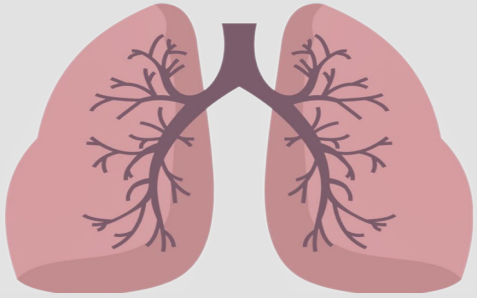
Effects of exercises on the respiratory system



Respiratory Block

Physiology 439 team work

- Black: in male / female slides
- Red : important
- Pink: in female slides only
- Blue: in male slides only
- Green: notes
- Gray: extra information
- Textbook: Guyton + Linda

Editing file

@Physiology_439

Objectives :

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

02 Interpret the effects of exercise on arterial (PO_2, PCO_2 and H^+) ions.

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

04 Explain causes of hyperventilation in exercise.

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.

Notice the increase of ventilation as well as O2 consumption

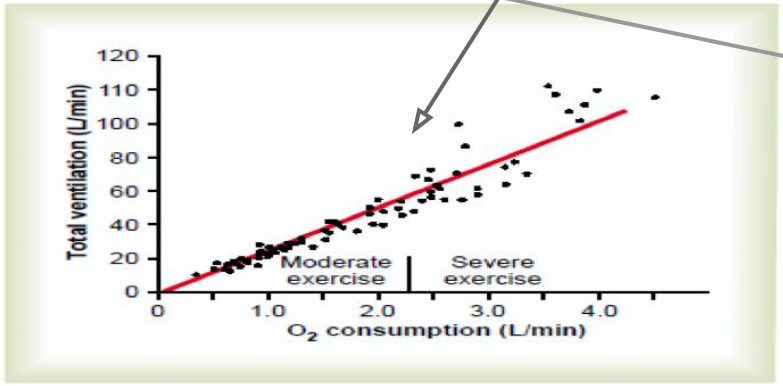


Figure 41–8

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

Initial drop in arterial PCO2 due to the sudden increase in ventilation

The body trying to maintain the arterial PCO2 almost exactly normal

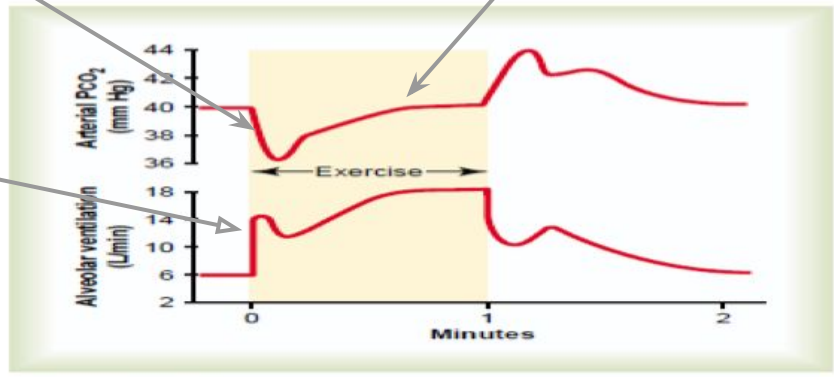


Figure 41–9

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 cause 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

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

Responses of the respiratory system to exercise

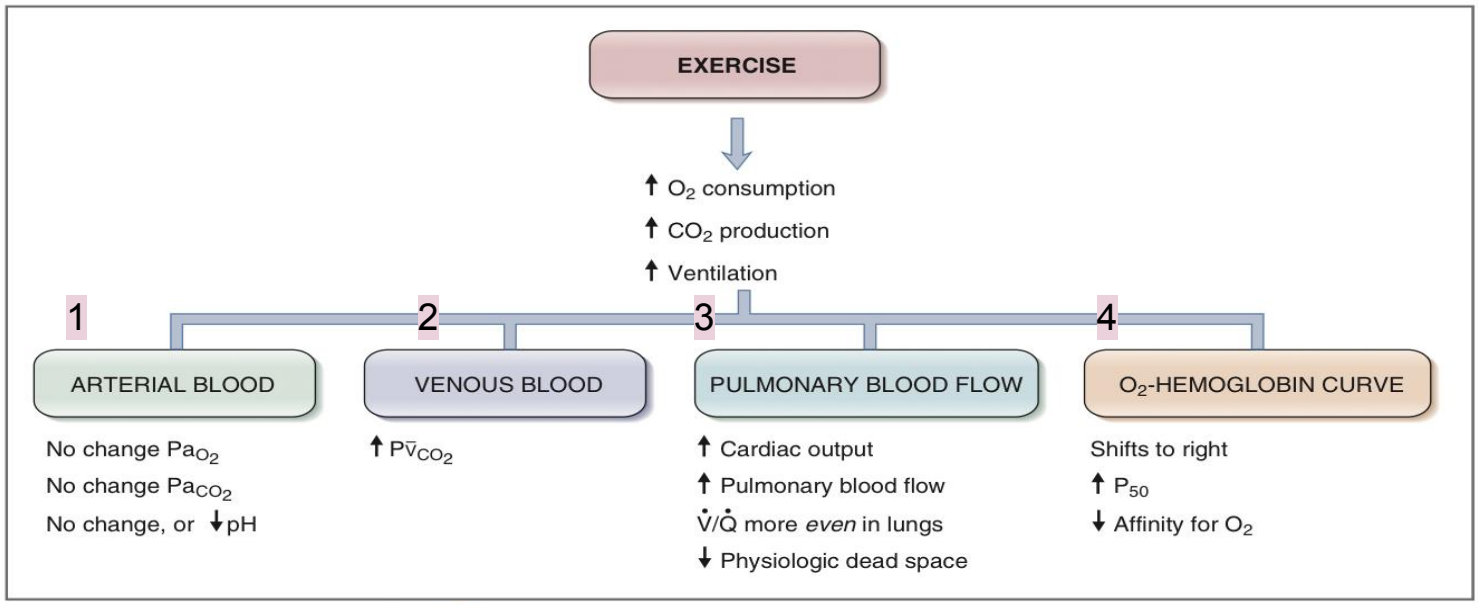


Fig. 5.34 **Responses of the respiratory system to exercise.**

1

Remarkably, mean values for arterial PO2 and PCO2 do not change during exercise. An increased ventilation rate and increased efficiency of gas exchange ensure that there is neither a decrease in arterial PO2 nor an increase in arterial PCO2. (The arterial pH may decrease, however, during strenuous exercise because the exercising muscle produces lactic acid.)

2

The PCO2 of mixed venous blood must increase during exercise because skeletal muscle is adding more CO2 than usual to venous blood

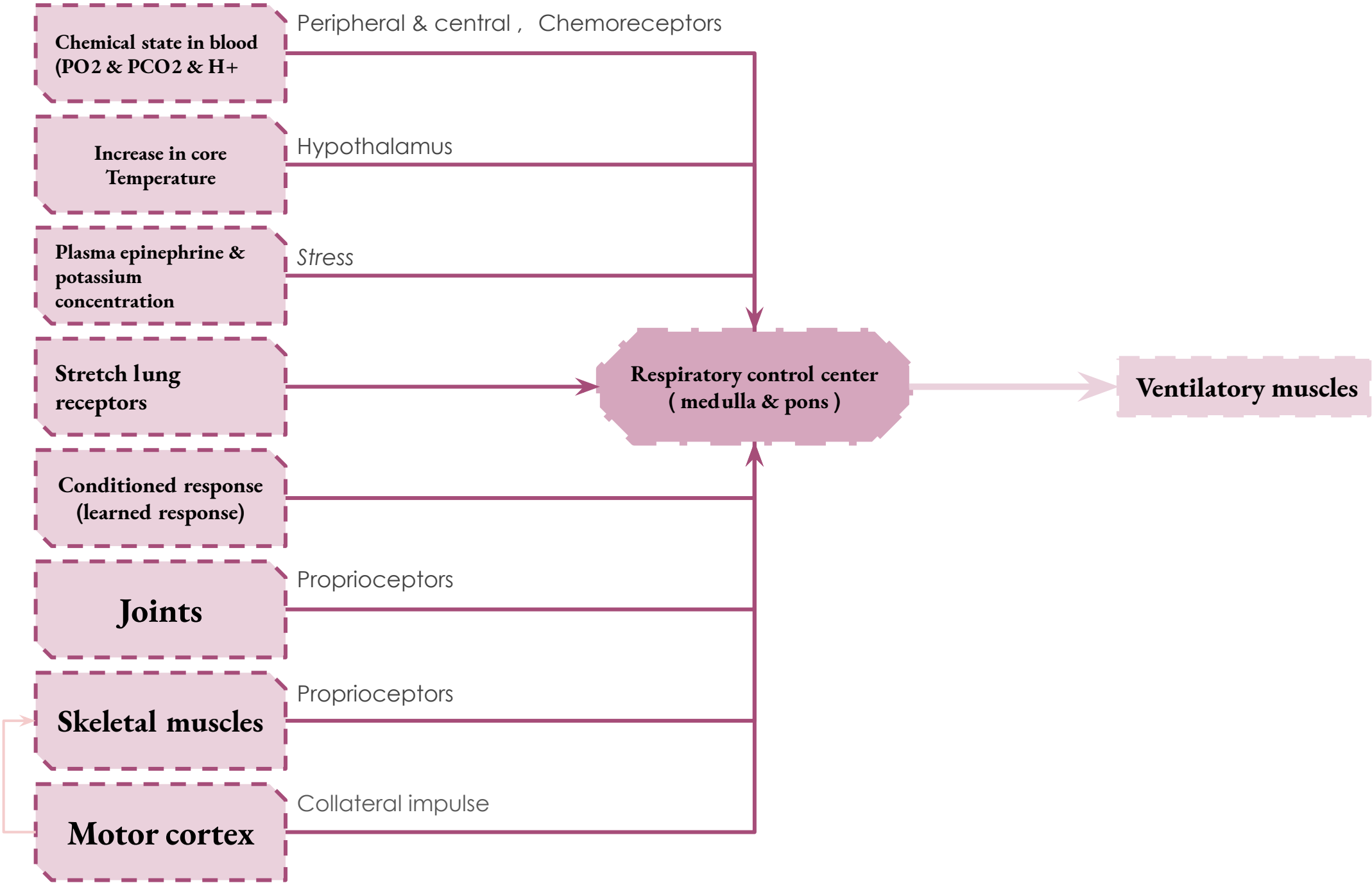
3

Cardiac output increases during exercise to meet the tissues' demand for O2. Because pulmonary blood flow is the cardiac output of the right heart, **pulmonary blood flow increases**. There is a decrease in pulmonary resistance associated with perfusion of more pulmonary capillary beds, which also improves gas exchange. As a result, pulmonary blood flow becomes more evenly distributed throughout the lungs, and the V/Q ratio becomes more "even," producing a decrease in the physiologic dead space.

4

During exercise, the O2-hemoglobin dissociation curve shifts to the right). There are multiple reasons for this shift, including increased tissue PCO2, decreased tissue pH, and increased temperature. The shift to the right is advantageous, of course, because it is associated with an increase in P50 and decreased affinity of hemoglobin for O2, making it easier to unload O2 in the exercising skeletal muscle.

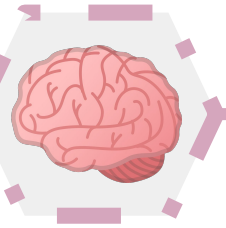
Summary of factors that stimulate ventilation during exercise



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

Brain

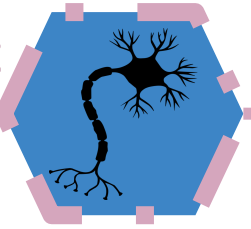
1



Direct nervous signal stimulate the respiratory center almost the proper amount to supply the extra oxygen required for exercise and to blow off extra carbon dioxide

Nervous respiratory system

2



Occasionally, the nervous respiratory control signals are either too strong or too weak

Chemical factors

3

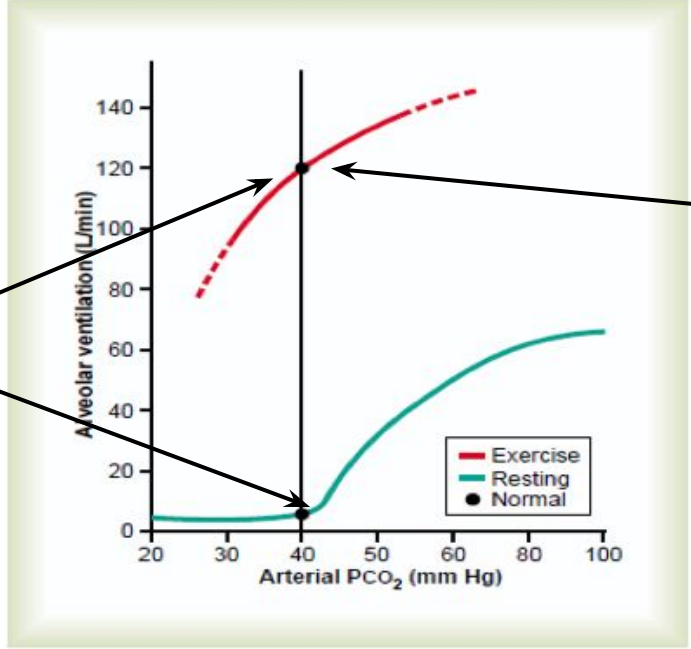
Then chemical factors play a significant role in bringing about the final adjustment of respiration required to keep the O2, CO2, and H+ ion concentrations of the body fluids as nearly normal as possible

The Neurogenic Factor for Control of Ventilation During Exercise Is a Learned Response (trained , skilled , gained etc…)

- 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

Important figure

Arterial PCO2 at a normal level of 40 mm Hg both in resting and during heavy exercise



Learned response
The alveolar ventilation increase to a level much higher than the normal to maintain arterial PCO2 In the normal level

Sometimes we see weightlifters take few deep breaths unconsciously before even try to rise the load, so the ventilation rate increase immediately with the beginning of exercise . Also that might happen when we see exam's class, our heart rate increase even if we don't have exam

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 1 mmHg

	O_2 diffusing capacity	CO_2 diffusing capacity It diffuses 20 times greater than O_2 due to its diffusion coefficient which is 20 times that of O_2
During rest	21 ml/min/mmHg ➢ Even if the oxygen pressure difference across the respiratory membrane is 11 mmHg —>11x21= 230ml oxygen diffusing through the membrane each minute. يعني حجم الاكسجين الي يدخل من الAlveoli للدم كل دقيقة هو 21ml لكل اختلاف 1 في الضغط. لكن الجسم يحتاج اقل شي 230ml من الاكسجين بالدقيقة؛ فنستنتج ان اختلاف الضغط ب11mmHg هو اقل ضغط يكفيني عشان اخذ احتياجي من الاكسجين بهالدقيقة لان كل ضغط منهم بيعطيني 21ml من الاكسجين. ➢ During rest tissues consume 250 , 230 ml O_2/min	400 ml/min/mmHg 21*20=400 الأكسجين قلنا 21 و Diffusion ال CO_2 اكبر منه الأكسجين ب20 مره يعني تقريبا بيكون 400
During exercise (Increases 3 folds)	65 ml/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.	Increase to 1200-1300 ml/min/mmHg نفس الشئ الأكسجين اثناء التمارين 65 ف يعني 65*20=1300

Extra

From Guyton

How to measure the diffusion capacity of Oxygen and Carbon Dioxide

The diffusing capacity for **CO_2** has never been measured because CO_2 diffuses through the respiratory membrane so rapidly that the average PCO_2 in the pulmonary blood is not far different from the PCO_2 in the alveoli—the average difference is less than 1 mm Hg

It is not practical to measure the **O_2**-diffusing capacity directly because it is not possible to measure accurately the O_2 tension of the pulmonary capillary blood.

However, the diffusing capacity for CO can be measured accurately because the CO tension in pulmonary capillary blood is zero under normal conditions. So, we measure O_2 capacity using CO

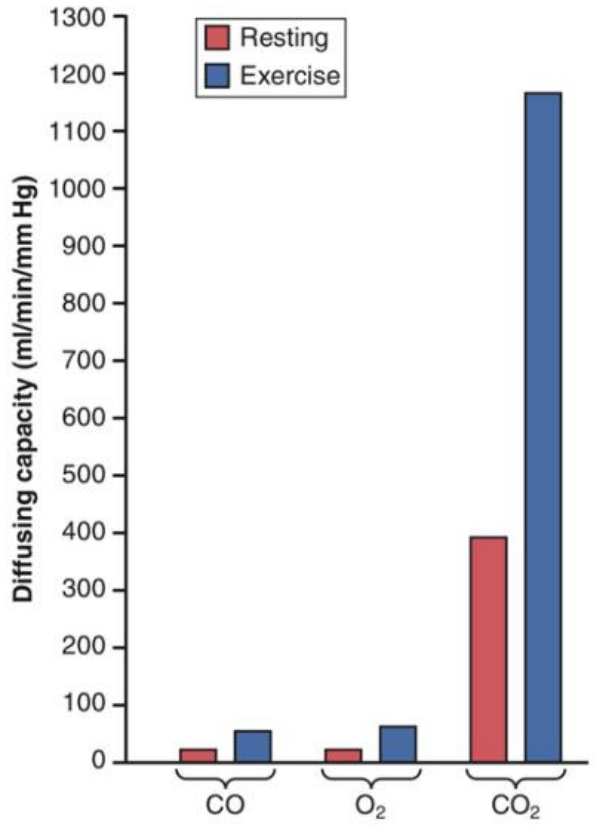


Figure 40-10. *Diffusing capacities* for carbon monoxide, oxygen, and carbon dioxide in the normal lungs under resting conditions and during exercise.

During exercise :

the oxygen requirement increased 20 times	cardiac output increased	Additional capillaries open up	The **time** blood remained in the pulmonary capillaries becomes **less** than half normal

But, the blood is almost completely saturated with oxygen when it leaves the pulmonary capillaries!

How?

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

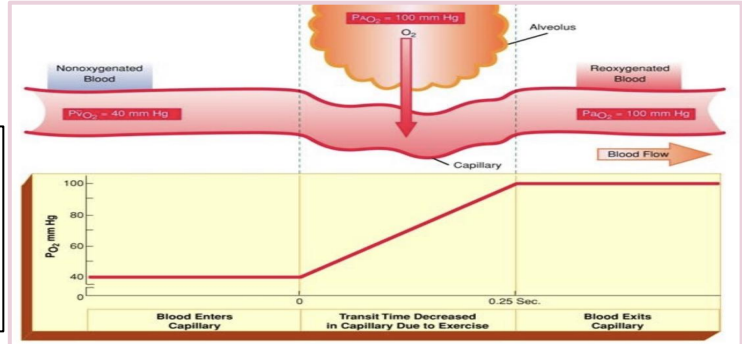
2- <u>At rest the blood normally stays in the lung capillaries about three times as long as necessary</u> to cause full oxygenation.

Therefore, even with shortened time of exposure in exercise, **the blood is still fully oxygenated or nearly so.**

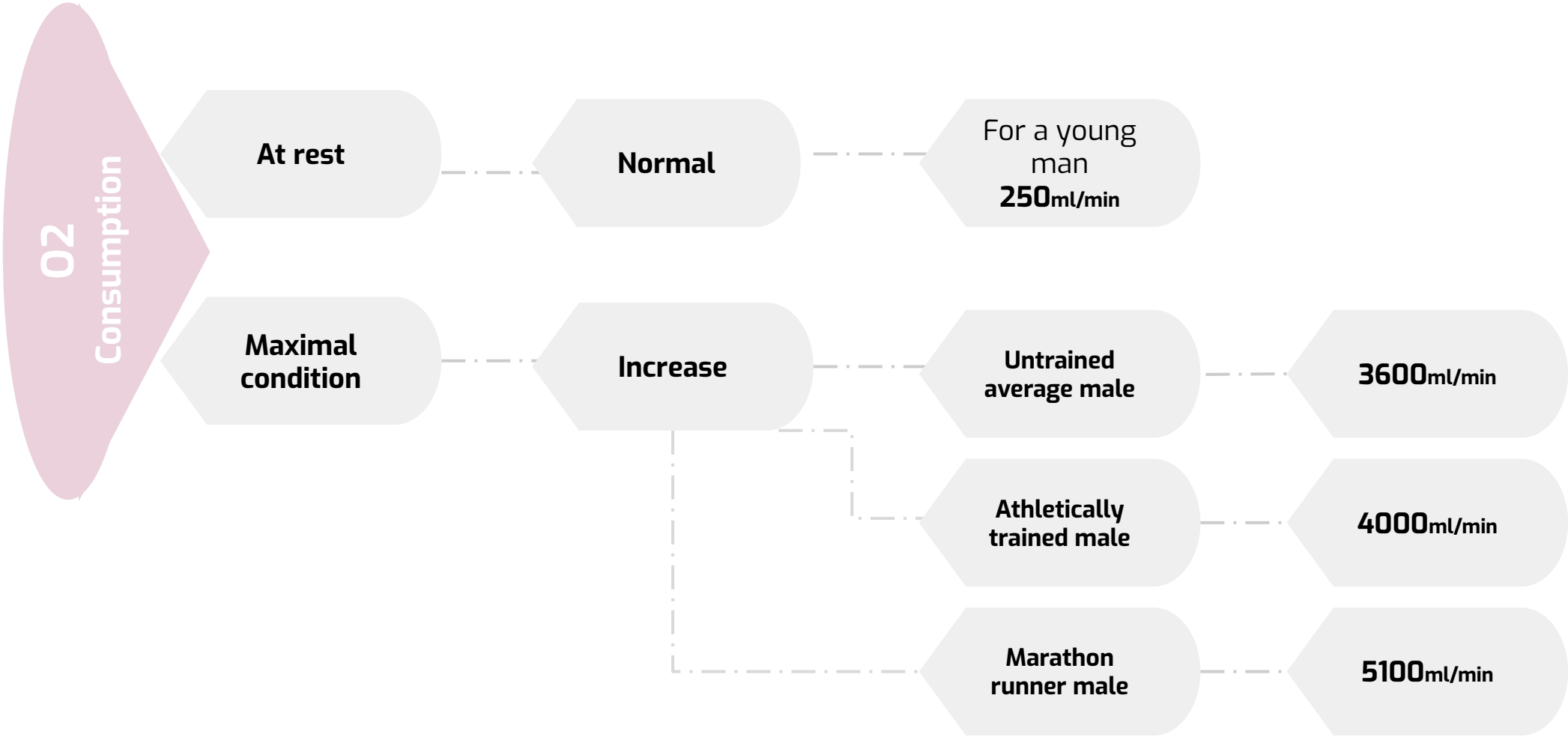
3-Dilatation of the other capillaries.

4-In addition to increased alveolar ventilation.

The curve show how the blood speed increase when it enter the pulmonary capillaries But that doesn't affect the saturation of O_2 and the blood maintain normal PO_2



Oxygen consumption and pulmonary ventilation in exercise



Oxygen Debt

It's the extra consumption of oxygen after completion of strenuous exercise. And its amount= about **11.5** liters of **O_2**.

1. You are doing constant exercise
2. After 5 min or more, exercise becomes ANaerobic
3. Anaerobic means **no** O_2 (here O_2 debt will start)
4. Your body will consume dissolved O_2 present in blood
5. Your hemoglobin and myoglobin now are deoxygenated
6. After the exercise, your body turns to its aerobic condition.
7. now you have to pay back all the O_2 that you used during exercise
8. That's why you start hyperventilation after exercise, to restore the O2 that you used during exercise
9. There is **no** O_2 debt in Aerobic condition.

After you finish the exercise, and paid back oxygen debt, you will still hyperventilated and consuming oxygen after exercise .. WHY? because When you were in anaerobic condition, you have used:

1. ATP, so you convert it to ADP.
2. Glucose, so you convert it to lactic acid.
3. Creatine phosphate.
4. High body temperature.

Excess post O_2 debt consumption is required to convert;

- ADP to ATP
- Lactic acid to glucose
- Creatine phosphate to its origin state
- Body temperature to its normal

Oxygen deficit:
Cellular energy use exceeds O_2 uptake.

متى تحصل هذه الحالة؟ اذا كان استهلاك الانسجة لـO_2 اكبر من الكمية اللي يقدر الشخص انه يحصل عليها.

Quiz

1- What happens during exercise?

A. Blood flow is uniform throughout the lung
B. Lung-diffusing capacity increases because blood flow is continuous in all pulmonary capillaries
C. Pulmonary blood volume decreases
D. The transit time of blood in the pulmonary capillaries does not change from rest

2-what is the main cause of intense ventilation during exercise ?

A. Changes in PO_2 and PCO_2
B. Changes in PCO_2 only
C. Brain cortex
D. Who said there is intense ventilation during exercise ?

3- During strenuous exercise, O_2 consumption and CO_2 formation can increase as much as 20-fold. Va increases almost exactly in step with the increase in O_2 consumption. Which option best describes what happens to the mean arterial O_2 tension (Po_2), CO_2 tension (Pco_2),and pH in a healthy athlete during strenuous exercise?

	Arterial Po_2	Arterial Pco_2	Arterial pH
A)	Decreases	Decreases	Decreases
B)	Decreases	Increases	Decreases
C)	Increases	Decreases	Increases
D)	Increases	Increases	Increases
E)	No change	No change	No change

4-Which of the following describes diffusing capacity of O_2 in the lung?

A. Does not change during exercise
B. Is greater than diffusing capacity for CO_2
C. Is greater in residents at sea level than in residents At 300 meter altitude
D. Is directly related to alveolar capillary surface area

Key Answers :

4: D
3: E
2: C
1: B

SAQs

1- which part of brain is involved in the ventilatory learned response during exercise ?

2- why the blood leaving the pulmonary capillaries is fully saturated even that O_2 consumption increase 20 folds during exercise ?

Answers: 1- cerebral cortex

2-

1- The diffusing capacity for oxygen increases almost three fold during exercise

2- at rest the blood in lung capillaries is 3 times as long as necessary

Thanks to 438 physiology team ❤️

Team leaders :

TeiF Almutiri | Abdulaziz Alkraida

Team Members

- Mishal Althunayan
- Basel Fakeeha
- Ibrahim altamimi
- Abdulaziz Alsuhaim
- Mohammad Alkatheri
- Bassam alasmari
- Morshed Alharbi
- Ahmad Al Khayat
- Mohammod alghedan
- Nawaf alghamdi
- Raed alntaifi
- Homoud alghadeb
- Mishal alhamed
- Musab alamri
- Fayez altbaa
- Khalid altowijeri
- Mohammed alsalman
- Renad Alhomaidi
- Aseel alshehri
- Noura abdulaziz
- Yasmin Al Qarni
- Alaa Alsulmi
- Farah Albakr
- Muneerah alsadhan
- Sarah alobaid
- Farrah alsaid
- Noura almsaud
- Hessah alalyan
- Rema alhdleg
- Raghad alsweed
- Raghad asiari
- Ghadah alouthman
- Haya alanazi
- Asma alamri
- Rania Almutiri
- Yara alasmari

Reviewed by

- Ghada Alothman
- homoud Algadheb

Contact us

The subleader:
Sarah alQhtani