CVS

PHYSIOLOGY

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In this sheet we'll discuss some special circulations such as: Skeletal muscles, pulmonary, Brain, and coronary circulations. Have fun

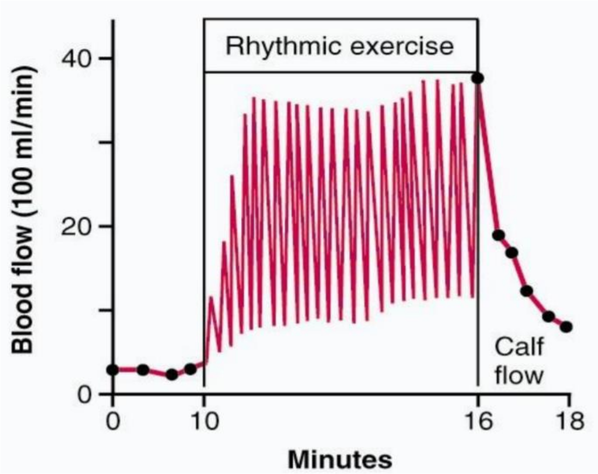
Blood Flow to Skeletal Muscles

- Blood flow control to muscles is important since skeletal muscles comprise around 40% of the body mass.
- Blood flow to skeletal muscles can increase almost 10-fold or up to 20-fold during physical activity because of vasodilation.
- We have two types of exercises:

1) Isotonic (rhythmic) exercise:

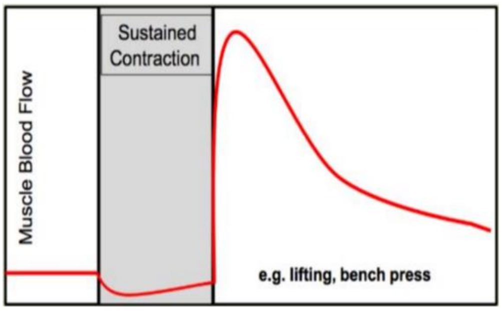
Oxygen delivery can be increased by increasing the extraction ratio from 25% to 75% and capillary density markedly increased

- In this exercise, the metabolic rate increases which induces the release of local vasodilators.
- **Overall**, blood flow increases but it is phasic. It decreases during contraction due to blood vessel compression and increases during relaxation.
- Resistance is decreased (due to local vasodilators).
- HR increases a lot during exercise with a slight increase in BP.
- This is called active hyperemia; where blood flow increases <u>during</u> exercise



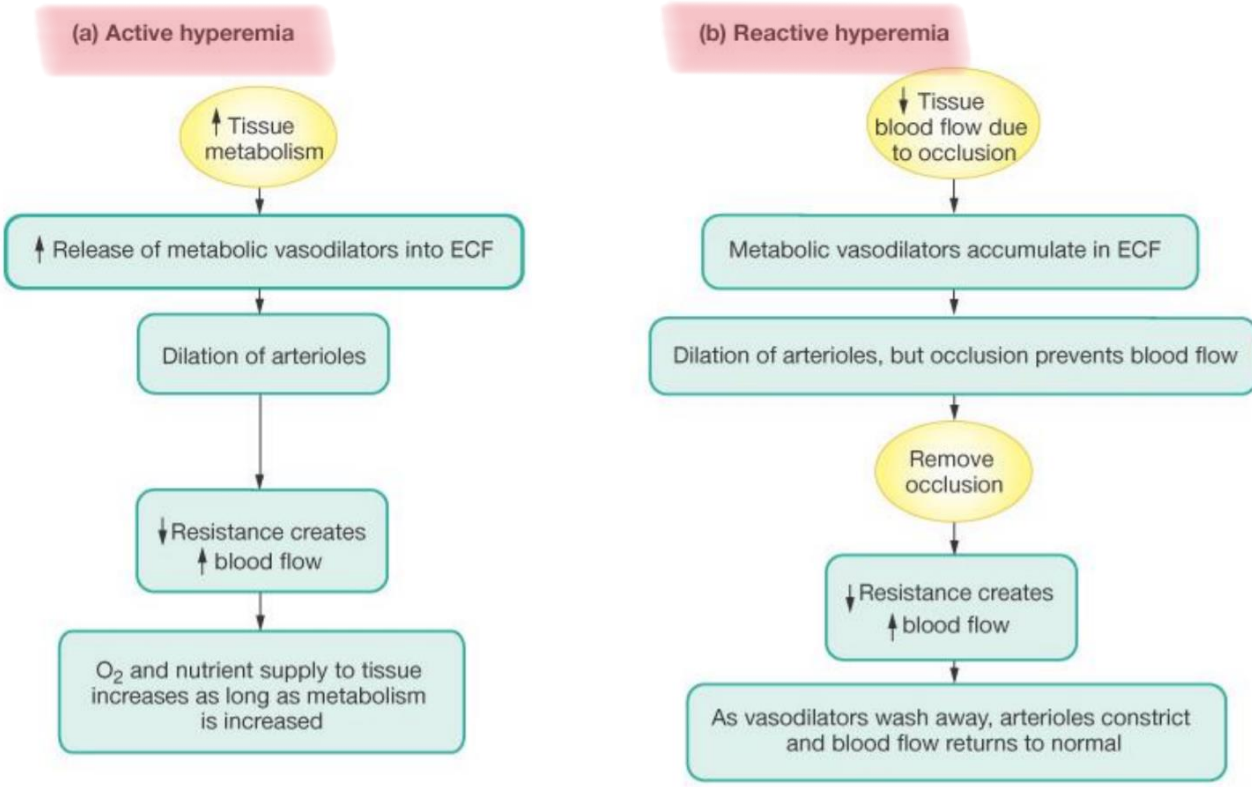
2) Isometric (sustained) exercise:

- With sustained contraction, blood flow decreases followed by a post-contraction response of increased blood flow when the contraction ends.
- During compression, local vasodilators are accumulated in response. Thus, after releasing the compression, vasodilators will markedly increase the flow.
- Resistance is increased (due to compression) with decreased blood flow during exercise.
- This is called reactive hyperemia; where blood flow increases <u>after</u> exercise



Note: during very intense exercise or sympathetic activation, high levels of epinephrine bind to α-receptors causing vasoconstriction. This is a protective response to prevent oxygen demands from exceeding cardiac muscle pumping ability.

The following figure summarizes what we have already said:



✓ Oxygen Extraction Ratio:

- It represents the percentage of oxygen extracted by the peripheral tissues from the oxygen-rich blood flow delivered to these tissues.
- Normally, the extraction ratio of the skeletal muscles at rest is 25%. So, if 20mL O_2/100mL blood reaches the tissue, it can only capture 5 mL. During exercise, it increases up to 75% (capture up to 15 mL O_2)
- <u>Muscles during exercise can meet their O2 requirements without increasing blood flow by increasing the Extraction ratio.</u>

✓ Humoral Control:

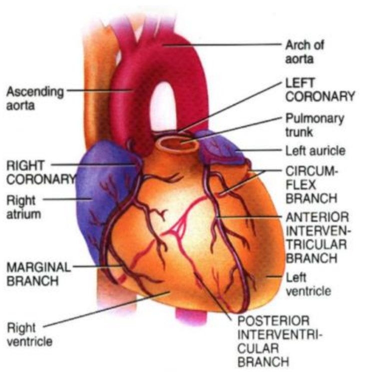
1. Adenosine (the most important one)
2. K^+
3. Osmolality
4. Endothelial-derived relaxing factor (nitric oxide)
5. H^+ (increased in acidosis)

- Nervous Control:
  - Epinephrine: Secreted from adrenals. It works on β and α receptors. Binding to β-receptors causes vasodilation in muscle and liver (especially in animals).
  - Norepinephrine: Secreted from sympathetic nervous system as well as adrenals. It works mainly on α receptors causing vasoconstriction in kidney and GIT.

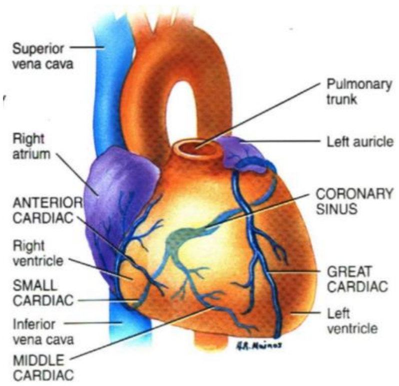
Note: Nervous control has the least contribution to blood flow control to skeletal muscles.

Blood Flow to the Heart

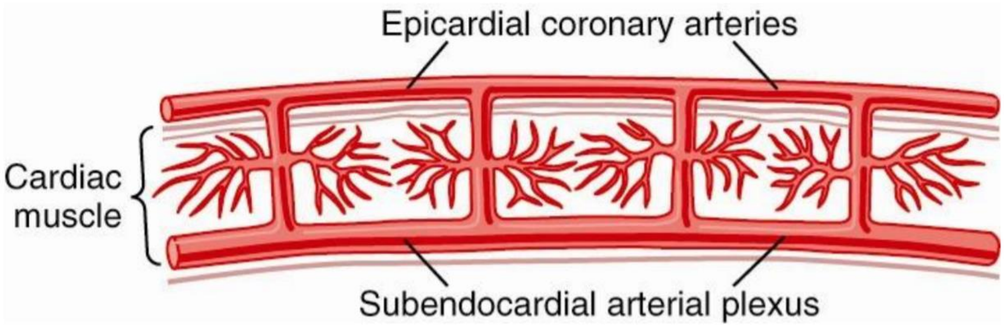
- Coronary circulation is influenced by aortic pressure and the pumping activity of the ventricles.
- During ventricular systole:
  - Coronary vessels are compressed.
  - Ceasing the myocardial blood flow.
  - Stored myoglobin supplies it with oxygen.
- During ventricular diastole (especially early diastole):
  - Upon releasing the compression due to systole, the blood flow increases, supplying the myocardium with oxygen and nutrients.
- Unlike skeletal muscles, the extraction ratio in the heart is already at maximum (75%) during rest. So, an increase demand for oxygen is met only by an increased blood flow.
- Anatomical Correlation: **The LAD artery**, which is a branch from the left coronary artery, is the most common artery to be blocked in anterior heart ischemia. For more



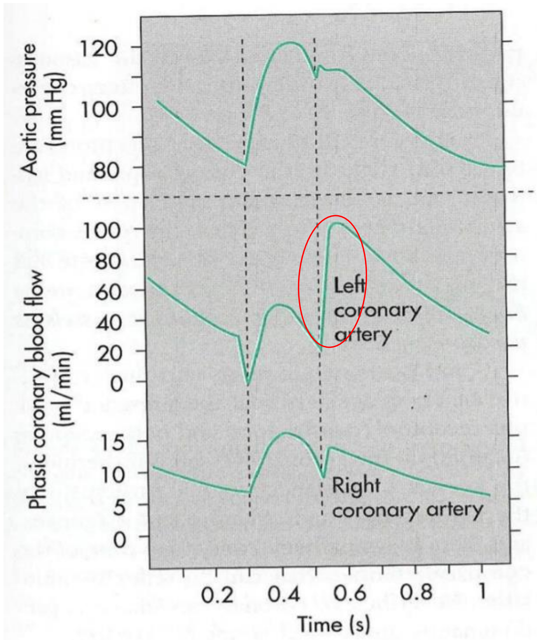
(a) Anterior view of coronary arteries

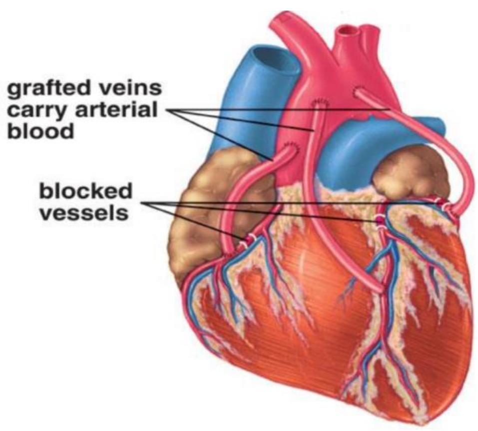


- ✓ Capillaries form two plexuses: Epicardial and Subendocardial. The subendocardial plexus is where pressure mainly increases during systole (remember it is the closest to contracting ventricles).



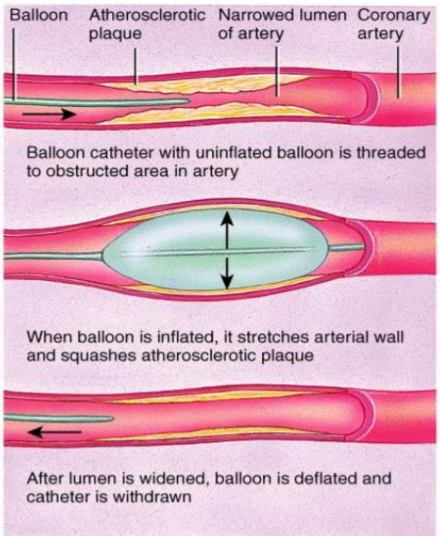
- ✓ In this figure we can see how blood flow changes during the cardiac cycle, especially in the right and left coronary arteries. We can first notice that the aortic pressure is at 80 mmHg during diastole and rises to 120 mmHg during systole. The blood flow in the left coronary artery is mainly during early diastole, indicated with the **sharp** increase in the figure. While in the right coronary artery it is mainly during systole. This is due to the strong contraction of the ventricles which compresses the vessels during systole. During systole, the pressure in the right ventricle increases moderately (up to 25 mmHg). On the other hand, the pressure in the left ventricle becomes so high (up to 120 mmHg) that <u>the vessels supplying the left ventricle are compressed and the flow decreases</u>. When systole ends the flow increases dramatically. Regarding the right ventricle, the <u>flow increases during systole due to the high pressure gradient between left and right ventricles</u> during that period. **Remember: coronary blood flow starts from the left ventricle.**



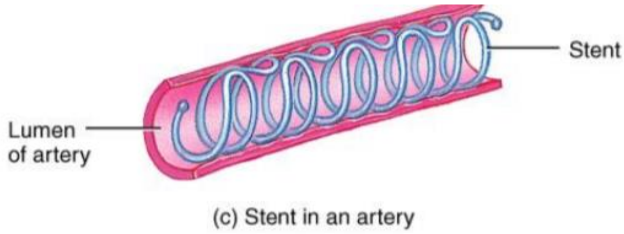


- ✓ Coronary bypassing operation: Upon coronary obstruction, coronary artery bypass graft is done. We take a segment from the saphenous vein in the leg and make an alternative route for blood from the aorta, **bypassing** the blocked part. This is used now if the patient has the 3 major arteries blocked.

- ✓ If the patient has 2 blocked arteries for instance, coronary angioplasty is done. We insert a balloon using a catheter from the femoral or radial artery all the way to the aorta then coronary arteries. We then release and inflate this balloon so it can open the blocked artery. A stent (tiny tube) can also be used instead of the balloon.



(b) Percutaneous transluminal coronary angioplasty (PTCA)



(c) Stent in an artery

Blood Flow to the Brain

- ✓ Blood flow to the brain should remain constant; as neurons are intolerant of ischemia. It is mainly controlled locally and by auto-regulation. Both theories can work in the case of brain:
- ✓ Metabolic control: the brain tissue is extremely sensitive to declines in pH, and increased carbon dioxide in which marked vasodilation occurs as a response. Remember that CO_2 can bind to H_2O forming bicarbonate and H^+, with the latter being a strong vasodilator.
- ✓ Myogenic control: it protects the brain from damaging changes in blood pressure:
  - Decreased MAP causes cerebral vessels to dilate to ensure adequate perfusion.
  - Increased MAP causes cerebral vessels to constrict, decreasing perfusion to a certain point.
- ✓ The brain is vulnerable under extreme systemic pressure changes:
  - MAP below 60mm Hg can cause syncope (fainting) and ischemia.

- MAP above ~~160~~ 180 can result in cerebral edema.
- CNS ischemic response: in case of extremely decreased MAP the brain may become ischemic. In this case, the brain can regulate its own blood flow by extensively increasing the sympathetic stimulation to increase the MAP and return the brain's blood flow back to normal. This is the final chance; if it succeeds the patient can survive. However, if it fails the patient will suffer from multiple organ failure, irreversible shock and death.

✓ Blood flow to the skin has two objectives:

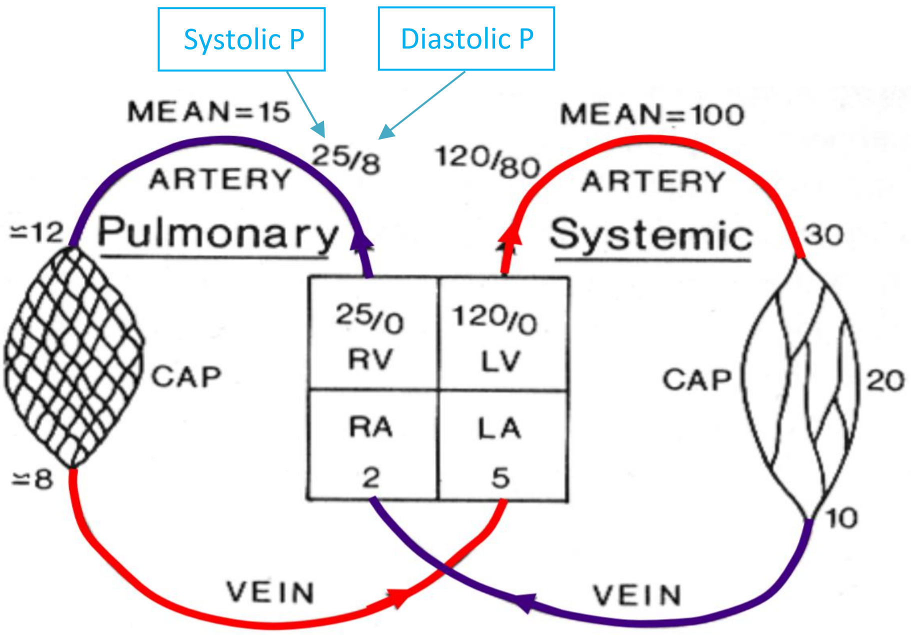
Blood Flow to the Skin

1. Supplies nutrients to cells in response to oxygen need.
2. <u>Aids in body temperature regulation</u> and provides a blood reservoir (<u>the most important).</u> Blood flow varies from 50 ml/min to 2500 ml/min, depending upon body temperature. In case of high temperature, there is vasodilation → increased blood flow to the skin → Increased heat loss… And vice versa.

✓ Blood flow to venous plexuses below the skin surface is controlled mainly by sympathetic nervous system reflexes initiated by temperature receptors and the central nervous system.

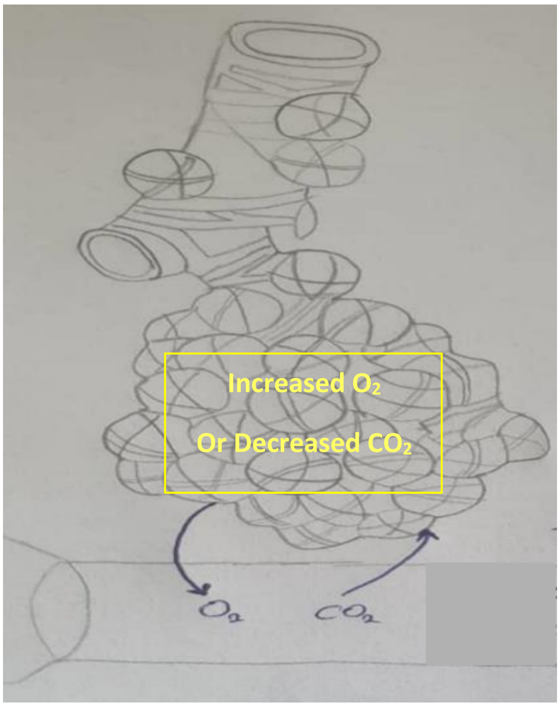
Pulmonary Circulation

✓ *This figure summarizes what we already know about pulmonary and systemic circulation*



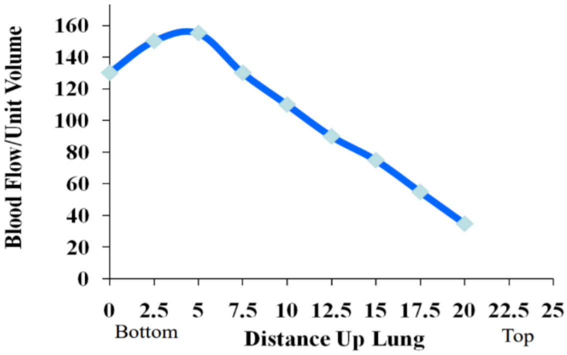
✓ Blood flow in the pulmonary circulation is different in that:

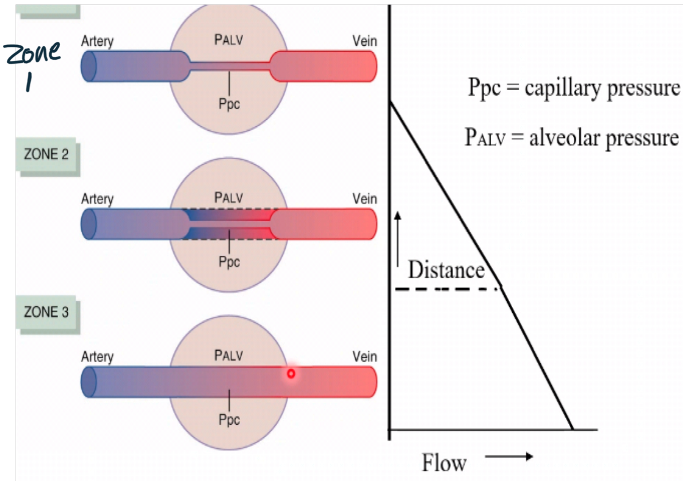
- The pathway is short.
- The systemic circulation resistance is 6-7 times more than the pulmonary.
- Pulmonary arteries carry deoxygenated blood, while veins carry oxygenated blood.
- The pulmonary circulation has a much lower arterial pressure (24/8 mm Hg) than the systemic circulation (120/80 mm Hg).
- The auto-regulatory mechanism is exactly the opposite of that in most tissues: Low oxygen levels in the blood cause vasoconstriction, whereas high levels promote vasodilation.
- Increased alveolar pO_2 increases blood flow and vice versa. This allows for proper oxygen loading in the lungs.



Let's look at this brilliant (not really) figure that was drawn by me ^^ If the oxygen content in lungs was high, it wouldn't make sense to constrict vessels (like we usually do with other tissue's vessels). On the contrary, it would be better to dilate vessels so we can grab the excess oxygen in lungs and distribute it.

✓ Blood flow is not distributed equally in the lungs because of gravity. It increases in the bottom part of the lung and decreases toward the top. Other factors contributing to this phenomenon is hydrostatic pressure caused by air in the alveoli. So, as we go toward the top, air compresses vessels causing decreased blood flow (alveolar pressure > arterial pressure).





إذا وصلت لهون اعرف انك شخص رائع وقطاعة 😂
هون خلصت رحلتنا مع الفسيولوجي لهاد السيستم الله ينولكم أعلى العلامات ❤️
دعواتكم

Good Luck!!