Cardiovascular (CV)

The goal of these lectures is to discuss basic physiology of the cardiovascular system (heart, vessels, blood pressure, control, hemostasis). This first lecture will introduce the cardiovascular (CV) topic and discuss the heart as a pump. The sections for this lecture are:

**Introduction to the CV system**
- Overall design of the CV system
- Pressure, flow and resistance

**The heart as the CV pump**
- Anatomy and cardiac muscle
- Cardiac cycle (electrical / mechanical)
- The cardiac output

Life is a series of chemical reactions occurring in compartmentalized environments.

The main purpose of life is to keep itself alive

Physiology, the study of how life works, is based on the simultaneous occurrence of the following three concepts:
- levels of organization
- structure / function relationship
- homeostatic regulation

Where we would like to be at the end of the cardiovascular and respiratory sections

PCO2
PO2
pH
Pa

inputs

chemo & baroreceptors

periphery

(local control)

baroreceptor mechanism (e.g. carotid sinus)

neural CV center
- cardio +
- cardio -
- vasoconstriction

output

extrinsic

heart

intrinsic

lung

(local control)
Cardiovascular (CV)

**Introduction, this CV lecture**
- Overall design of the CV system
- Pressure, flow and resistance

**Blood pressure regulation, next CV lecture**
- Arterial and venous pressure
- Blood volume, arterial pressure and baroreceptors
- Other CV reflexes and responses

**The heart as pump, this CV lecture**
- Anatomy and cardiac muscle
- Cardiac cycle’s electrical and mechanical events
- The cardiac output

**CV patterns in health / disease, last CV lecture**
- Hemorrhage, hypotension, upright posture
- Exercise and training
- Hypertension and heart failure
- Coronary disease

**Vessels as tubes, next CV lecture**
- Arteries and arterioles in general
- Capillaries and veins
- The lymphatic system

**Hemostasis, last CV lecture**
- Formation of a platelet plug
- Blood coagulation, clot formation
- Anticlotting systems and drugs

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**Introduction**

levels of organization  
structure - function  
homeostatic regulation
Introduction

Homeostasis, or constancy of the internal environment, is needed for chemical reactions underlying life to occur. It is maintained, predominantly, through negative feedback mechanisms.

Chemical reactions are ultimately controlled by negative feedback mechanisms.

Effectors mechanism

Comparators compare what it should be with what it actually is and generate an error signal.
Introduction

“The Cardiovascular System:”

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>FUNCTION</th>
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<tbody>
<tr>
<td>Heart</td>
<td>Chambers through which blood flows from veins to ventricles. Atrial contraction adds to ventricular filling but is not essential for it.</td>
</tr>
<tr>
<td>Atria</td>
<td>Chambers whose contractions produce the pressures that drive blood through the pulmonary and systemic vascular systems and back to the heart.</td>
</tr>
<tr>
<td>Ventricles</td>
<td>Low-resistance tubes conducting blood to the various organs with little loss in pressure. They also act as pressure reservoirs for maintaining blood flow during ventricular relaxation.</td>
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<tr>
<td>Vascular system</td>
<td>Major sites of resistance to flow, responsible for the pattern of blood flow distribution to the various organs; participate in the regulation of arterial blood pressure.</td>
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<tr>
<td>Arteries</td>
<td>Sites of nutriant, metabolic end product, and fluid exchange between blood and tissues.</td>
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<tr>
<td>Arterioles</td>
<td>Sites of nutrient, metabolic end product, and fluid exchange between blood and tissues.</td>
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<td>Capillaries</td>
<td>Low-resistance conduits for blood flow back to the heart. Their capacity for blood is adjusted to facilitate this flow.</td>
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<td>Veins</td>
<td>Liquid portion of blood that contains dissolved nutrients, ions, wastes, gases, and other substances. Its composition equilibrates with that of interstitial fluid at the capillaries.</td>
</tr>
<tr>
<td>Blood</td>
<td>Includes erythrocytes that function mainly in gas transport, leukocytes that function in immune defenses, and platelets (cell fragments) for blood clotting.</td>
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The structural elements of the cardiovascular system are organized as ......>>>

Introduction

“Overall design of the CV system”

Pressure, flow and resistance

......>>> a double pump with blood output to, and blood input from, capillaries......>>>
Introduction

Overall design of the CV system

Pressure, flow and resistance

Remember that afferent / efferent pathways might be neuronal and / or endocrine

......>>> where exchange between blood and tissues occurred......>>>

......>>> under homeostatic control provided by communication systems......>>>
Introduction

Overall design of the CV system

Pressure, flow and resistance

---

heart as pump

The heart as the pump of the CV system

Anatomy and cardiac muscle

Cardiac cycle's electrical and mechanical events

The cardiac output

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The function of the heart, the main pump of the cardiovascular system
Heart as pump

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intercalated disks and gap junctions are important structural and functional heart elements
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Intercalated disks and gap junctions are important structural and functional heart elements

Electrical events in the heart are based on ionic differences across the cardiocyte plasmalemma
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electrical events in the heart are based on ionic differences across the cardiocyte plasmalemma

Characteristics of cardiocytes not present in skeletal muscles

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### Heart as pump

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#### Cardiac cycle's electrical and mechanical events

- **The cardiac output**

  Electrical events in the heart are based on ionic differences across the cardiocyte plasmalemma.

- **Electrical events in the heart**
  - Based on ionic differences across the cardiocyte plasmalemma.
  - Electrical events include action potentials and conduction of impulses.
  - These events are essential for the coordination of cardiac muscle contraction and relaxation.

- **Mechanical events**
  - Cardiac contraction and relaxation are driven by calcium ions.
  - Calcium ions are released from the sarcoplasmic reticulum and bind to troponin, activating myosin for muscle contraction.

- **Electrical events**
  - Include action potentials and conduction of impulses.
  - These events are critical for synchronizing contraction across the heart.

- **Mechanical events**
  - Cardiac muscle contraction and relaxation are controlled by calcium ions.
  - Calcium ions bind to troponin, activating myosin to cause muscle contraction.

- **Automaticity**
  - The heart has the ability to generate spontaneous action potentials without external stimuli.
  - This property is mediated by specialized automatic cells that maintain a steady rate of spontaneous depolarization.

- **Variable force of contraction**
  - The heart's force of contraction is influenced by both extrinsic and intrinsic factors.
  - Factors include sympathetic and parasympathetic neurotransmission, cardiac hormones, and intrinsic cellular mechanisms.

- **Na / Ca channels and Ca channels**
  - These channels play a crucial role in regulating the intracellular calcium concentration, which is essential for muscle contraction.
  - The balance between Na and Ca channels regulates the cell's excitability and contractility.

- **Intercalated disks**
  - These structures facilitate electrical coupling between cardiocytes, allowing synchronized conduction of impulses across the heart.

- **Increased intracellular calcium**
  - Leads to enhanced muscle contraction by sensitizing myosin to actin, thereby increasing the force developed by cardiac muscle fibers.

- **Automaticity**
  - The heart has automaticity, allowing it to generate spontaneous action potentials without external stimuli.
  - This property is mediated by specialized automatic cells that maintain a steady rate of spontaneous depolarization.

- **Variable force of contraction**
  - The heart's force of contraction is modulated by both extrinsic and intrinsic factors.
  - Factors include neurotransmission, hormonal influences, and intrinsic cellular mechanisms.

- **Na / Ca channels and Ca channels**
  - These channels are integral to regulating intracellular calcium levels, which govern muscle contraction.
  - The interplay between Na and Ca channels is crucial for maintaining the excitability and contractility of cardiac muscle fibers.

- **Intercalated disks**
  - These structures serve as intercellular bridges, enabling electrical coupling between cardiocytes and ensuring coordinated electrical conduction.

- **Increased intracellular calcium**
  - Results in enhanced muscle contraction by sensitizing myosin to actin, thereby increasing the force generated by cardiac muscle fibers.

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\[ \text{CO} = \text{SV} \times \text{HR} \]

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\[ CO = SV \times HR \]

Déjà vu from skeletal muscle ???

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