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Integrated Cardiac Output and Respiratory Function

M1 – Cardiovascular/Respiratory Sequence

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Fall 2008

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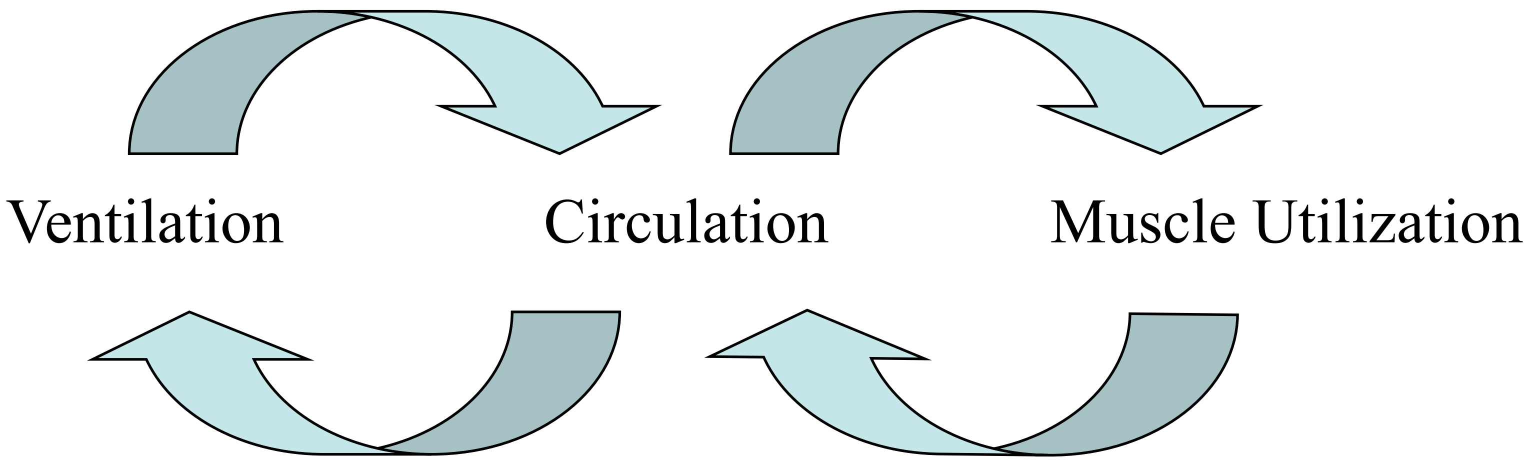
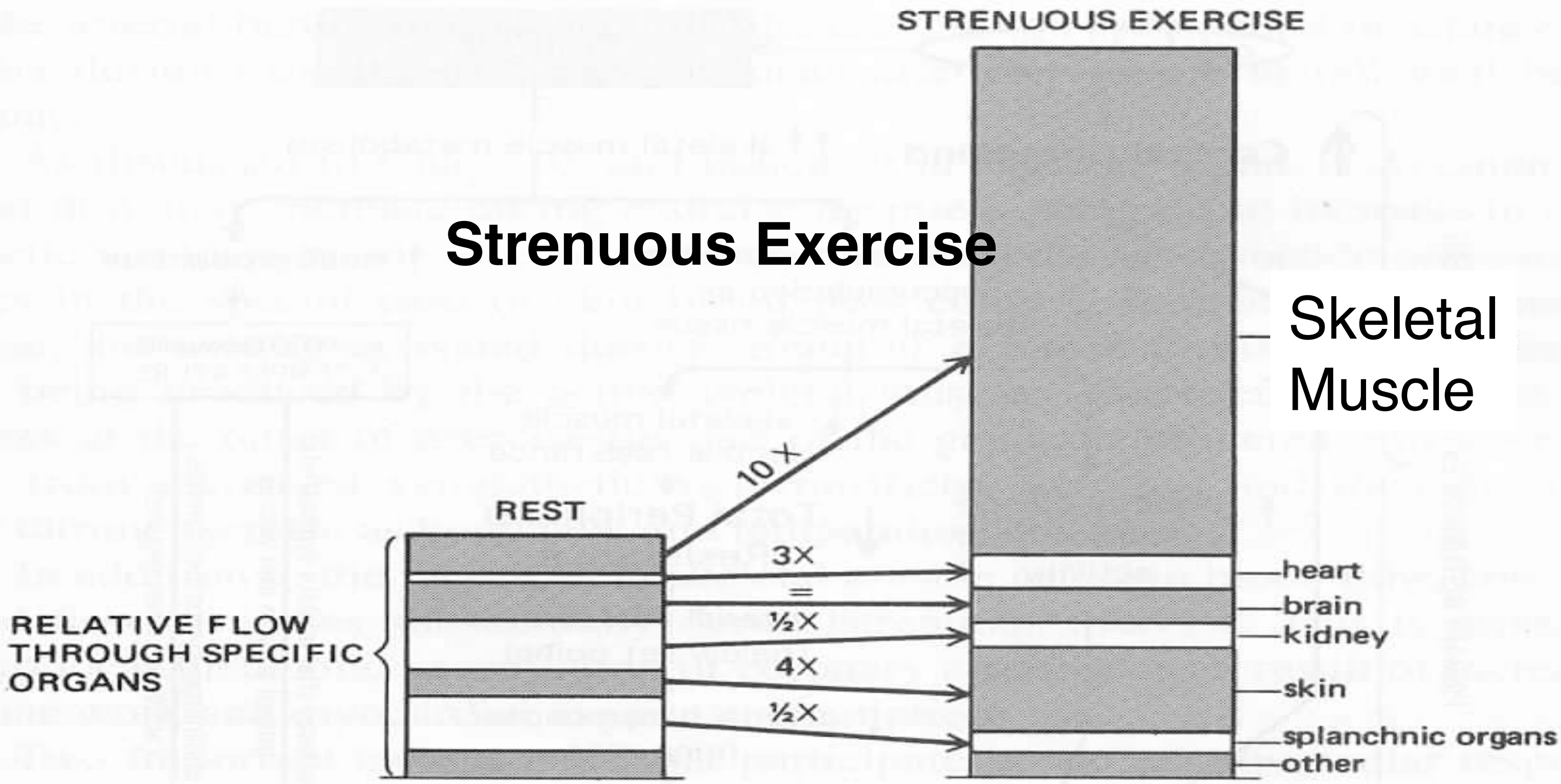
Exercise



Exercise

- With exercise, $\dot{V}O_2$ increases
- one initially increases both ventilation and cardiac output
  - Ventilation and perfusion remain matched
  - DO_2 remains much greater than $\dot{V}O_2$

Strenuous Exercise



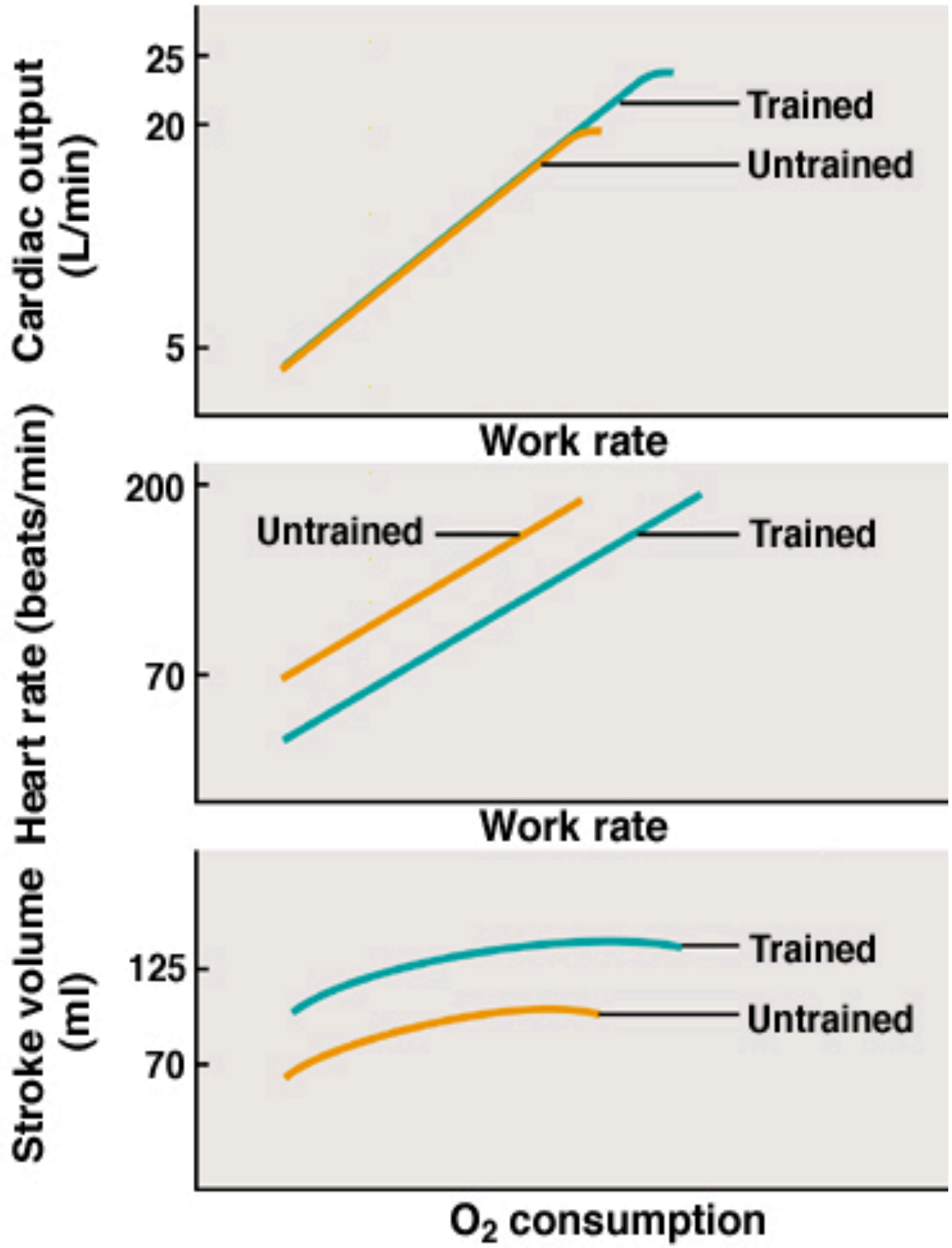
cardiac output	6 liters/min	18 liters/min
heart rate	70 beats per minute	160 beats per minute
ejection fraction	60%	80%
arterial pressure	120/80 mmHg	150/80 mmHg
central venous pressure	2 mmHg	2 mmHg

Figure 11-4 Cardiovascular adjustments to strenuous exercise.

 Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.

M&H 10.4

Change in cardiac output/ heart rate/ stroke volume



Exercise

- At higher levels of exercise, DO_2 can not keep up with increasing $\dot{V}O_2$
  - $\dot{V}O_2$ is maintained by increasing oxygen extraction
    - $\dot{V}O2 = CO \times (CaO_2 - CvO_2)$
  - CvO_2 falls and eventually MvO_2 falls
- Eventually, oxygen delivery is inadequate for the level of work, and the muscle shifts to anaerobic metabolism
  - Anaerobic threshold

Oxygen delivery and oxygen saturation of mixed venous blood

- Normal mixed venous oxygen saturation (MvO2) = 75%
- If oxygen delivery falls, and tissue metabolism continues, then MvO2 will fall
- In principle, we should know that oxygen delivery is sufficient if we know that MvO2 is normal
- There are a few caveats…

Caveats

- Suppose blood moves from the arterial circulation to the venous circulation without unloading oxygen
  - Large shunts, congenital and man-made
  - Micro shunts
  - Toxins poisoning mitochondria
- If oxygen isn’t removed from arterial blood, the MvO2 may be normal, despite inadequate oxygen delivery

REVIEW
OF

Worked Problems

as time permits.

Prior questions

- What is the total O_2 content of 100 ml of plasma (PO_2 100 mmHg)?

Ans. 0.31 ml

Henry's Law for O_2

The content of dissolved oxygen is equal to the product of the oxygen solubility coefficient and oxygen partial pressure.

$$C_{dO_2} = a_{O_2} \, P_{O_2}$$

Linear straight line Relationship like y = mx.

C_{dO_2} = content of dissolved O_2 mL/dL

a_{O_2} = solubility coefficient for O_2 in blood

$$a_{O_2} = 0.0031 \text{ mL/mm Hg/dL}$$

dL = 100 mL

Prior questions

- What is the O_2 content of 100 ml of blood (Hb 15 gm/dL; PO2 100 mmHg)?

Ans. 20 ml

Typical Arterial Blood Oxygen Content

P_{O_2} = 100 mm Hg S_{O_2} = 97% [Hb] = 15 gm/dL

1.34 mL O_2 /gm Hb = O_2 capacity =Hb_s

Dissolved O_2

$$C_{dO_2} = a_{O_2} \; P_{O_2} = 0.0031 \times 100 = 0.31 \text{ mL / dL}$$

Bound O_2

$$C_{bO_2} = S_{O_2} \, [\,Hb\,] \; Hb_s = 0.97 \times 15 \times 1.36 = 19.79 \text{ mL / dL}$$

Total Oxygen Content

$$C_{dO_2} + C_{bO_2} = 0.31 + 19.79 = \mathbf{20.1 \text{ mL / dL}}$$

Integrated Question 1

- CaO_2 = 19 ml/dL
- CvO_2 = 14.5 ml/dL
- Cardiac output by thermal dilution = 8 liters/min
- What is the $\dot{V}O_2$?

$$\dot{V}O_2 = CO \times (CaO_2 - CvO_2)$$

$$\dot{V}O_2 = 80 \text{ dL/min} \times (19 - 14.5 \text{ ml/dL}) = 360 \text{ ml/min}$$

Integrated Question 2

$\dot{V}O_2 = 250$ ml/min

$CaO_2 = 20.5$ ml/dL

$CvO_2 = 16$ ml/dL

- *What is the cardiac output?*

$$CO = \dot{V}O_2/(CaO_2 - CvO_2)$$

$$CO = 250 \text{ ml/min} / (20.5 - 16 \text{ ml/dL})$$
$$= 250/4.5 = 55 \text{ dL/min} = 5.5 \text{ L/min}$$

Integrated Question 3

- Determine oxygen delivery

  PaO_2 = 96 mmHg

  O_2 saturation = 97%

  Hb = 12 gm/dL

  Cardiac output = 6 liters/min

  DO2 = CO x CaO_2

  CaO_2 = (1.34 x 12 gm/dL x .97) + (96 x .003)
  = 15.6 + .29 = 15.9 ml/dL

  DO_2 = 60 dL/min x 15.9 ml/dL = 954 ml/min

Integrated Question 4

Which of the following maneuvers will increase oxygen delivery to the greatest degree (all else being equal)?

A. supplemental oxygen to increase PO_2 from 90 to 120 mmHg – *little effect*

B. supplemental oxygen to increase O_2 saturation from 88% to 98% - *<12% increase*

C. transfusion to increase hemoglobin from 9 gm/dL to 12 gm/dL – *33% increase*

D. increase cardiac output from 5 liters/min to 8 liters/min – ***60% increase***

Integrated Question 5

- A healthy individual is a given a drug that increases cardiac output from 5 to 7 liters/min. One would anticipate which of the following as a consequence of this change?

A. Oxygen consumption increases
B. arterial oxygen saturation increases
C. arterial oxygen saturation decreases
D. mixed venous oxygen saturation increases
E. mixed venous oxygen saturation decreases

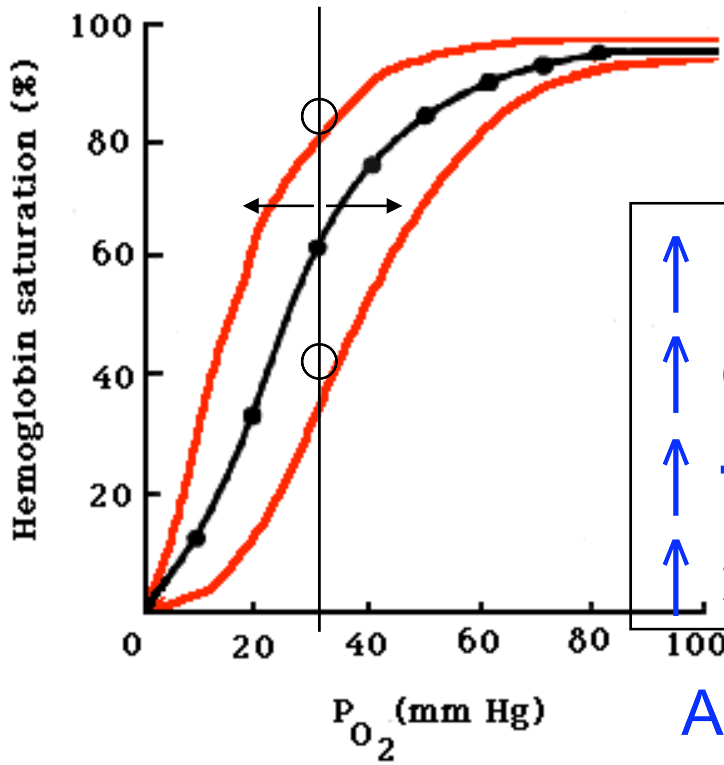
Hemoglobin affinity for oxygen is not static

left shift (lungs)

- ↓ H^+
- ↓ CO_2
- ↓ temperature
- ↓ 2,3 BPG

Summary

At any PO_2 more O_2 bound.



right shift tissues

- ↑ H^+ (Bohr shift)
- ↑ CO_2
- ↑ temperature
- ↑ 2,3 BPG

At any PO_2 less O_2 bound.

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Slide 6: Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.
Slide 7: McGraw-Hill
Slide 21: Source Undetermined