Heart Matters: Physiology of the Body’s Powerhouse
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BIOGRAPHY:

Igor Mitrovic, MD is Jack D. and DeLoris Lange Endowed Chair in Systems Physiology I, Professor in Department of Physiology University of California San Francisco. Dr. Mitrovic is Director of Professional School Education at his Department and he is responsible for the professional school physiology education at UCSF. He directs and co-directs several courses in the Schools of Medicine and Pharmacy. His professional interests are centered around teaching and mentoring as well as development and improvement of the professional school curricula. His research interests include neurobiology of stress and stress resilience as well as neurobiology of addiction and pain. He is a recipient of numerous teaching awards from all the professional schools at UCSF. Besides University work, he is also a Scientific Director of Institute For Health Solution, a non-profit organization that studies and promotes approaches which lead to increased stress resilience and improved emotional well being. Dr. Mitrovic is also a Visiting Professor at University of Kragujevac School of Medicine (Kragujevac, Serbia) as well as recipient of the Honorary Doctorate Degree from the University of Kragujevac.

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# Cardiovascular Physiology

## Heart Matters: Physiology of Body's Powerhouse

**Little pump that could**
- "Electronic" control
- Generates pressure to force blood flow
- Two sets of cardiac problems
  - "Electrical"
  - "Mechanical"

**Objectives:**
- Describe the origin of the electrical impulses in the excitable (e.g., heart) cells (or, how cells are like batteries)
- Explain what happens when a heart muscle cell is electrically activated
- Name the place of origin of the normal electrical impulse in the heart and describe its spread
- Correlate the signals (waves) recorded in the ECG with the electrical activity in the heart muscle
- Speculate on the possible consequences of "electrical failure" in the heart
- Describe the process of electro-mechanical coupling
- Explain the mechanism of ventricular pressure generation and its function in cardiovascular system
- Speculate on the consequences of the mechanical failure of the heart

## Heart’s Electrical problems

- **Fibrillations**

## Heart’s mechanical problems

- [Link to resource](http://nihseniorhealth.gov/heartfailure/heartfailuredefined/01.html)
Heart: two pumps for two circulatory systems

- Left heart:
  - Systemic
- Right heart:
  - Pulmonary

Systemic circulation and Pulmonary circulation

Heart cells are like batteries

- Specialized proteins called ion pumps and ion channels generate electric potential (inside of a cell is more negative than outside)
  - Na⁺[145]
  - K⁺[4]
  - Ca⁺⁺[2]

What happens when one ventricular heart cell (battery) is switched “on”

Heart muscle cells are electrically connected!

- Specialized proteins called “gap junctions” allow for current flow between the heart muscle cells

Signal that “turns on” the cardiac cells starts in the atria

- There is a coordinated spread of electrical current from SA node through ventricles
Electrical signals (action potentials in different parts of the heart)

<table>
<thead>
<tr>
<th>Pacemaker</th>
<th>SA Node</th>
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<tbody>
<tr>
<td>Atrial myocyte</td>
<td></td>
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<tr>
<td>AV Node</td>
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<tr>
<td>Purkinje fiber</td>
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<tr>
<td>Ventricular myocyte</td>
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</tbody>
</table>

Pacemaker potential is unstable – oscillates; origin of electrical impulses

Atrial cells are turned on before signal arrives to ventricular cells

Atrial cells are turned on before signal arrives to ventricular cells

Electrocardiograph (ECG) registers electrical activity of the heart muscle
Coordinated current spread results in coordinated contraction

Heart’s Electrical problems

- Fibrilations

Heart’s Electrical problems

- Blocks in conduction between atria and ventricles

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- Little pump that could
  - Heart electrical activity is controlled by specialized pacemaker and conductive cells
  - Electrical activity can be regulated by sympathetic and parasympathetic nervous system
  - Electrical activation of heart muscle generates ECG waves
  - Irregular electrical activity results in heart problems

How does the pump do it?
**Electro-mechanical coupling (aka excitation-contraction coupling)**

- **T-tubules enable extracellular fluid to reach deep inside cardiomyocyte**

**Calcium enters cytoplasm when the muscle cell is "turned on" (aka activated or depolarized)**

**What makes fluid move through a tube (or a set of connected tubes)?**

\[ P_1 - P_2 = \Delta P \]

\[ Q = \Delta P \]

**Systemic circulation and Pulmonary circulation**

- **Right heart**
- **Left heart**
- **Capillaries in lungs**
- **Capillaries in tissues**
- **Venules and systemic veins**
- **Elastic arteries**
- **Arteriole**
- **Venules and systemic veins**

Valves

Regulation of blood vessel radius

**Ventricular contraction generates driving pressure...**

**Heart’s mechanical problems: failing pump**

[compantr.png](http://nihseniorhealth.gov/heartfailure/heartfailuredefined/01.html)
Which pump is failing?

Heart Matters:
Physiology of Body’s Powerhouse

- Little pump that could
  - Electrical activation of heart muscle cells causes calcium-mediated contraction
  - Ventricular contraction generates driving pressure that pumps blood from veins to arteries
  - Ventricular contraction strength depends on free calcium in the muscle cytoplasm and can be regulated by sympathetic nervous system
  - Failing heart is characterized by the inability to generate sufficient contractile force ("mechanical" failure)