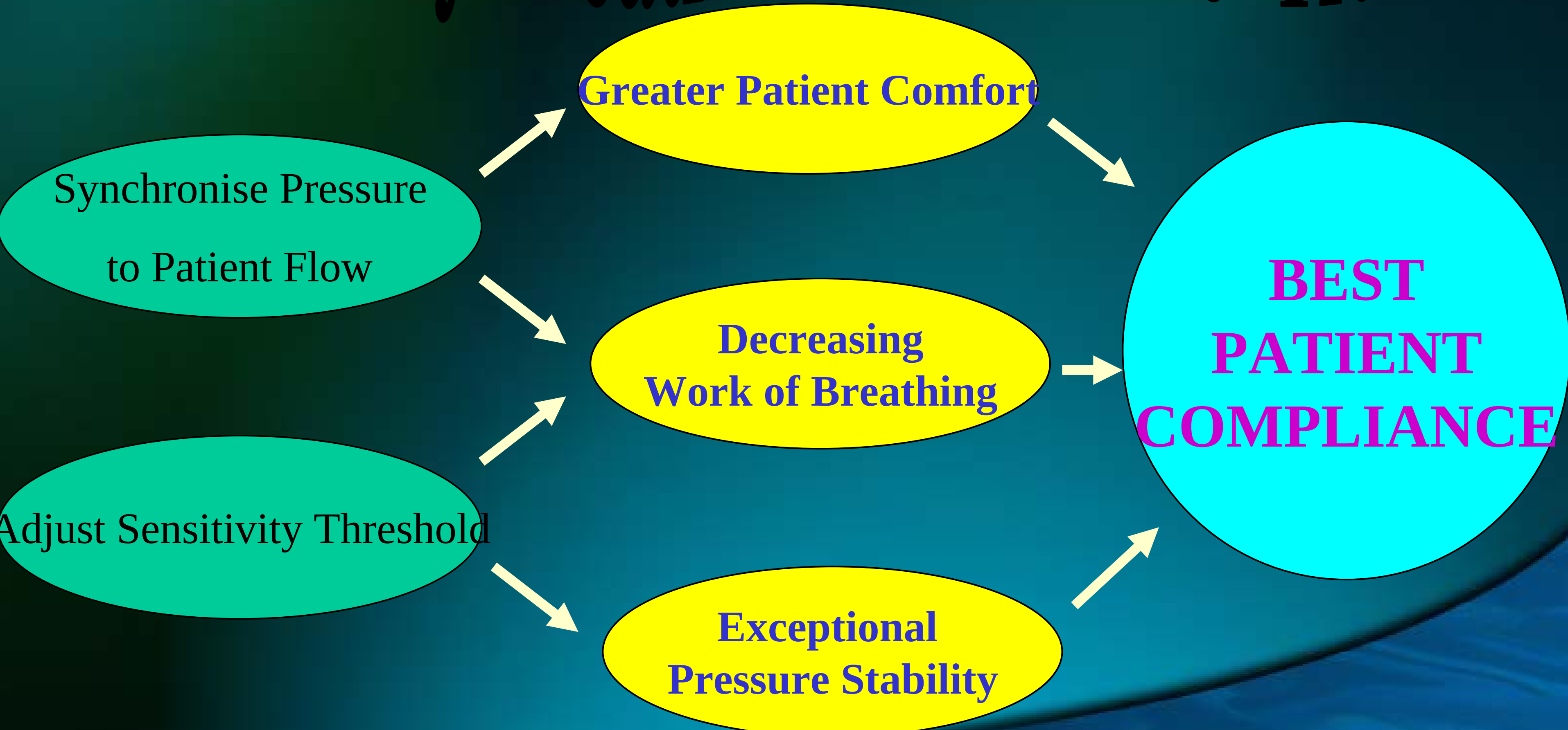
Benefit :

Detects gradual changes in patient flow

from prolonged exhalation periods.

Main results from the "Auto -Trak Sensitivity™
associated with our BiPAP technology

Breath by breath with the Auto-Trak



Featuring BiPAP Auto-Trak Sensitivity.
Optimum Response Automatically

The Best compliance

for the Best ventilation

from Acute to Home Care.

RESPIRONICS Product where our Auto -Trak Sensitivity™ technology is integrated:

Duet Lx

BiPAP® ST30, ST/D30

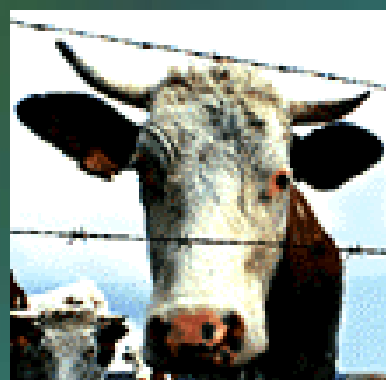
Harmony™

Focus

Vision™

PUBLIC NOTICE !!

How would you know if your cow suffers from Mad Cow Disease?



If your cow sounds like this...
Prepare the grill!

If your cow sounds like this...
You better buy some fish or chicken!