Oxygen Transport and Consumption

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CE Activity /Speaker Information & Disclosures

CE Information:

Nursing continuing education for this activity is provided by Memorial Regional Hospital – approved by the Florida Board of Nursing to provide education for nurses.This activity has been approved for 1 hour / 1 CE.

Speaker Information:

Edna Trepanier, MSN, MBA, BSCHEM, RN, CCRN is a full-time nurse manager of a 41-bed post intervention unit of a trauma level 1 hospital in Hollywood, FL. She is an Associate Professor at the University of Phoenix, Ft. Lauderdale campus and Broward College, Central Campus at Davy, FL. Ms. Trepanier had published two Chemistry manuals in the Philippines and was a coauthor of an educational article on Diabetic Feet published with Nursing Spectrum in 2010. She lectures extensively both locally and nationally on numerous nursing topics.

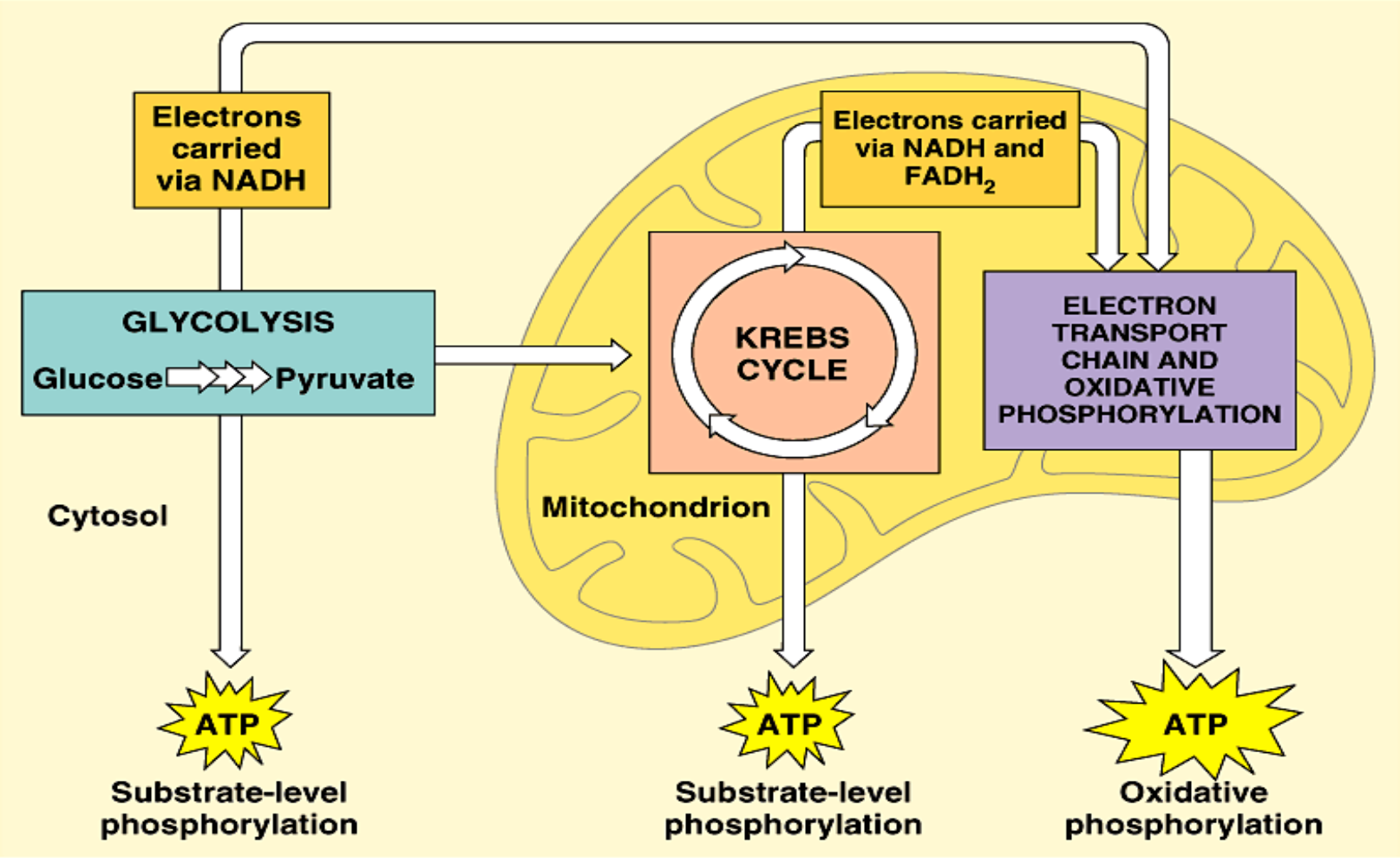
Disclosures:

The planners of this educational activity have reported no conflicts of interest to disclose. The speaker, Ms. Trepanier, reports that she has no conflicts of interest to disclose with respect to this educational activity.

Objectives

- **Describe the gas exchange from the lungs and into the cells**
- **Explain the relationship of the oxyhemoglobin dissociation curve to tissue oxygenation**
- **Explain the process of oxygen delivery and oxygen consumption at the tissue level**

Why Oxygen is so important…



Oxygenation and Transport

- **Concepts**
  - **Oxygen supply**
  - **Oxygen demand**
    - The amount of oxygen the cells require to meet their metabolic process
  - **Oxygen consumption**
    - The amount of oxygen the cells actually use

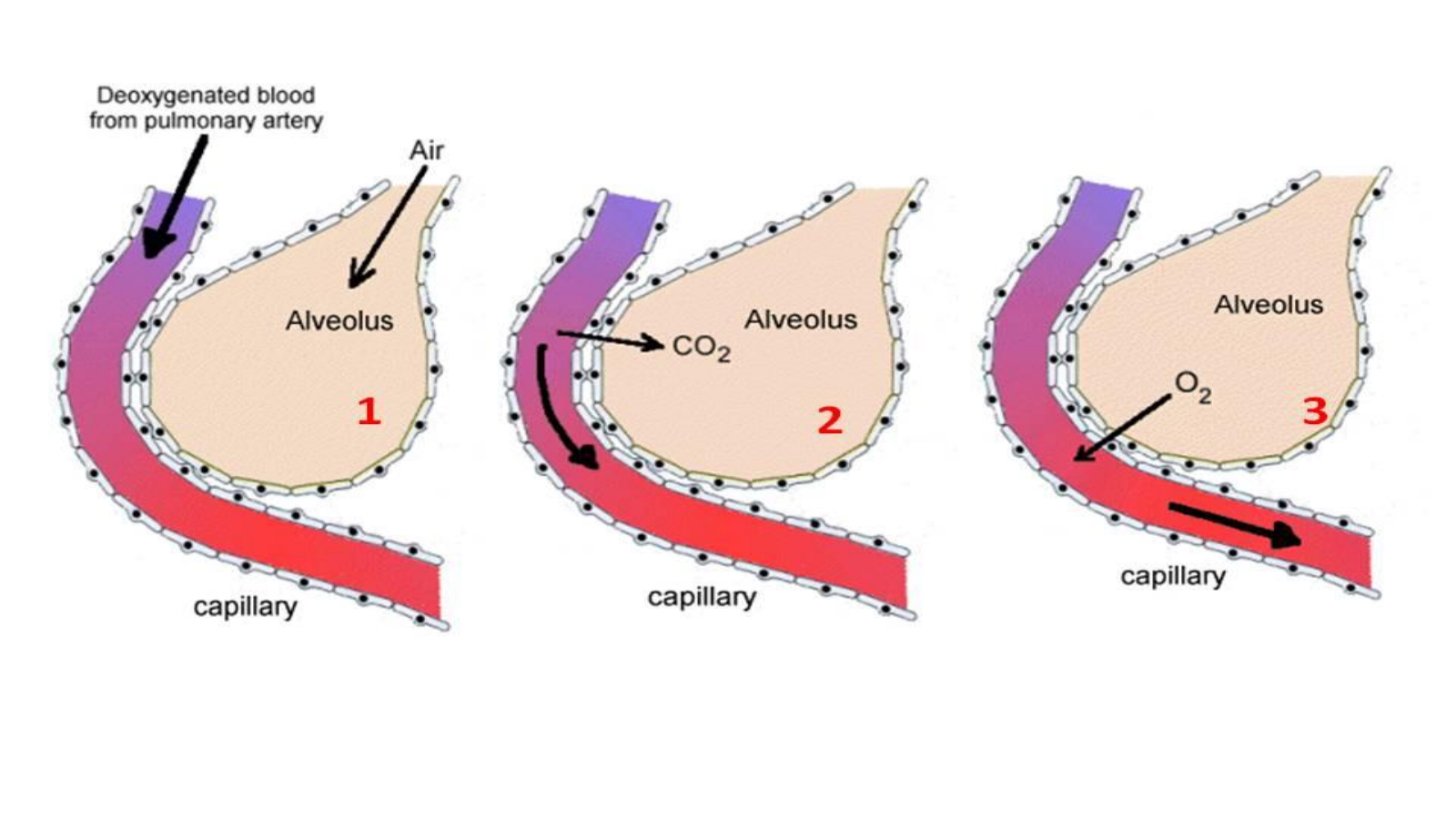
(Alspach, 2010)

Oxygen Supply and Demand

- **Determinants of oxygen supply**
  - Diffused oxygen
  - Blood oxygen content
  - Oxygen transport
  - Oxygen extraction

(Alspach, 2010)

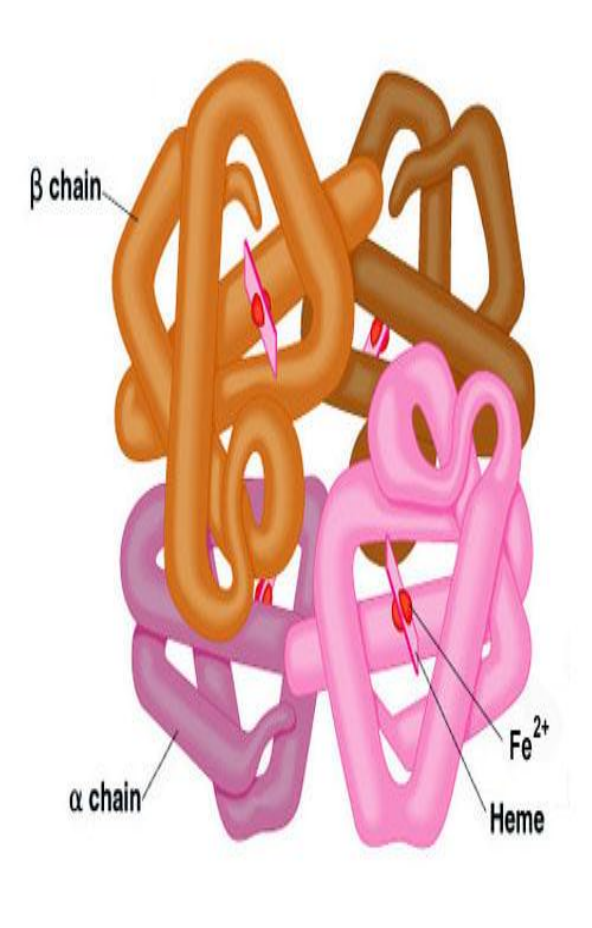
Alveolar Gas Exchange (Diffusion)



Diffused Oxygen (Alspach, 2010)

- 97%-98 % of diffused O_2 combines with Hgb to form
  Oxyhemoglobin
- Oxygen saturation **(SaO_2)**
  - SaO_2 = on ABG
  - SpO_2 = on pulse oxymetry
- 1 Hgb = max of 4 oxygen
- Hgb represents the O_2

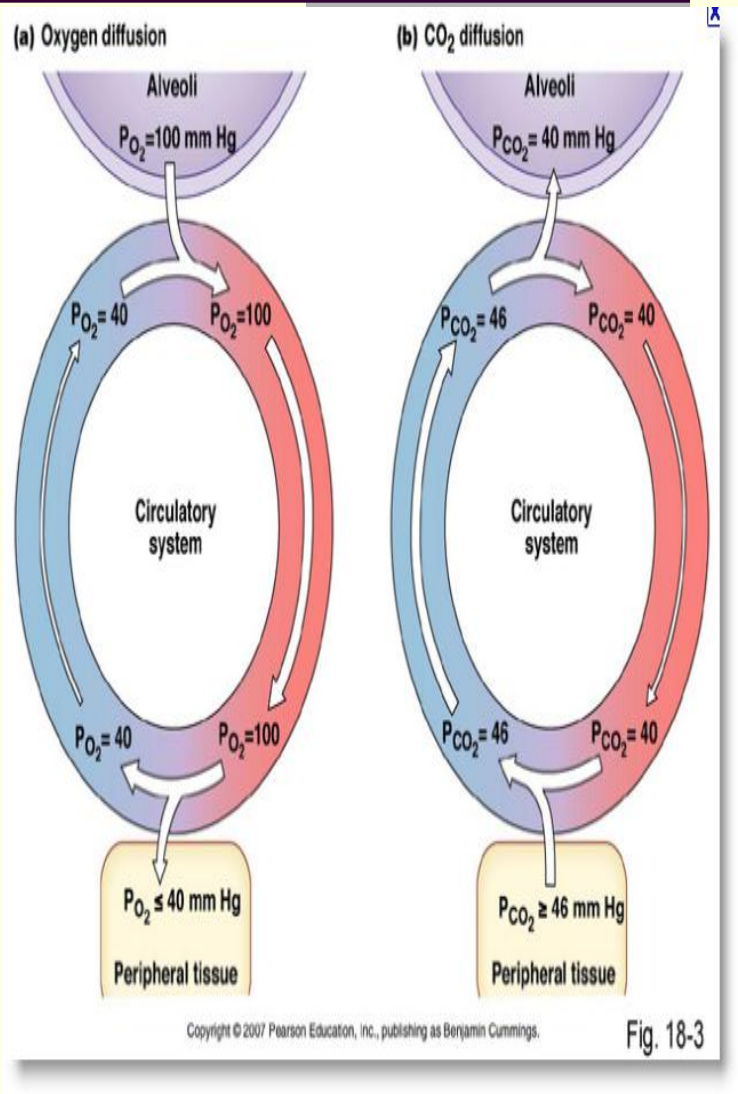
  Carrying capacity



(Lough, 2010, Pulmonary CCRN)

Diffused Oxygen

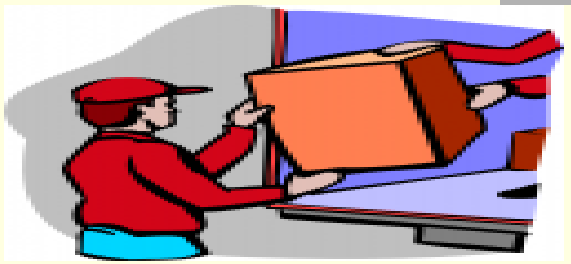
- 2%-3% of total O_2 dissolved in plasma
- Partial pressure of O_2 (**PaO_2**)
  - Pressure gradient
    - Driving pressure to move oxygen from:
      - High to low pressure in lungs
      - Capillary membrane into the cells



(Lough, 2010 Pulmonary CCRN)

How PaO_2 and SaO_2 Work Together

- PaO_2 is the "loading dock"

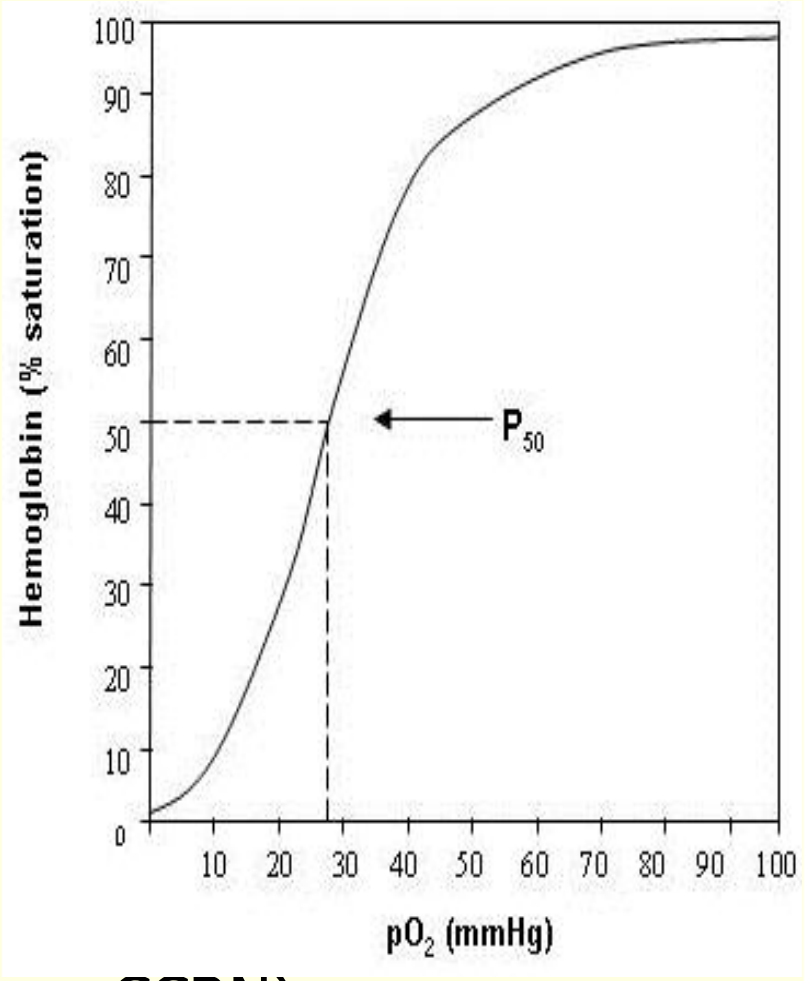


- SaO_2 is the "conveyor belt" or "transport"

- **Which one unloads O_2 into cells?**

Oxyhemoglobin Curve

- **SaO_2 is shown on Vertical Axis**
  - 97% of oxygen is bound to hemoglobin
- **PaO_2 is shown on Horizontal Axis**
  - 3% of oxygen dissolved in plasma



(Lough, 2010, Pulmonary CCRN)

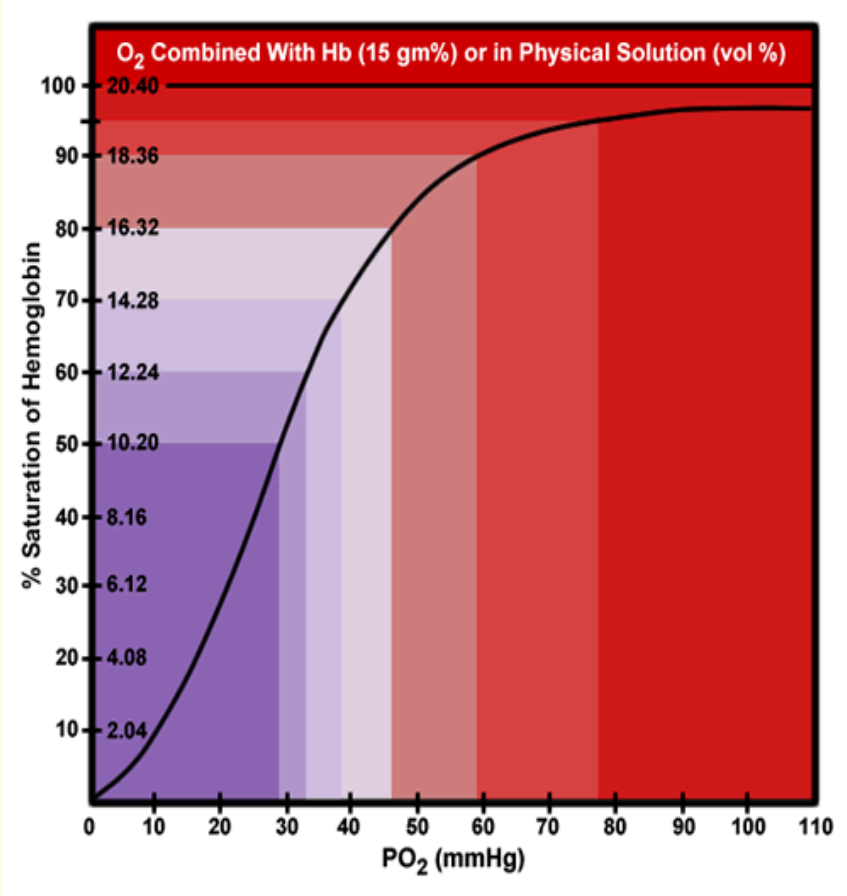
Oxyhemoglobin Curve

- **30 – 60 – 90 Rule**
  - When PO_2 is 30 mm Hg – SaO_2 is 60%
    - Usually when PvO_2 30 – SvO_2 is 60%
  - When PO_2 is 60 mm Hg – SO_2 is 90%
    - Usually when PaO_2 60 – SaO_2 (SpO_2) is 90%

(Lough, 2010, Pulmonary CCRN)

Oxyhemoglobin Curve: Arterial

- Arterial Association
  - Flat top part of the curve is arterial
  - Approximately SPO_2 is 90% and PaO_2 is at 60 mmHg
- Allows O_2 to saturate Hgb adequately as long as PaO_2 is above 60 mmHg
- Important in high altitude and in old age

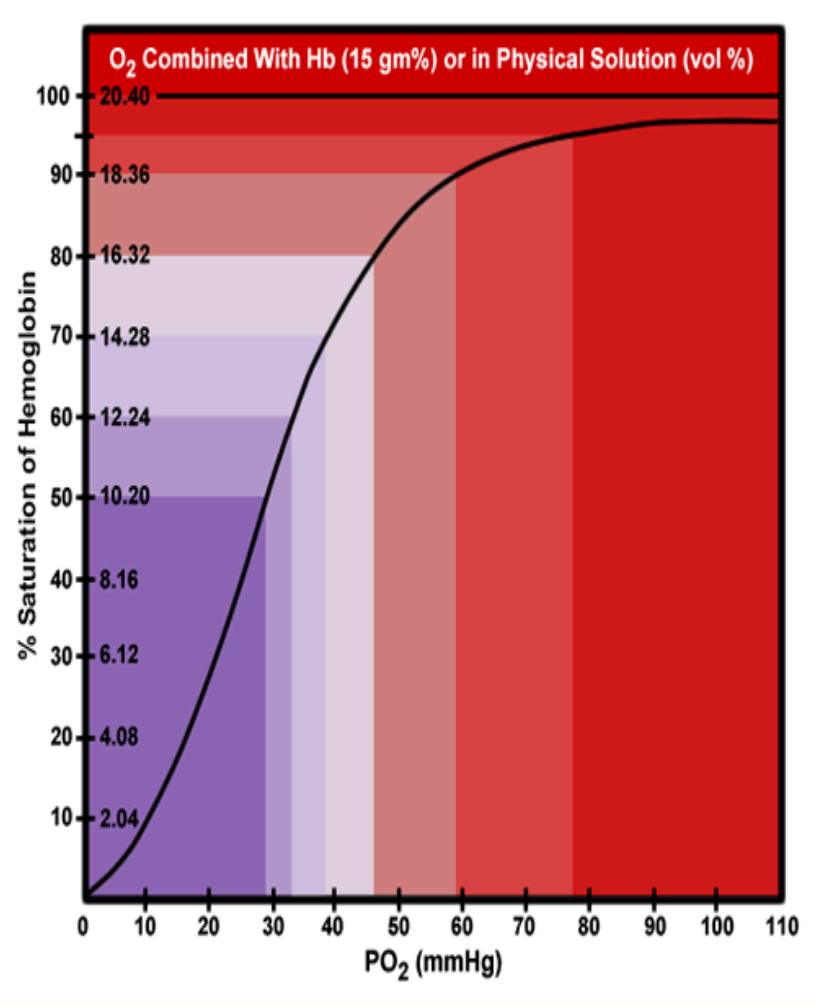


(Urden, Stacy, & Lough, 2006)

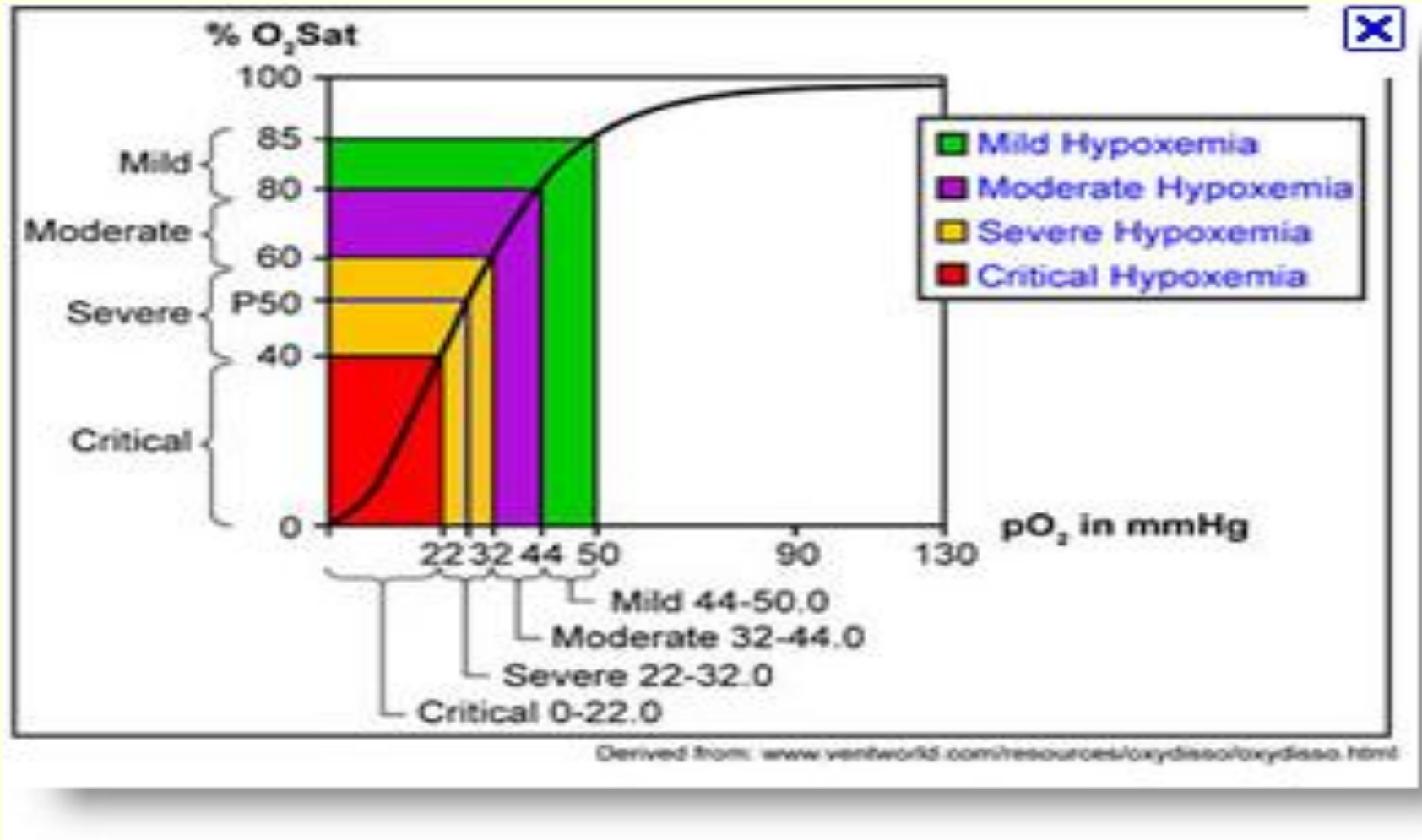
Oxyhemoglobin Curve - Venous

- Venous blood
  - Descending limb of the curve is venous (remaining 2/3 of the curve)
- SvO_2 is 60-80%
- PvO_2 30-40 mm Hg
- O_2 dissociation
- Purpose: body can unload large quantities of O_2 to tissues with small decreases in O_2

(Urden, Stacy, & Lough, 2006)



Oxyhemoglobin Dissociation Curve

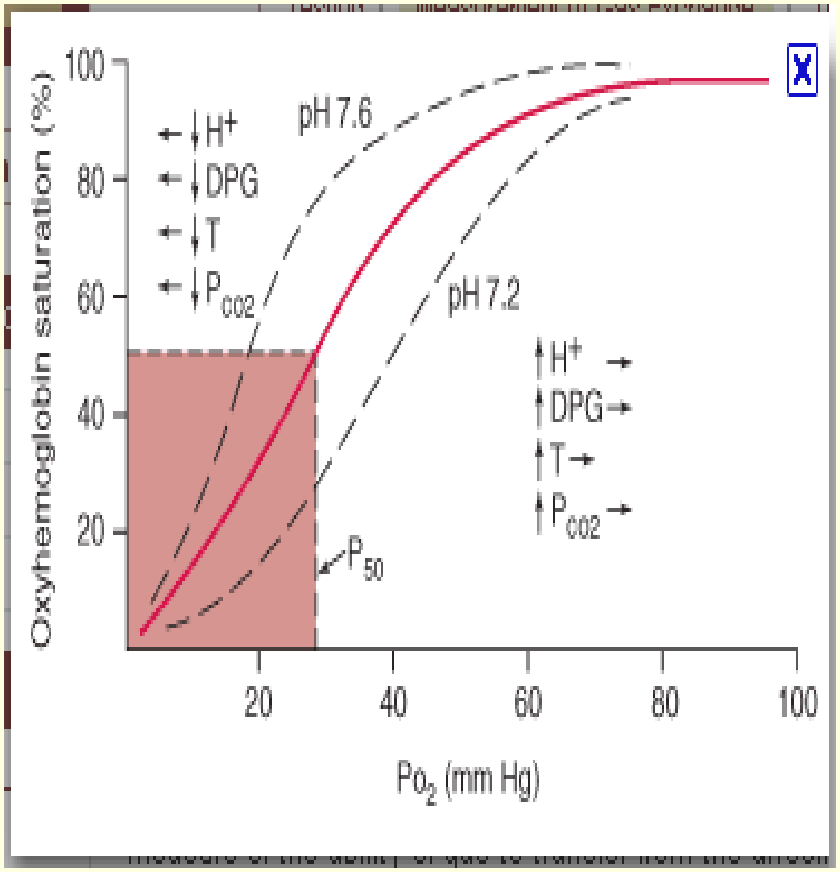


Oxyhemoglobin Curve

- Shift to the Right
  - ↓ **pH**
  - ↑**PCO_2**
  - ↑ **temp**
  - ↑ **2, 3, DPG**

ACID

- 2,3,DPG (Diphosphoglycerate) is a metabolite of glucose in the RBC that helps oxygen dissociate from hemoglobin at the tissue level
- (Lough, 2010, Pulmonary CCRN)

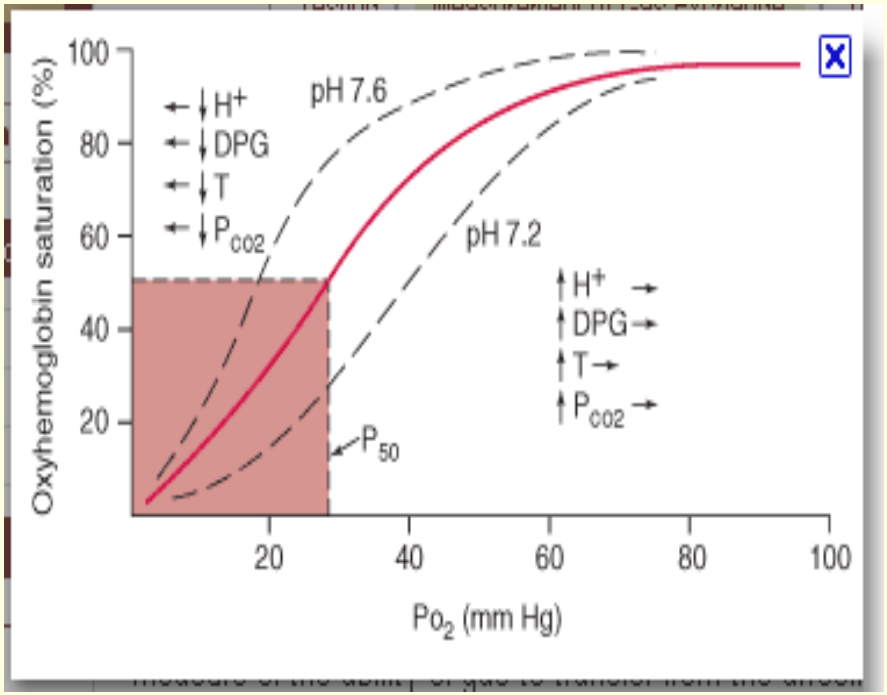


Also known as the “Bohr Effect”

Oxyhemoglobin Curve

- Shift to the Left
  - ↑ **pH**
  - ↓**PCO_2**
  - ↓ **temp**
  - ↓ **2, 3, DPG**

ALKALI



(Alspach, 2010)

Blood Oxygen Content (CaO_2)

- **CaO_2 or arterial oxygen content**
  - Sum of the oxyhemoglobin & dissolved O_2 in the arterial blood
  - Factors affecting CaO_2
    - Hemoglobin
    - SaO_2
    - SaO_2

    - (Klumer, 2011)

Oxygen Transport

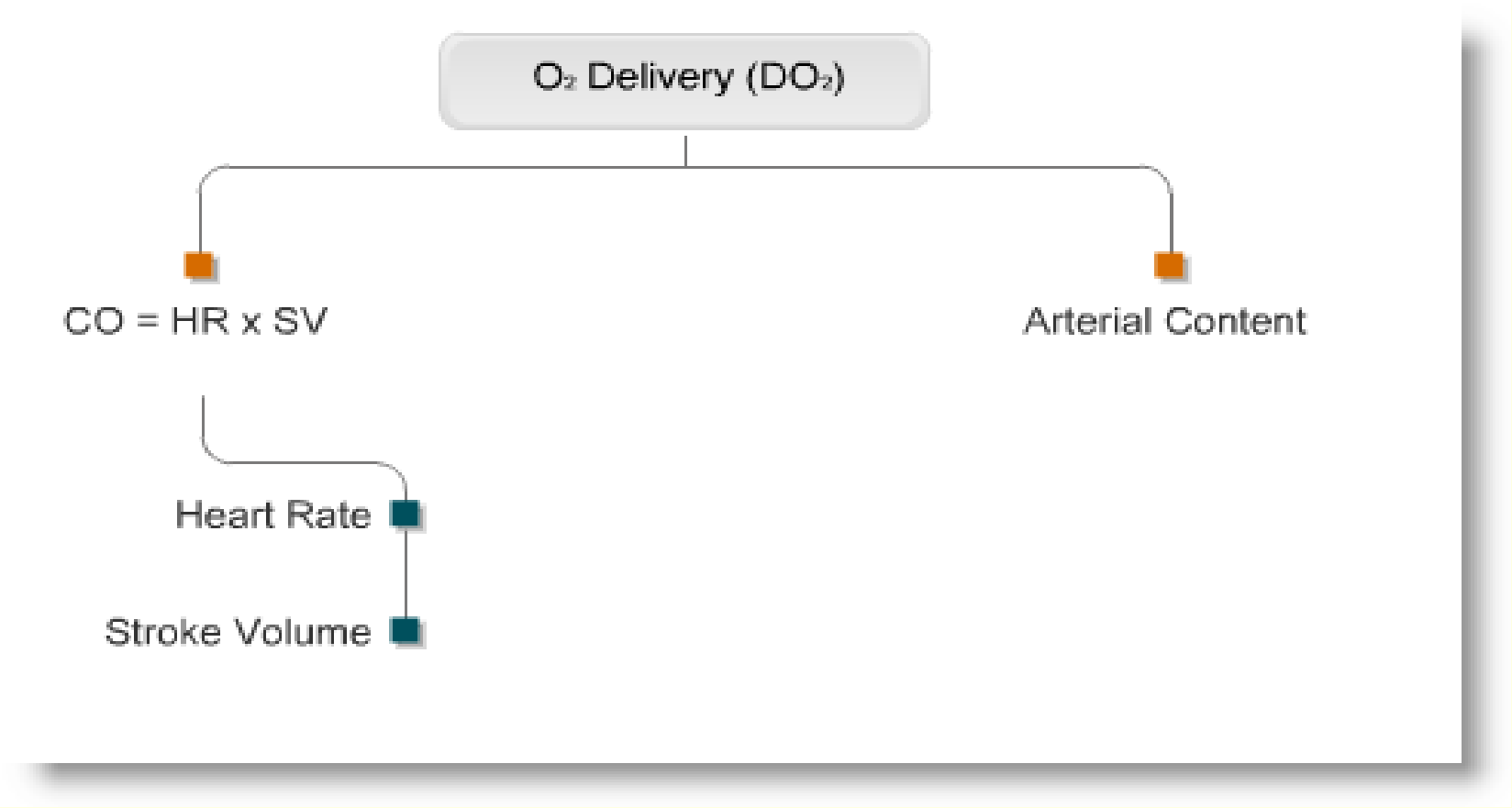
- Cardiac output is important determinant
  - HR X Stroke Volume
  - Stroke Volume
    - Preload
    - Afterload
    - Contractility
    - (Klumer, 2011)

Oxygen Extraction

- Oxygen reaching tissues
  - Dissolved O_2 diffuse into cells
- Conditions that impair oxygen diffusion
  - Severe sepsis
  - Carbon monoxide poisoning
  - (Klumer, 2011)

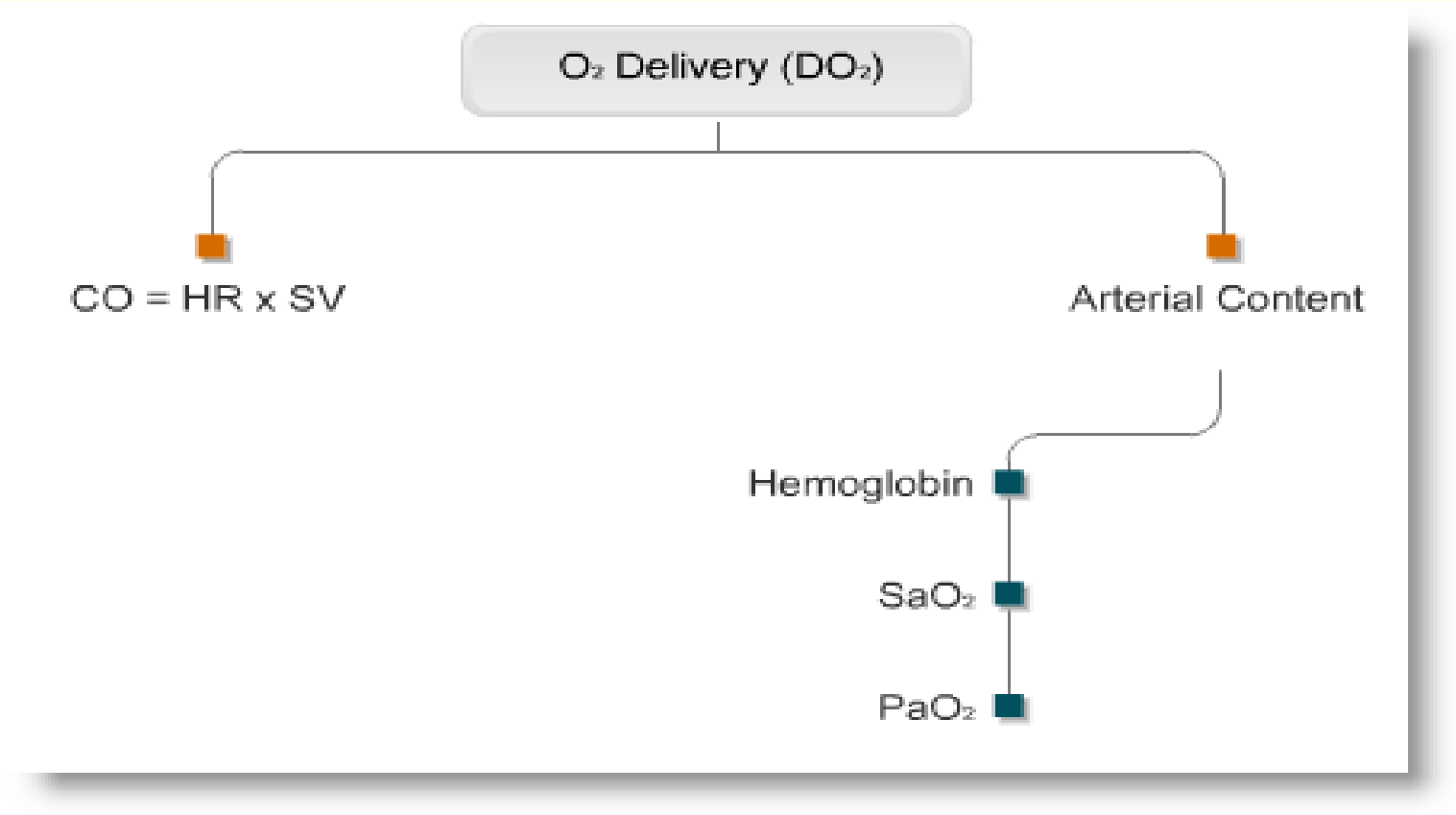
Oxygen Delivery (DO_2) (Alspach, 2010)

- Left : CO Right: Arterial Oxygen Content



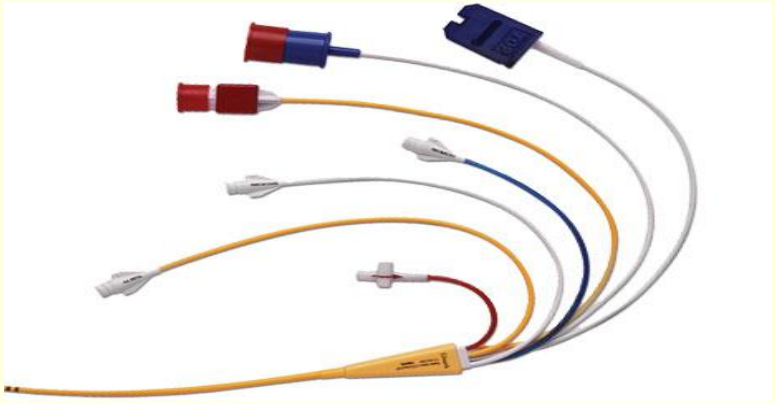
Oxygen Delivery (DO_2) (Alspach, 2010)

- Left : CO Right: Arterial Oxygen Content

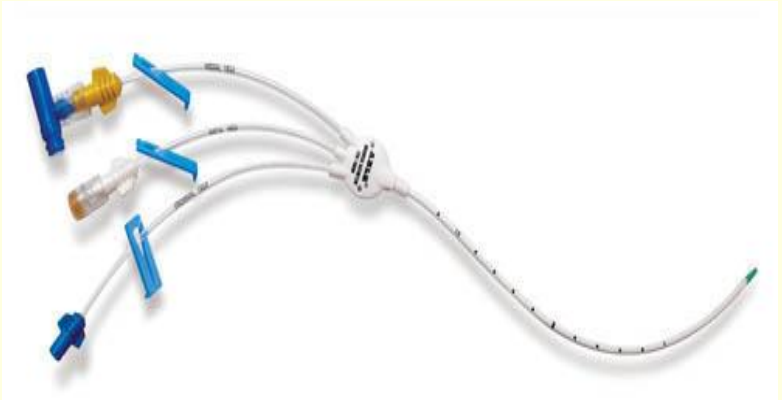


Types of Catheters to Measure Oxygen Saturation of Blood (Alspach, 2010)

- Continuous Mixed Venous Oxygen Saturation Monitoring (SvO_2)



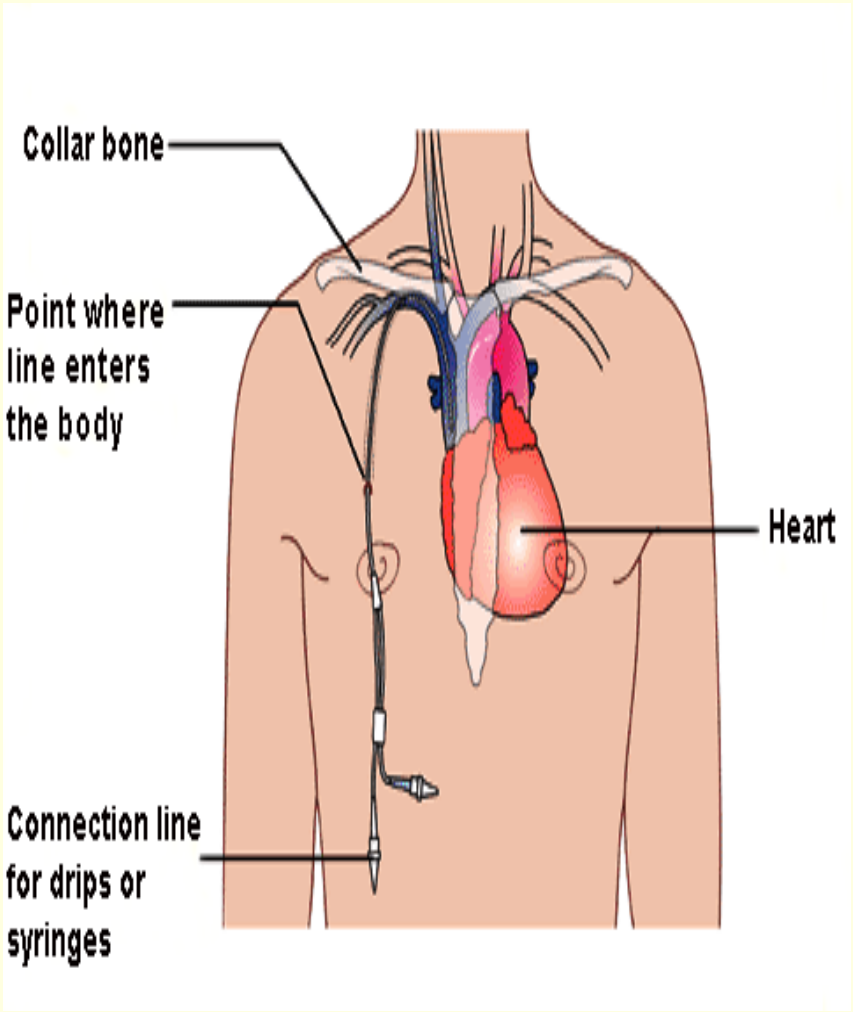
- Continuous Central Venous Oxygen Saturation Monitoring ($ScvO_2$)

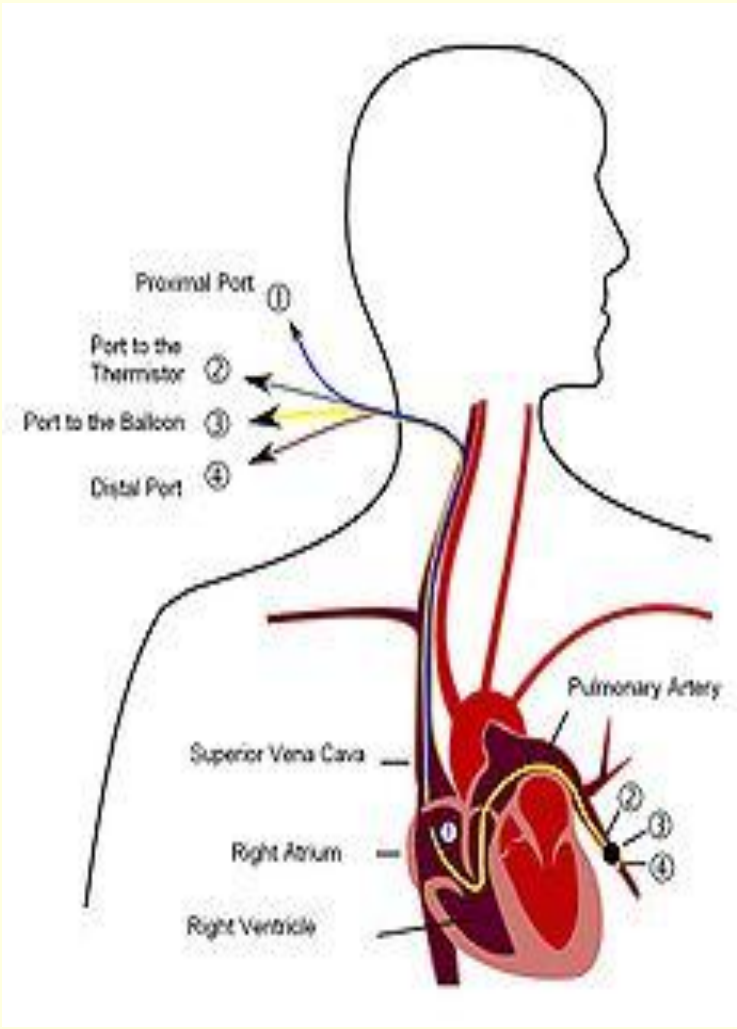


Central Venous $ScVO_2$ Saturation Continuous SvO_2 Monitoring (Alspach, 2010)

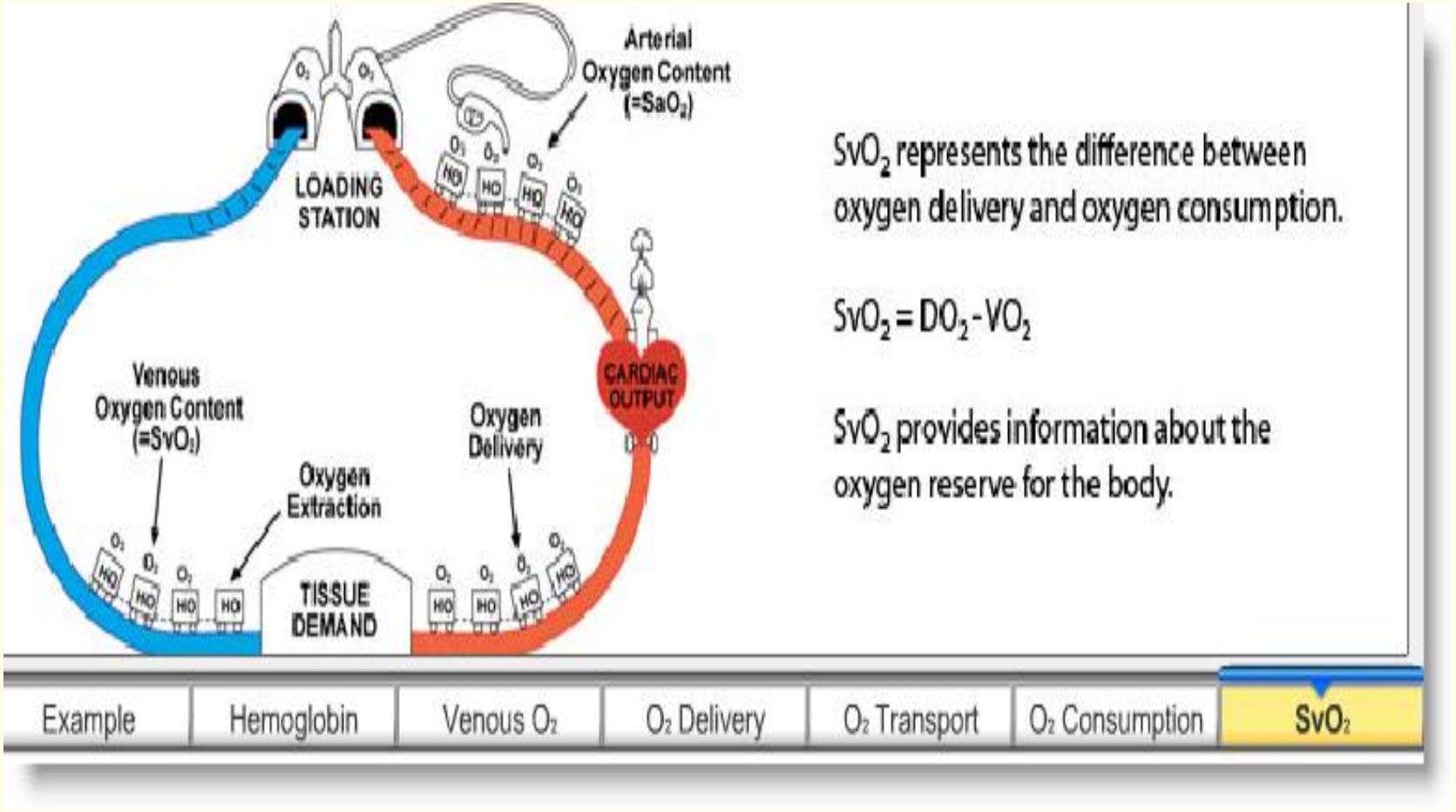
- **Central Venous – $ScVO_2$ catheter**
  - Measured in superior vena cava from beroptic CVP cath
  - Normal **$ScVO_2$ is 65-85%** (average 80%)
- **Pulmonary Artery – SvO_2 Catheter**
  - Measured from distal lumen of fiberoptic PA catheter
  - Also called “Mixed Venous Blood Gas”
  - Normal **SvO_2 is 60-80%** (average 75%)
- Why is there a difference in these 2 values?

$ScvO_2$ versus SvO_2 (Alspach, 2010)





SVO_2 = Difference Between O_2 delivery & O_2 Consumption (VO_2)



Causes of Decreased SvO_2 (Alspach, 2010)

A decreased SvO_2 value indicates more oxygen is being extracted.

Causes of decreased SvO_2:

Decreased delivery

- Falling hemoglobin
- Falling cardiac output
- Falling SaO_2

Increased demand

- Seizures, shivering
- Pain
- Increased activity
- Hyperthermia

(CCRN Pulmonary)

Causes of Increased SvO_2

An increase in the SvO_2 value indicates that less oxygen is being extracted.

Regardless of the change in the SvO_2 value, you must assess the patient in an effort to determine why the SvO_2 value is changing.

Causes of increased SvO_2:

Increased delivery
- Increased CO
- Administration of blood products
- Increased FiO_2

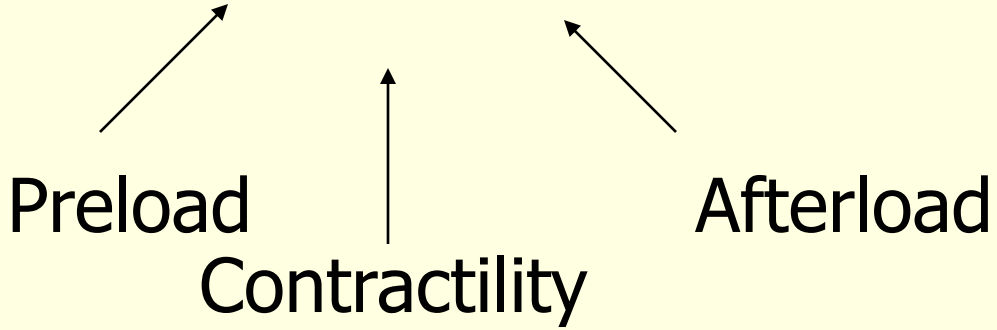
Decreased demand
- Hypothermia
- Relief of pain
- Anesthesia

- Sepsis:
  - Demand increased
  - Oxygen extraction inhibited
- Wedging a pulmonary artery catheter
  - SvO_2 will increase by 10-20%
  - Mixed venous blood no longer flowing by the catheter. The light source is now reflected off arterialized blood. When the balloon is deflated, the SvO_2 value will return to previous setting.

(CCRN Pulmonary)

Cardiac Factors that Affect SVO_2 Values

- Stroke Volume x HR = Cardiac Output



Cardiopulmonary Factors that affect SVO_2

- Ventilation
  - Inspired O_2, work of breathing, SaO_2 (SpO_2)
- Hemoglobin
  - Sufficient RBCs for transport
- Cardiac Output
  - Adequate flow and perfusion

Metabolic/Tissue Factors that Affect SVO_2

- Muscle / Tissue / Organ Activity
  - ↑ O_2 consumption (tissues use more oxygen)
    - Septic patient
  - ↓ O_2 consumption (tissues use less oxygen)
    - Cold anesthetic patient

CCRN Questions

CCRN Question

- A 76 y.o. female is admitted to ER with exposure and hypothermia. Her temp. is 35.4°C, pH 7.53, & $PaCO_2$ 42 mm Hg. The oxyhemoglobin dissociation curve shows:
- A. Shift to the left, ↑ O_2 tissue delivery
- B. Shift to the right, ↑ O_2 tissue delivery
- Shift to the right, ↓ O_2 tissue delivery
- Shift ot the left, ↓ O_2 tissue delivery

CCRN Question

- A 56 y.o. male admitted to ICU with acute respiratory failure + sepsis. Temp 39.2ºC, pH 7.24, PaO_2 58 and $PaCO_2$ 55 mmHg. The oxyhemoglobin dissociation curve shows:

  - A. Shift to the left, $\uparrow O_2$ tissue delivery
  - B. Shift to the right, $\uparrow O_2$ tissue delivery
  - C. Shift to the right, $\downarrow O_2$ tissue delivery
  - D. Shift to the left, $\downarrow O_2$ tissue delivery

CCRN Question

- Susan has an SvO_2 catheter in place and the reading shows 40% for over 10 minutes. The critical care nurse should?
  - A. Check $PaCO_2$, CO and Hemoglobin
  - B. Do nothing this is a normal venous value
  - C. Check the catheter, SpO_2, CO and VO_2
  - D. Check CO, Hemoglobin and an ABG

References

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