Effects of exercise on the respiratory system.

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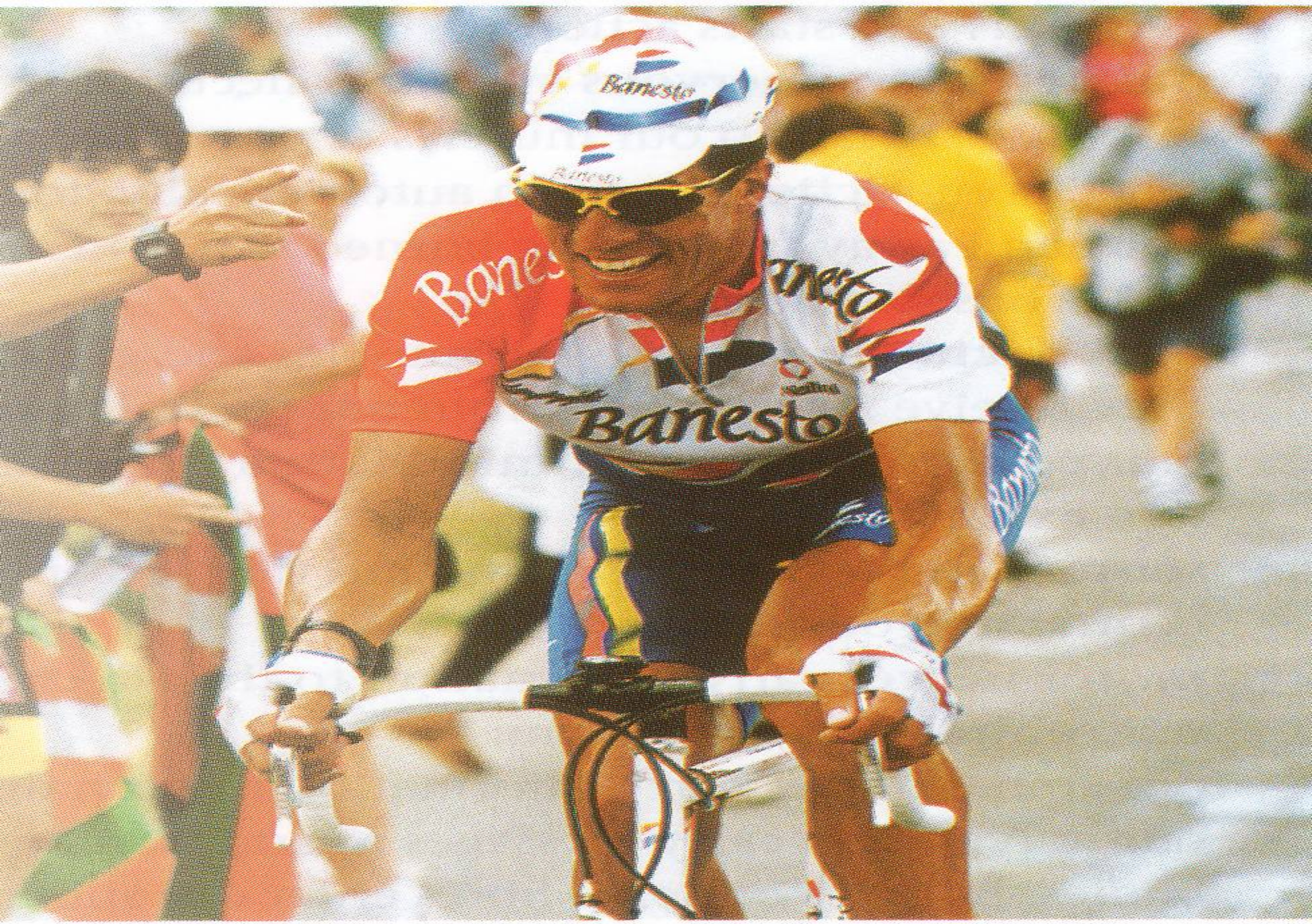


When we exercise, we need more oxygen

Objectives

By the end of this lecture the students should be able to: -

1-Describe the effects of moderate and severe exercise on oxygen consumption, and ventilation volumes.

2- Interpret the effects of exercise on arterial PO_2, PCO_2 and H^+ ions.

3-Define the diffusing capacity of the respiratory membrane, and its typical values at rest, and explain its changes in exercise.

4-Explain causes of hyperventilation in exercise.

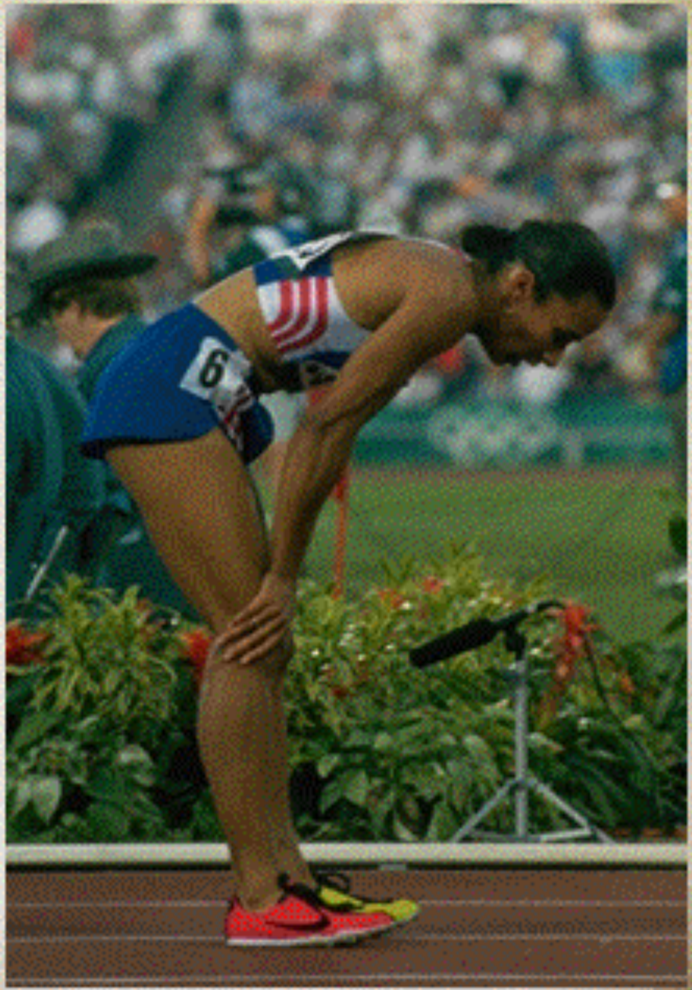
The respiratory system and exercise

When we exercise more oxygen is needed by the working muscles and more carbon dioxide must be removed from the muscles.

As a result:

- our rate of breathing increases;
- we increase the depth of our breathing, up to our vital capacity;
- we increase the blood flow through the lungs;
- we increase the oxygen taken up and used by the body.

Oxygen used during exercise can be up to twenty times a person's normal oxygen uptake.



Effect of Exercise on the respiratory system

- The blood gases do not always have to become abnormal for respiration to be stimulated in exercise.
- Instead, respiration is stimulated mainly by neurogenic mechanisms during exercise.

Regulation of respiration during exercise.

In strenuous exercise O2 consumption and CO2 formation may increase 20 folds but alveolar ventilation increases almost exactly in step with the increased levels of metabolism.

Therefore the arterial PO2, PCO2, PH all remain almost exactly normal.

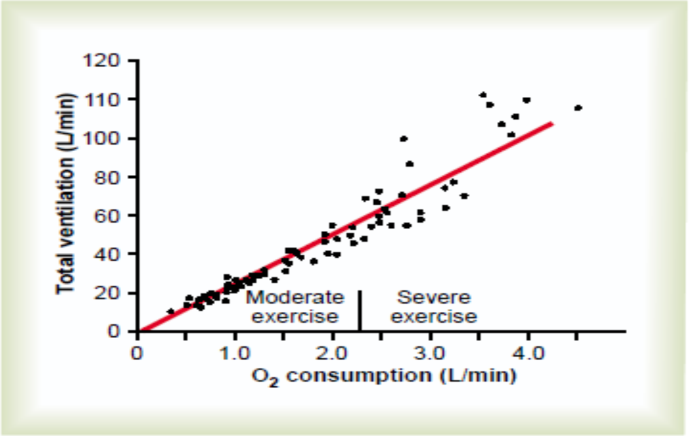


Figure 41–8

Effect of exercise on oxygen consumption and ventilatory rate. (From Gray JS: Pulmonary Ventilation and Its Physiological Regulation. Springfield, Ill: Charles C Thomas, 1950.)

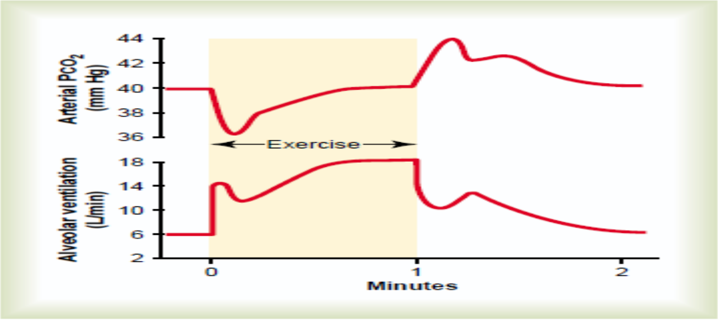


Figure 41–9

Changes in alveolar ventilation *(bottom curve)* and arterial PCO_2 *(top curve)* during a 1-minute period of exercise and also after termination of exercise. (Extrapolated to the human being from data in dogs in Bainton CR: Effect of speed vs grade and shivering on ventilation in dogs during active exercise. J Appl Physiol 33:778, 1972.)

What causes intense ventilation during exercise?

- The brain, on transmitting motor impulses to the exercising muscles, transmits at the same time collateral impulses into the brain stem to excite the respiratory center.
- A large share of the total increase in ventilation begins immediately on initiation of the exercise, before any blood chemicals have had time to change. This is mostly due to neurogenic signals

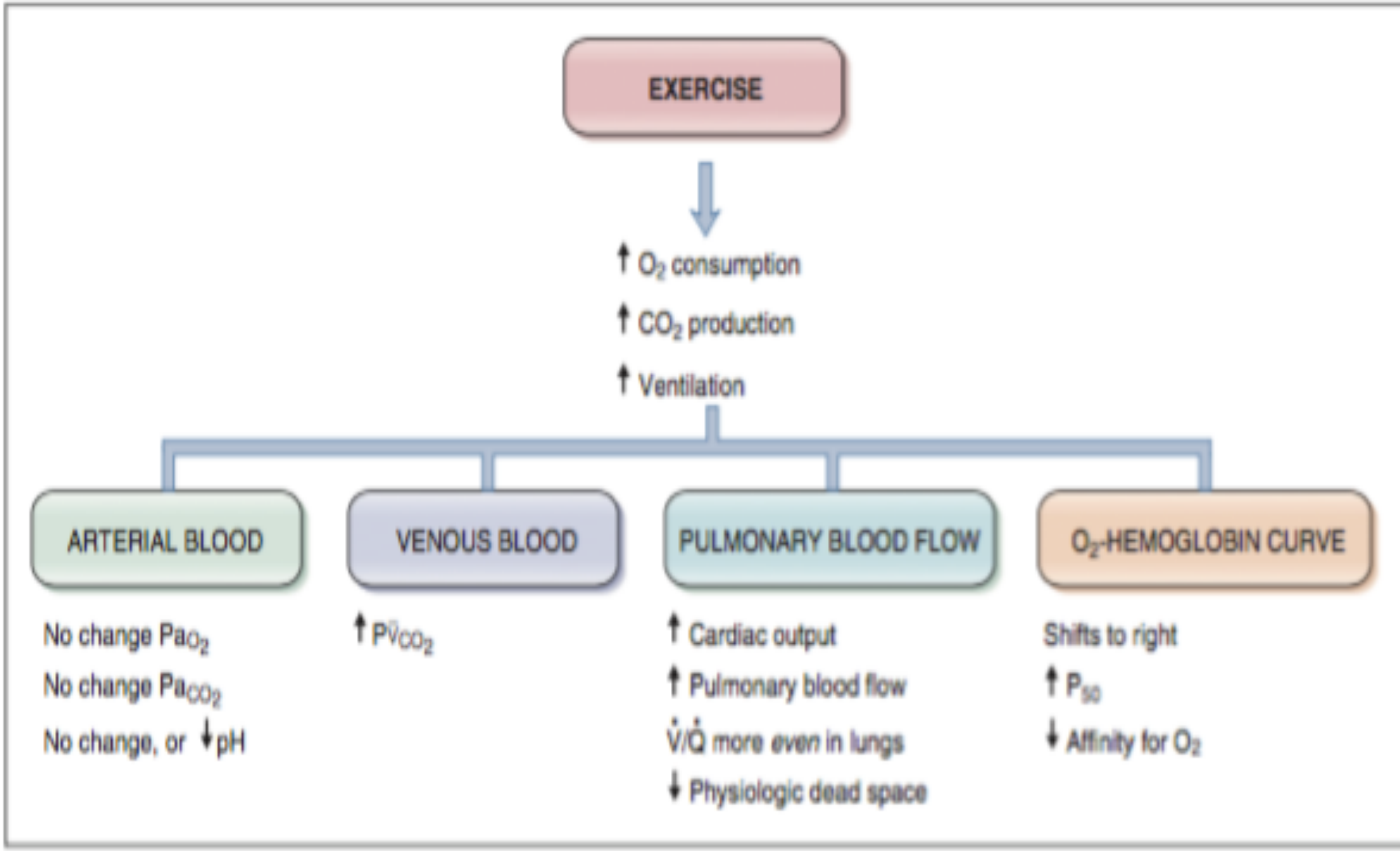
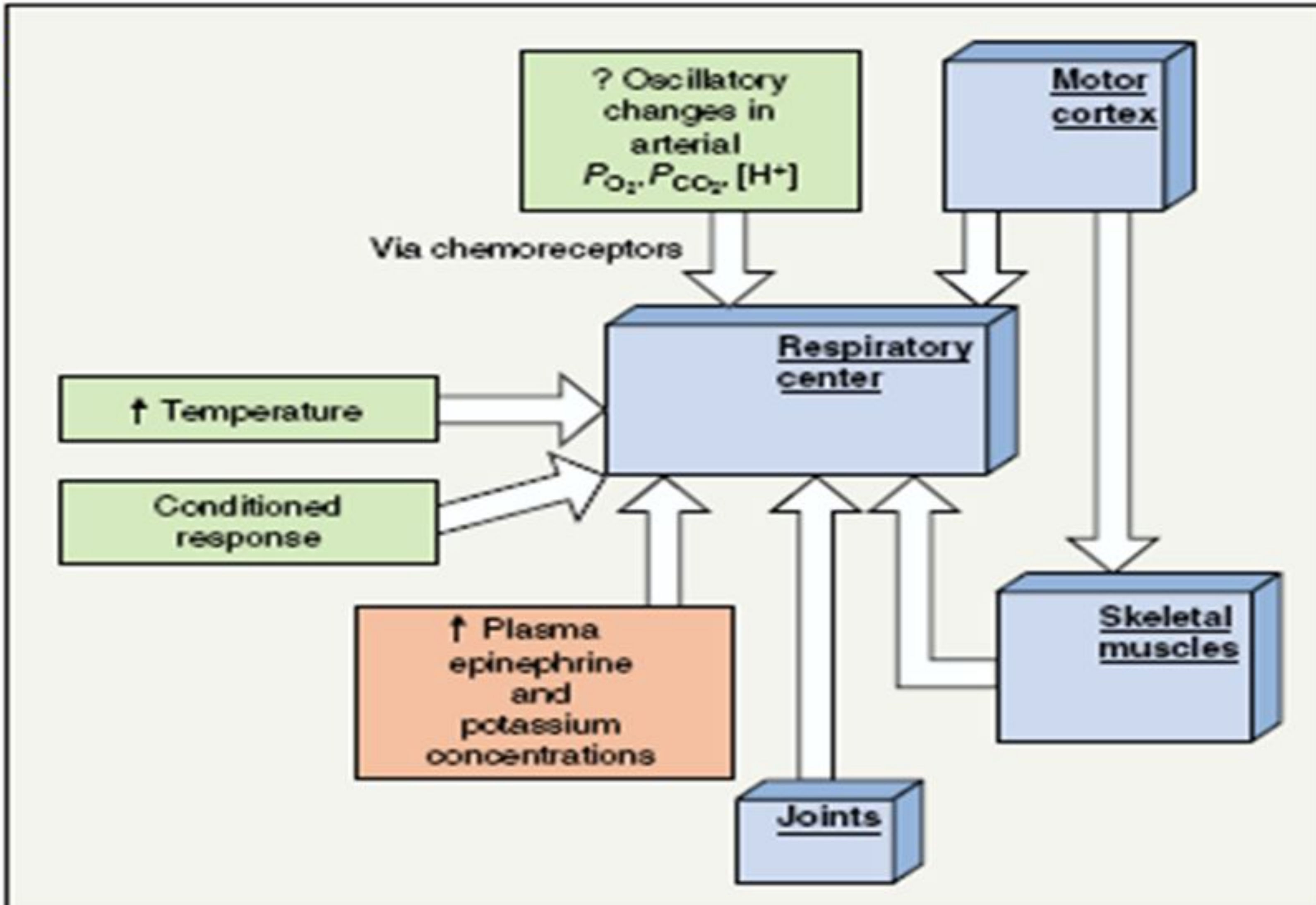


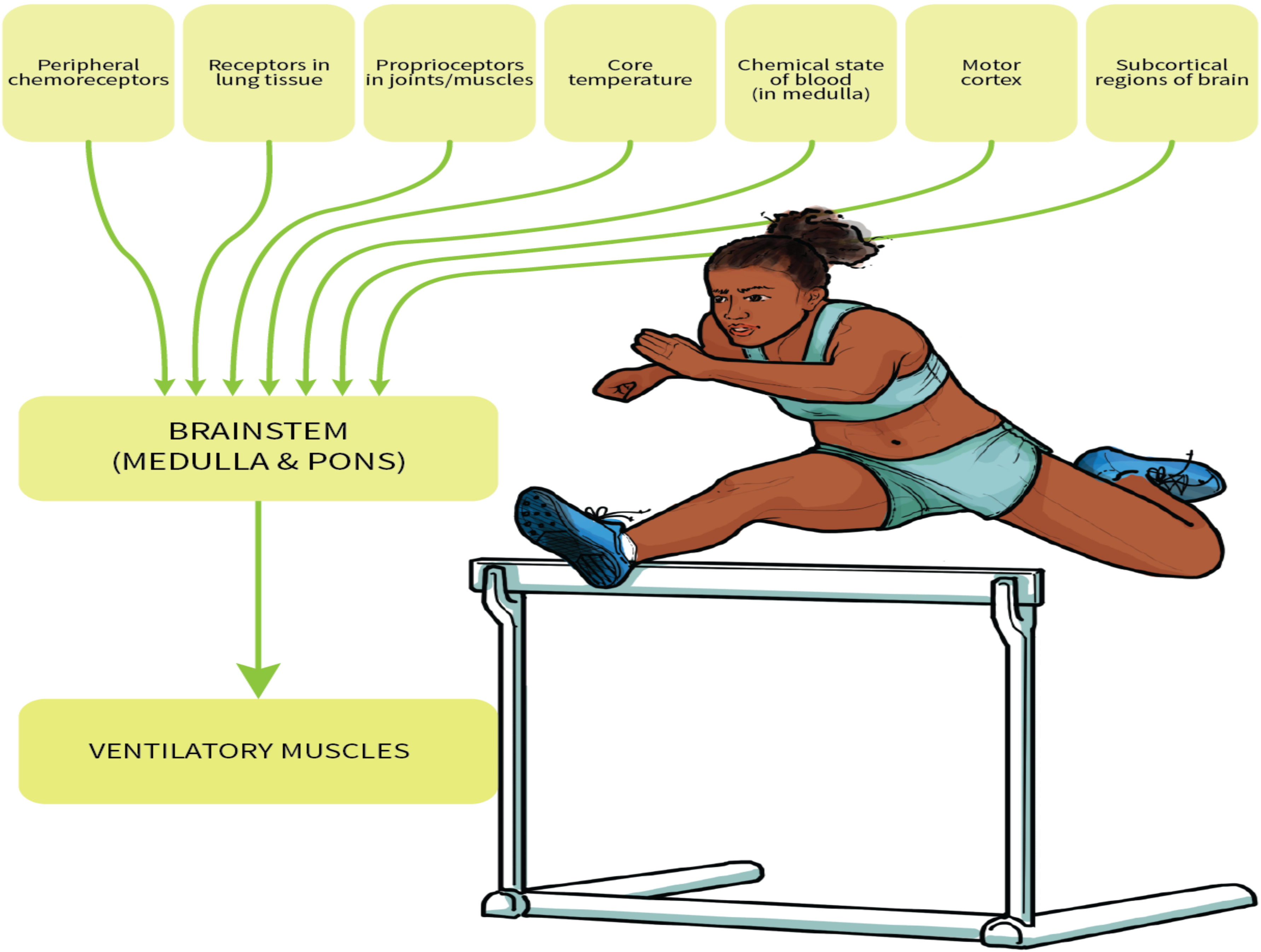
Fig. 5.34 Responses of the respiratory system to exercise.

Summary of factors that stimulate ventilation during exercise



What cause intense ventilation during exercise?

- Neural signals from the motor areas of the brain to the respiratory center.
- The joint proprioceptors
- Body temperature (hypothalamus).
- Possibility that the neurogenic factor for control of ventilation during exercise is a learned response.


Peripheral chemoreceptors
Receptors in lung tissue
Proprioceptors in joints/muscles
Core temperature
Chemical state of blood (in medulla)
Motor cortex
Subcortical regions of brain
BRAINSTEM (MEDULLA & PONS)
VENTILATORY MUSCLES

Relation Between Chemical and Nervous Factors in the Control of Respiration During Exercise.

- Direct nervons signal stimulate the respiratory center *almost* the proper amount to supply the extra oxygen required for exercise and to blow off extra carbon dioxide.
- Occasionally, the nervous respiratory control signals are either too strong or too weak.
- Then chemical factors play a significant role in bringing about the final adjustment of respiration required to keep the O2, CO2, and H+ ion concentrations of the body fluids as nearly normal as possible.

The Neurogenic Factor for Control of Ventilation During Exercise Is a Learned Response.

- The ventilatory response during exercise, is at least partly a *learned* response.
- With repeated periods of exercise, the brain becomes more able to provide the proper signals required to keep the blood PCO2 at its normal level.
- The cerebral cortex is involved in this learning, because experiments that block only the cortex also block the learned response.

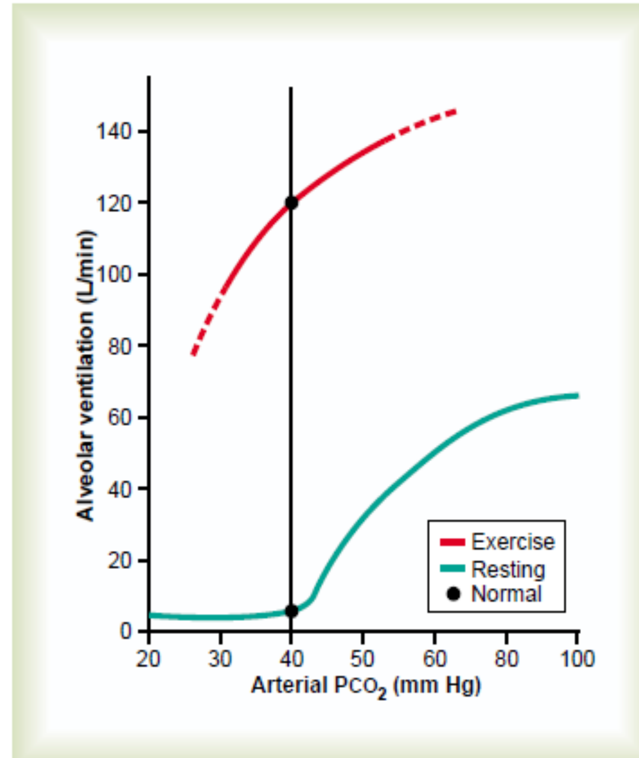


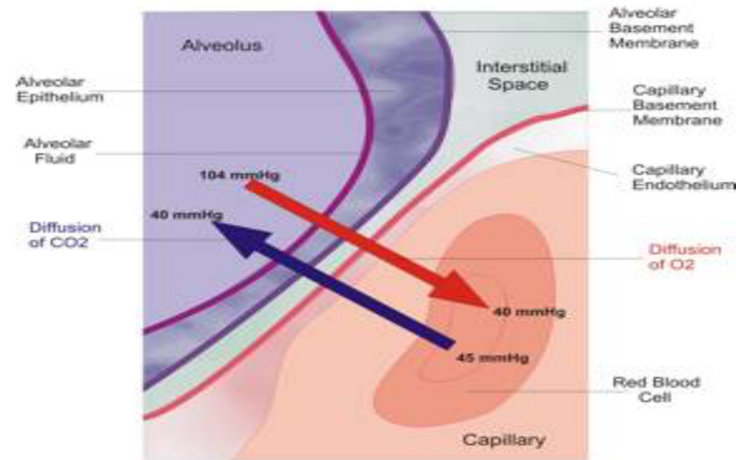
Figure 41–10

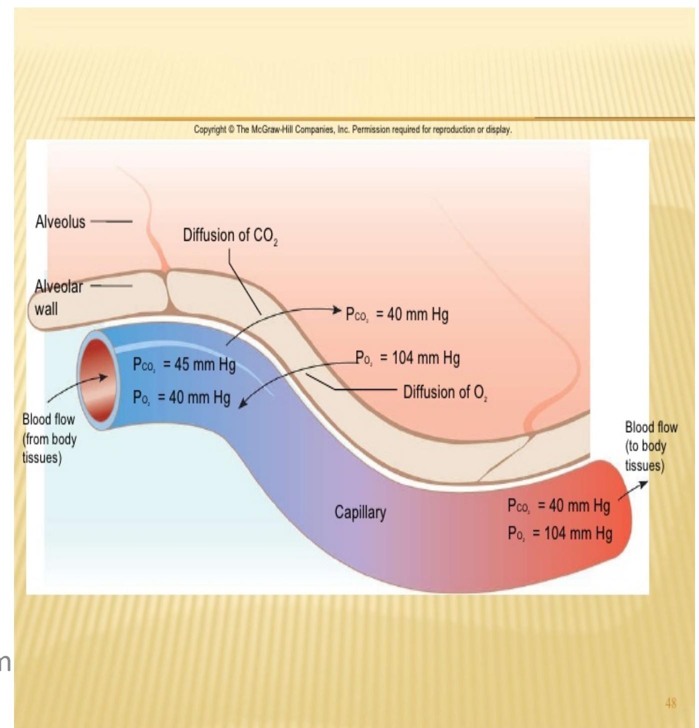
Approximate effect of maximum exercise in an athlete to shift the alveolar P_{CO_2}-ventilation response curve to a level much higher than normal. The shift, believed to be caused by neurogenic factors, is almost exactly the right amount to maintain arterial P_{CO_2} at the normal level of 40 mm Hg both in the resting state and during heavy exercise.

Diffusion capacity of the respiratory membrane

- Is the volume of gas that diffuses through the membrane each minute for a pressure difference of 1mmHg.
- **Diffusing capacity for oxygen at rest**

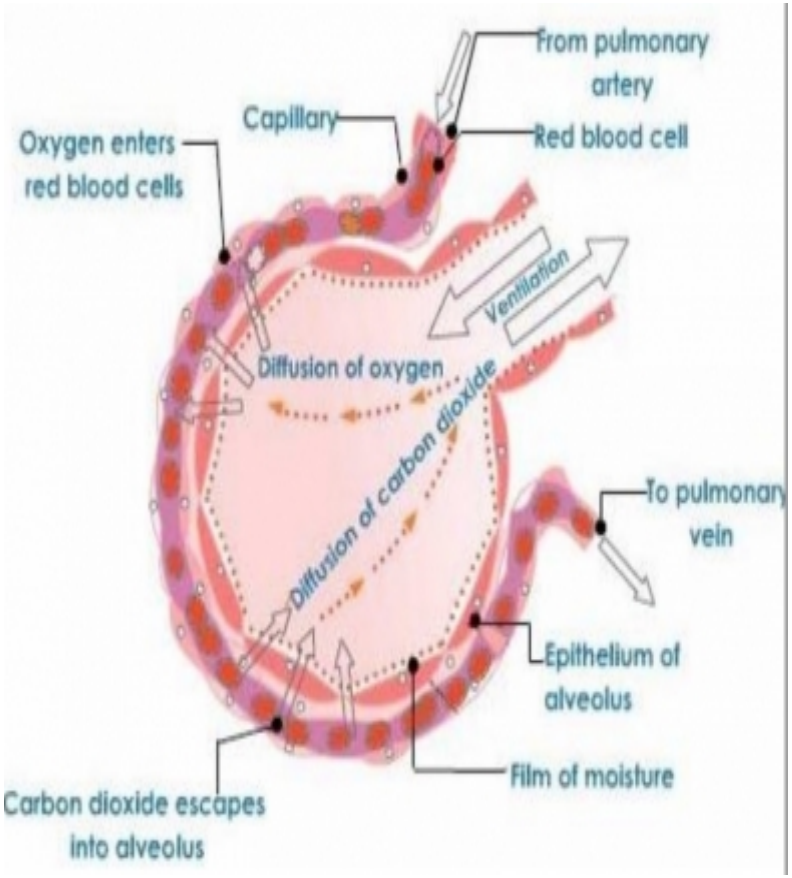
  21ml/min/mmHg
- Even if the oxygen pressure difference across the respiratory membrane is 11mmHg----------11x21= 230ml oxygen diffusing through the membrane each minute.
- During rest tissues consume 250 ml O2 /min





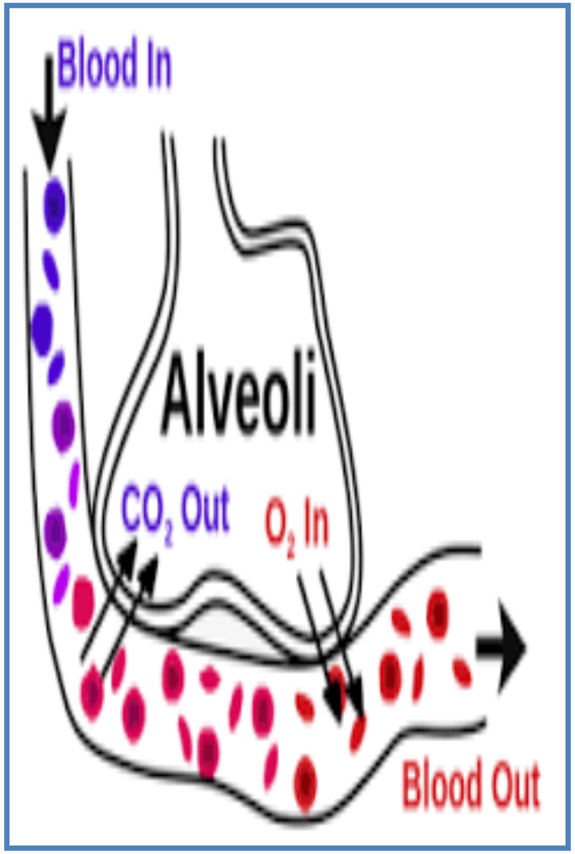
Changes in the oxygen- diffusing capacity during exercise

- **65ml/min/mmHg**
- This is due **to increased number of open pulmonary capillaries** which was dormant, thereby increasing the surface area for gas exchange.
- In addition to **increased alveolar ventilation**.



Diffusing capacity for carbon dioxide

- It diffuses 20 times greater than oxygen due to greater diffusion coefficient which is 20 times that for oxygen.
- Diffusion capacity for carbon dioxide 400ml/min/mmHg.
- During exercise 1200 to 1300ml/min/mmHg.



- During exercise the oxygen requirement increased 20 times, and cardiac output increased and so the time blood remained in the pulmonary capillaries becomes less than half normal despite the fact that additional capillaries open up.
- But the blood is almost completely saturated with oxygen when it leaves the pulmonary capillaries.

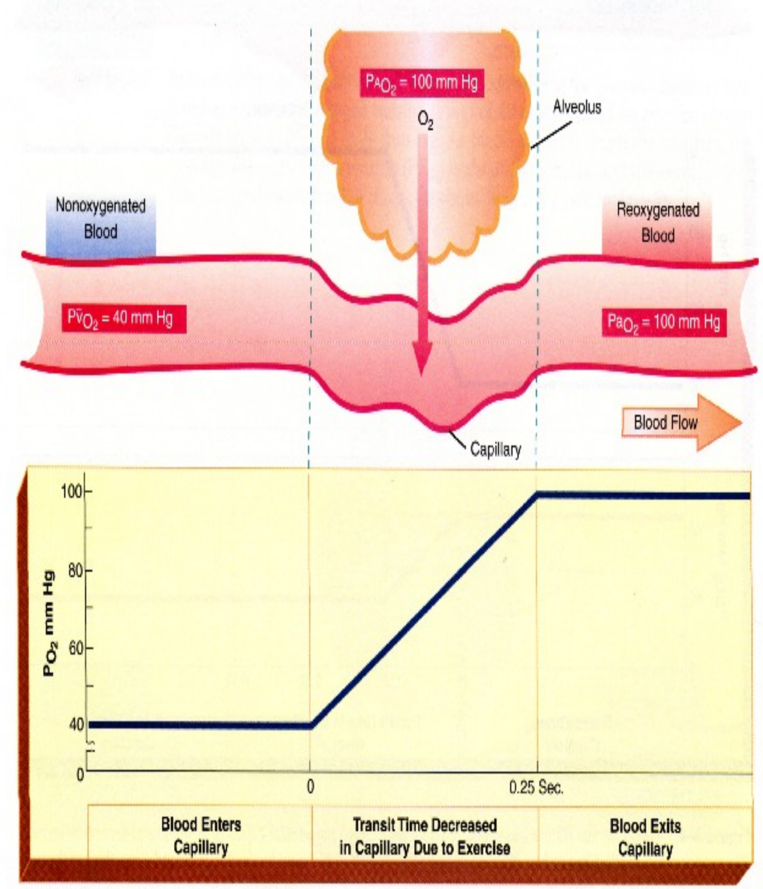
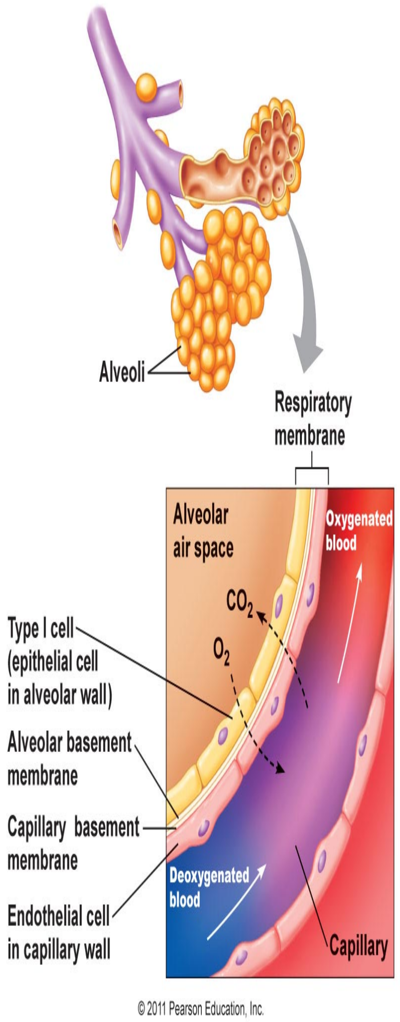


Figure 3-5. *During exercise or stress, the total transit time for blood through the alveolar-capillary membrane is less than normal (normal = 0.75 sec). In the healthy individual, however, oxygen equilibrium usually occurs. $P\bar{v}_{O_2}$ = partial pressure of oxygen in mixed venous blood; PA_{O_2} = partial pressure of oxygen in alveolar gas; Pa_{O_2} = partial pressure of oxygen in arterial blood.*

Reasons for this are as follow:

1- The diffusing capacity for oxygen increases almost three fold during exercise, this results mainly from increasing numbers of capillaries participating in the diffusion, and a more even V/Q ratio all over the lung.

2- At rest the blood normally stays in the lung capillaries about three times as long as necessary to cause full oxygenation. Therefore, **even with shortened time of exposure in exercise, the blood is still fully oxygenated or nearly so.**



Oxygen Consumption and Pulmonary Ventilation in Exercise.

- Normal oxygen consumption for a young man at rest is about 250 ml/min.
- However, under maximal conditions,
- this can be increased to approximately the following average levels:

ml/min

- Untrained average male -------------- 3600
- Athletically trained average male --- 4000
- Male marathon runner------------------ 5100

Gasping for air after a hard race, to repay the oxygen debt.

OXYGEN DEBT-

Oxygen Debt Is the Extra Consumption of Oxygen After Completion of Strenuous Exercise (about 11.5 liters), .

You will develop oxygen debt after about 5 minutes or more of constant exercise. This is the point when the exercise becomes ANAEROBIC (without the use of oxygen) and which has to be paid back. If the exercise is just AEROBIC (with oxygen) there will be no oxygen debt.

Oxygen Debt :-

Excess post exercise O_2 consumption.

Required to convert :-

1- **Lactic acid to glucose.**

2- **ADP → ATP.**

3- **Creatine phosphate to its original state.**

4- **body temperature to normal.**

Oxygen Deficit :-

Cellular energy use exceeds O_2 uptake.

Runners at the end of a race are often left gasping for air