Subject | Physiology
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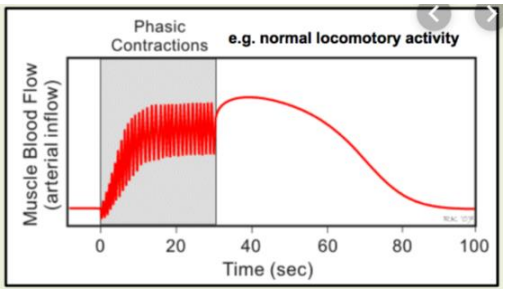
Blood Flow to The Muscles

- Blood flow control to the muscle is important due to the fact that skeletal muscles comprise around 40% of the body mass.

- The regulation of blood flow to skeletal muscle is controlled **locally** and tightly dependent on the **metabolic** demand for oxygen leading to a **proportional** change in blood flow. The precisely regulated control of blood flow serves to **ensure adequate oxygen supply** to the working muscle. Blood flow can increase almost 10-fold or more during physical activity. There are 2 types of exercises:

1- In isotonic exercises 'rhythmic':

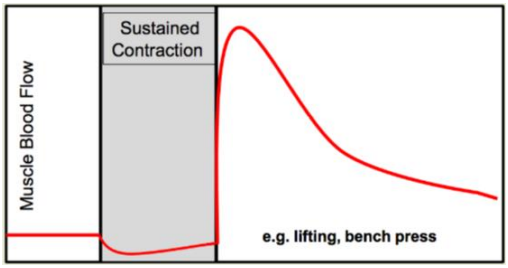
- ⇨ In this exercise, the **metabolic rate increases** which induce the release of local **vasodilators**.
- ⇨ Overall, blood flow **increases** but it is **phasic**; it **decreases** during **contraction** due to blood **vessel** compression and **increases** during relaxation.
- ⇨ **PVR** is **decreased** (due to local vasodilators) and **blood flow** is **increased**.



- ⇨ **HR increases** a lot during exercise with a slight increase in BP.
- ⇨ This is called **active hyperemia**; where blood flow increases **during** exercise

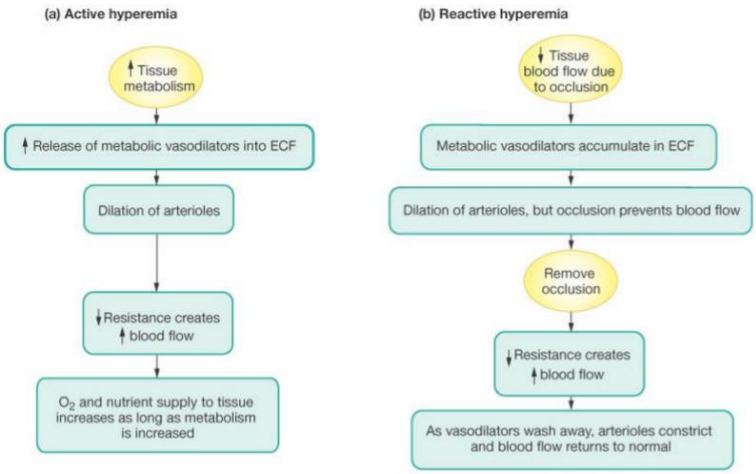
2- In isometric exercises 'sustained':

- ⇨ 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.
- ⇨ **BP** is **increased** (due to compression) with **decreased** blood flow **during** exercise.



- ⇨ This is called **reactive hyperemia**; where blood flow increases **after** 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.*



Oxygen Extraction Ratio

- It represents the **percentage** of oxygen **extracted** by the peripheral tissues from the oxygen-rich blood flow **delivered** to these tissues.
- **Decreased O_2** concentration during exercise affects the vessels' smooth muscles directly causing **vasodilation** to **increase blood blow** meeting the O_2 increased demand.
- Muscles during exercise can meet their O_2 requirements **without** increasing blood flow by **increasing the Extraction ratio**.
- Normally, the extraction ratio of the skeletal muscles at rest is **25%.** During **exercise,** it increases up to **75%** to meet the muscles O2 demand **without** increasing blood flow.

Humoral Control

- Humoral control of the circulation means control by **substances** in the body fluid, such as hormones and locally produced factors. The **main vasodilators** of the **skeletal muscles'** vessels are:

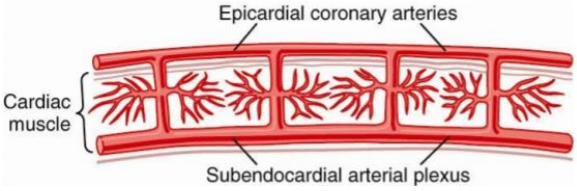
  1- Adenosine (most important local vasodilator of the skeletal muscles)
  2- K+
  3- Osmolality
  4- EDFR (nitric oxide)

Blood Flow of the Heart

- There are 2 types of **vasculatures** in the cardiac muscle:

  1- Epicardial coronary arteries

  2- Subendocardial arterial plexus: where pressure mainly increases during ventricular systole.



- The extraction ratio of the cardiac muscle **at rest is at its maximum** value (75%); meaning it **cannot** increase further. Thus, an increase in O_2 demand can only be met by **increased blood flow**.

Coronary Artery Blood Flow

- Coronary blood flow is mainly dependent on **aortic pressure** and the **pumping activity** of the **ventricles**.

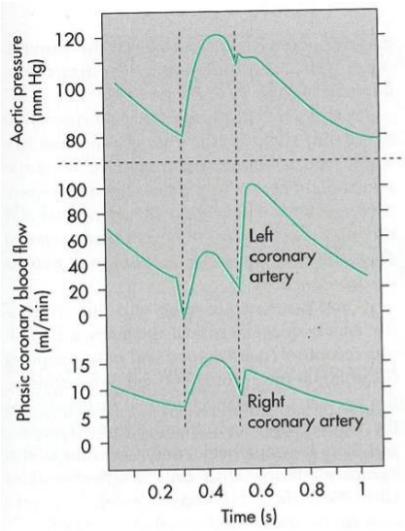
  a- During ventricular systole:

  ⇨ Coronary vessels are **compressed; ceasing** the myocardial blood flow. During that, stored **myoglobin** supplies it with oxygen.

  b- During ventricular diastole:

  ⇨ Upon releasing the compression due to systole, **reactive hyperemia** of the coronary vessels occurs **increasing** the blood flow, thus supplying the myocardium with oxygen and nutrients.

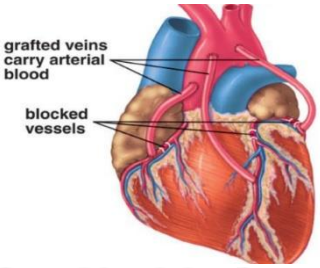
⇨ Most of the coronary *(left coronary artery especially)* **blood flow** is during **ventricular diastole**. **Decreased diastolic pressure** *(as in aortic regurgitation)* dangerously disrupts the coronary blood flow which is further **aggravated** with **exercise**; decreasing the available oxygen to supply the myocardium *(fatal).*



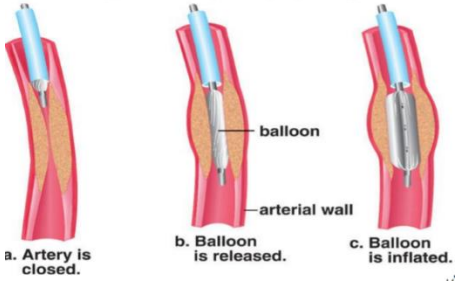
Side Note: *As seen in the picture, the blood flow in the **left** coronary artery is mainly **during early diastole**, while in the **right** coronary artery it is mainly **during systole**. This can be attributed to **blood pressure**; in which the **right** coronary artery has a much **lower pressure** compared to the **left** artery.*

- **Sympathetic stimulation** causes coronary artery **constriction**. However, it will also cause **increased** heart **activity** which induces the release of **local vasodilators**. The local regulation effect on the coronary arteries **overcomes** the sympathetic stimulation causing coronary arteries **vasodilation**.
- The **parasympathetic** effect is the opposite, it causes **decreased** activity leading to **decreased** local vasodilators release → **vasoconstriction**.

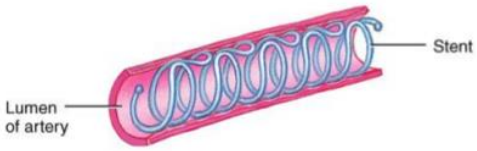
Coronary Artery Blockage



1- Upon coronary obstruction, **Coronary artery bypass graft** is done. It redirects blood around a section of a blocked or partially blocked coronary artery to improve blood flow.



2- **Coronary angioplasty** is a procedure used to widen a blocked or narrowed coronary arteries by inserting a catheter into the blocked coronaries and inflate a balloon to open them.



3- **Stents** are tiny tubes that can be inserted into a blocked artery to keep it open restoring the blood flow.

Blood Flow to the Brain

- Blood flow to the brain should remain **constant**; as neurons are **intolerant** of ischemia, it is mainly controlled locally.
- **Metabolic control**: the brain tissue is extremely **sensitive** to **declines** in pH, and **increased** carbon dioxide (decreased blood flow) in which marked **vasodilation** occurs as a response.
- **Myogenic control:** it protects the brain from **damaging changes** in **blood pressure**:
  - **a- Decreased MAP** cause cerebral vessels to **dilate** to ensure adequate perfusion.
  - **b- Increases in MAP** cause cerebral vessels to **constrict**.
- The brain is **vulnerable under extreme systemic pressure changes**:
  - **a-** MAP **below 60mm Hg** can cause **syncope** (fainting) and **ischemia**.
  - **b-** MAP **above 160** can result in **cerebral edema**.
- **CNS ischemic response**: in case of **extremely decreased MAP (<60 mmHg)**, the brain can become ischemic. In this case, the brain can regulate is own blood flow by **extensively increasing** the **sympathetic** stimulation to **increase** the **MAP** and return the brain's blood flow back to **normal**.

Blood Flow to the Skin

- Blood flow through the skin:
  - **a- Supplies nutrients** to cells in response to oxygen need.
  - **b- Aids in body temperature** regulation and provides a blood reservoir.
- 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.

Blood flow to the Lungs

- Blood flow in the pulmonary circulation differs in:

  a- The pathway is **short**.

  b- The **systemic** circulation resistance is 6-7 times **more** than the **pulmonary**.

  c- Pulmonary arteries carry deoxygenated blood, while veins carry oxygenated blood.

  d- The pulmonary circulation has a much **lower arterial pressure** (24/8 mm Hg) than the systemic circulation (120/80 mm Hg).

  e- The autoregulatory mechanism is exactly the **opposite** of that in most tissues:

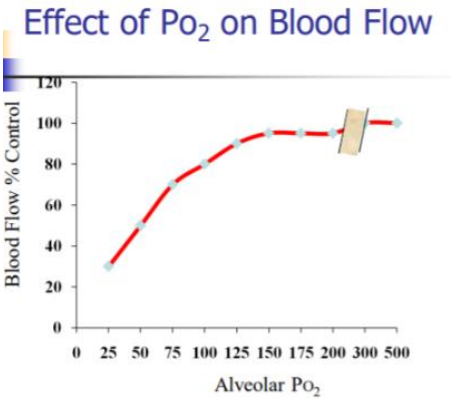
  ⇨ **Low oxygen** levels in the blood cause **vasoconstriction**, whereas **high levels** promote **vasodilation**.

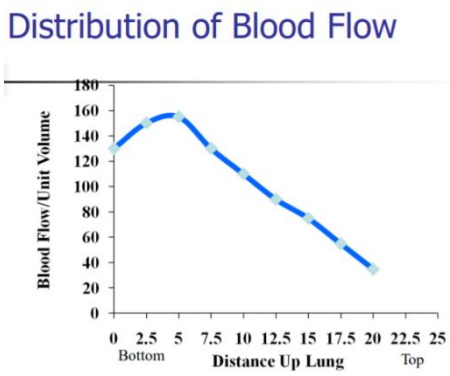
  Extra note: *hypoxia cause vasoconstriction to redirect blood away from poorly-ventilated lung regions toward well-ventilated lung regions.*

  ⇨ **Increased** alveolar pO_2 **increases** blood flow and vice versa.

  ⇨ This allows for **proper oxygen loading** in the lungs.

  f- Blood flow in the lungs increases the bottom part of the lung and decreases toward the top *'this will be explained in the respiratory system'*.





Good Luck