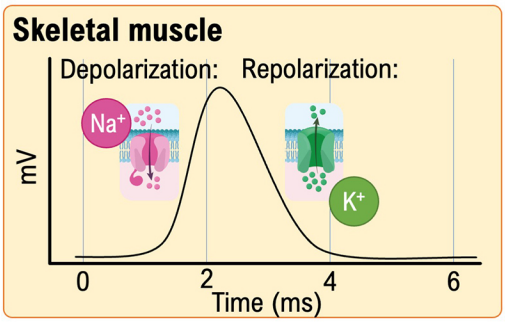
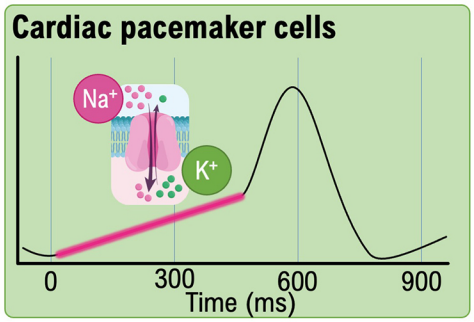
TOPIC: CARDIAC ACTION POTENTIALS

Introduction to Action Potentials in Cardiac Cells

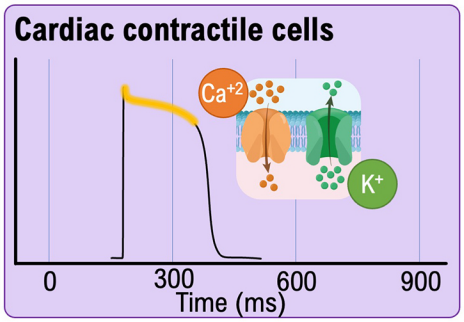
- Two types of cells in our heart:
  - **Pacemaker Cells:** _____ set the heart rhythm.
  - **Contractile Cells:** _____ majority of heart muscle.



-Rapid __polarization & __polarization



-Slow __polarization



-Slow __polarization

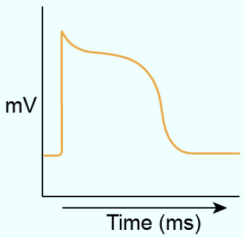
Differences:

- Cardiac cells use Na^+, __, & K^+
- Slow ___polarization or ___polarization:
  - Due to _____ ions crossing membrane at once (K^+ and either Ca^{+2} or Na^+).

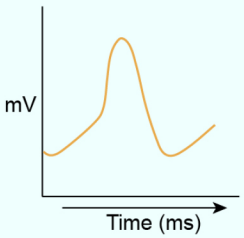
EXAMPLE

In the table below, put a check in the boxes under cardiac pacemaker cells and cardiac contractile cells if they possess the given feature. Then, match the action potential graphs with the type of cell it is showing.

Feature	Cardiac Pacemaker	Cardiac Contractile
Slow repolarization		
Slow depolarization		
Utilizes only Na^+ and K^+ ions		
Utilizes Na^+, Ca^{+2}, and K^+ ions		
Graph		



Graph A



Graph B

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PRACTICE

Which of the following correctly identifies a difference between action potentials in cardiac and skeletal muscle?

a) Skeletal muscles utilize K^+ and Ca^{+2} during action potentials while cardiac contractile cells use K^+ and Na^+.

b) Action potentials in cardiac contractile and cardiac pacemaker cells are longer lasting than action potentials in skeletal muscle.

c) Cardiac pacemaker cells have a slow repolarization while skeletal muscles have a slow depolarization.

d) The action potentials in each type of tissue are the same.

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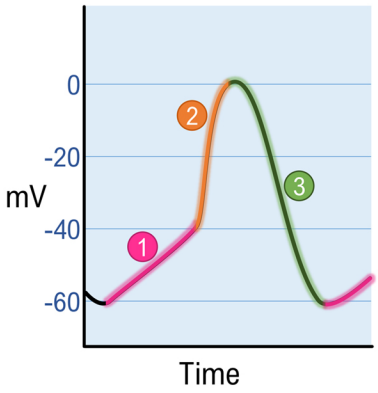
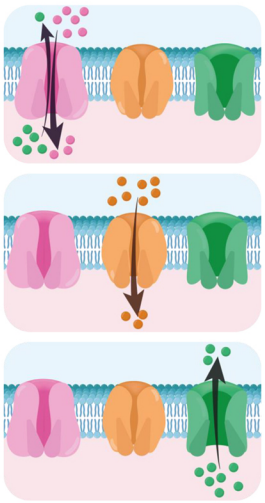
Pacemakers: Molecular Physiology

- *Recall:* Pacemaker cells: 1) have a slow ___polarization and 2) use Na^+, ___, & K^+ ions.
- **Autorhythmicity:** ability of certain heart cells to create their own _____ potentials.
  - **Pacemaker Potential:** _____ depolarization _____ outside signal.





1. Special voltage gated channels open:
   Allow Na^+ _____ and K^+ _____ of the cell.
   - Slow ___polarization: *pacemaker potential*
2. At threshold, voltage gated _____ channels open:
   Ca^{+2} _____ the cell.
   - ___polarization
3. Ca^{+2} channels close, voltage gated K^+ open:
   K^+ _____ the cell.
   - ___polarization
4. Go to 1. (No _____ potential)

- Intrinsic rate of depolarization = ~100 times per minute.

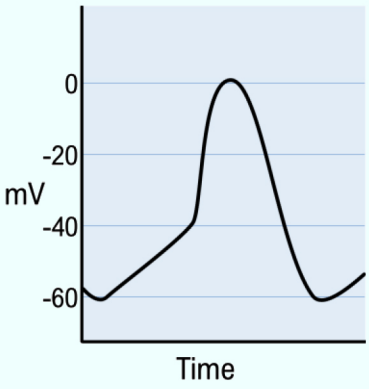
EXAMPLE

The graph below shows the membrane potential of a typical pacemaker cell.

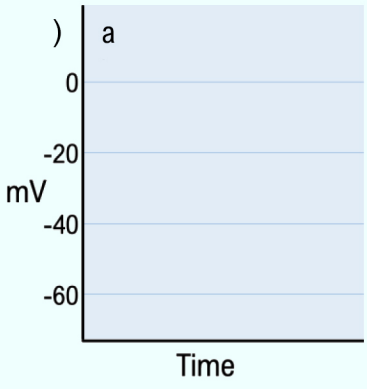
a) Draw how you think the curve would look if the permeability of the Sodium/Potassium channels is increased.

b) Draw how you think the curve would look if the permeability of the Sodium/Potassium channels is decreased.

c) For both cases, indicate how this change would generally affect heart rate.

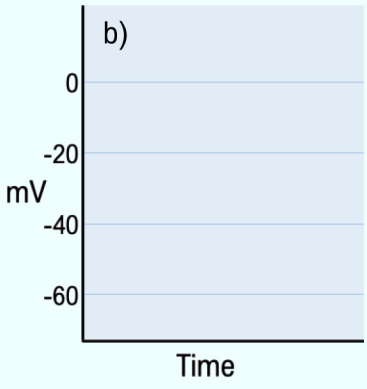


Normal



Increased permeability

HR: _____



Decreased permeability

HR: _____

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PRACTICE

Calcium ion channels open in response to changes in membrane potential. What type of opening mechanism do calcium ion channels in cardiac muscle exhibit?

a) Ligand-gated. b) Voltage-gated. c) Mechanically-gated. d) Time-gated.

PRACTICE

Autorhythmicity is a unique feature of cardiac pacemaker cells. What feature of cardiac pacemaker cells allows them to be autorhythmic while other cardiac cells are not?

a) Pacemaker cells use Ca^{+2} ions, unlike other action potentials.

b) Sodium channels in pacemaker cells allow both calcium and sodium to pass through.

c) The pacemaker potential is stimulated by polarization of the cell.

d) Unlike other action potentials, the first channel to open is the potassium channel, leading to repolarization.

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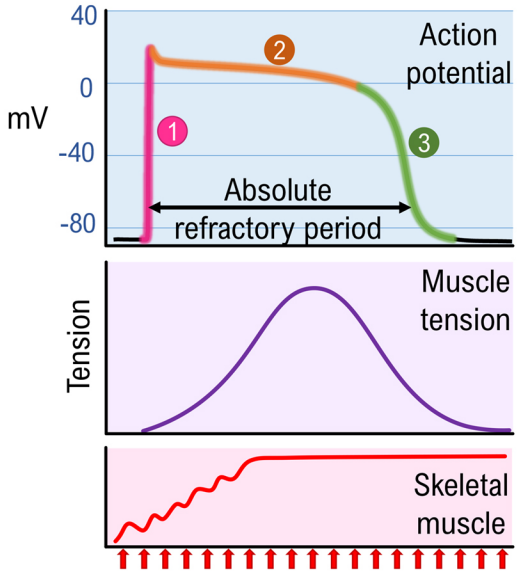
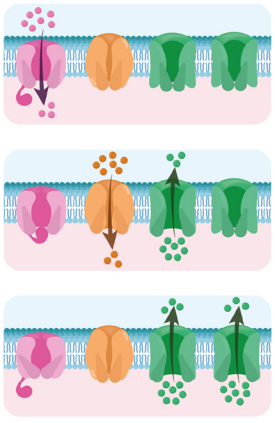
Contractile Tissue: Molecular Physiology

- *Recall:* Contractile cells: 1) have a slow ___polarization and 2) use Na^+, ___, & K^+ ions
- **Absolute Refractory Period**: period when cells _____ respond to APs since they are not repolarized.
  - **Plateau phase:** prolongs the absolute refractory period—forces _____.





1. Na^+ channels _____.
   - Cell ___polarizes.

2. ___ & K^+ channels open slowly.
   ___ into cell; ___ out.
   - Cell _____.

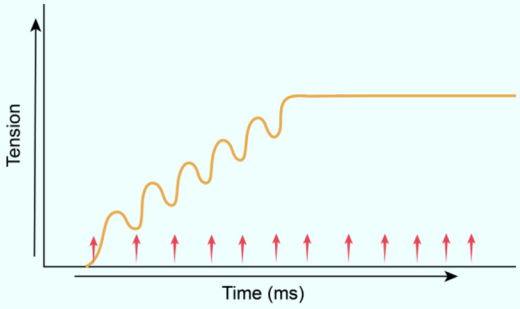
3. ___ channels close;
   ___ channels open fully.
   - Cell ___polarizes.

- Skeletal muscle has a _____ refractory periods.
  - _____ APs: leads to tetany (sustained contraction).

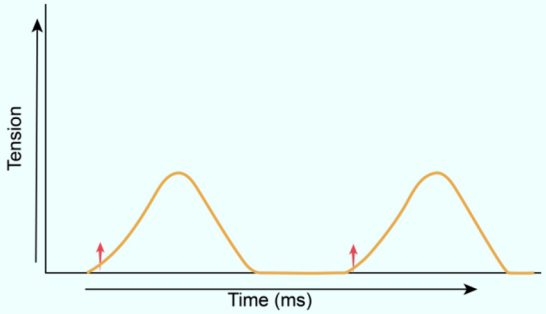
EXAMPLE

Two tension graphs are shown below, one for a cardiac contractile tissue and one for skeletal muscle tissue. In both graphs, the yellow line represents the tension in the cell, and the red arrows represent the arrival of an action potential.

a) Identify which graph shows cardiac contractile tissue and which shows skeletal muscle tissue.



Tissue type: _____



Tissue type: _____

b) The skeletal muscle shown is exhibiting a tetanic contraction. How does the molecular physiology of cardiac contractile tissue prevent tetanic contractions in heart muscle?

_____

_____

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PRACTICE

Cardiac contractile tissue uses sodium, calcium, and potassium channels for depolarization and repolarization. During which phase of the action potential is the calcium channel open?

a) Depolarization phase.
b) Plateau phase.
c) Repolarization phase.
d) Resting phase.

PRACTICE

How would you expect the absolute refractory period of a contractile cell to change if more potassium channels opened sooner after polarization?

a) Absolute refractory period would increase.
b) Absolute refractory period would decrease.
c) There would be no change; absolute refractory period is determined by the calcium ion channels.
d) It's impossible to tell as opening potassium channels will have an unpredictable effect on sodium channels.

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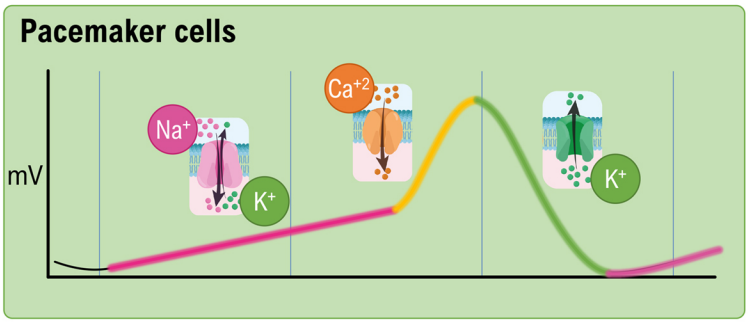
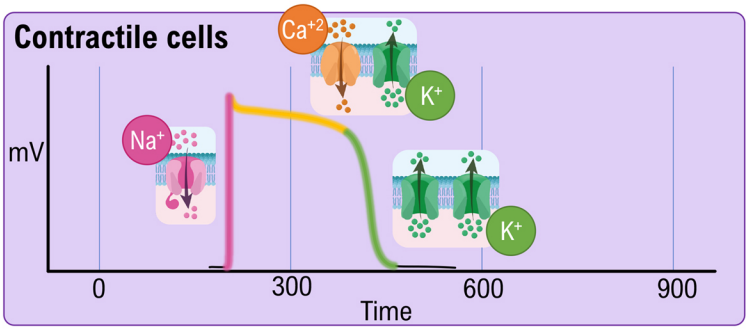
Comparing Action Potentials in Pacemaker and Contractile Cells

◆ *Recall:* **Pacemaker Cells**: _____ set the heart rhythm. **Contractile Cells:** _____ majority of heart muscle.



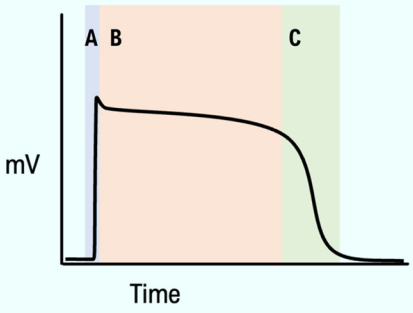
1. Na^+ flows into the cell K^+ flows out.
   Opposite flow of ions slows __polarization.
2. Ca^{+2} flows into the cell: __polarization.
3. K^+ flows out of cell: __polarization.
4. No resting potential: __polarization begins again.

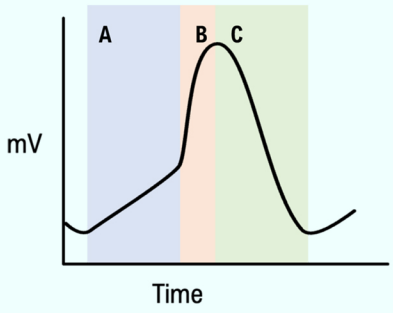


1. Na^+ flows into the cell: rapid __polarization
2. Ca^{+2} flows into the cell and K^+ flows out.
   Opposite flow of ions slows __polarization.
3. K^+ flows out of cell: __polarization.

EXAMPLE

The graphs below show action potentials for cardiac contractile and cardiac pacemaker cells. Different sections of the action potential graph are colored in blue (labeled A), orange (labeled B), and green (labeled C). For each section, identify which ions are moving out of the cell and which are moving in.





Contractile Cell:

	Ions In	Ions Out
A		
B		
C		

Pacemaker Cell:

	Ions In	Ions Out
A		
B		
C		

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PRACTICE

The movement of ions in opposite directions at the same time is responsible for which of the following?

a) Slow depolarization in cardiac pacemaker cells.

b) Slow repolarization in cardiac pacemaker cells.

c) Slow depolarization in cardiac contractile cells.

d) Both A & C are correct.

PRACTICE

Which statement below correctly describes how the channels that are active during the pacemaker potential are different from other ion channels used in action potentials?

a) They are voltage gated.

b) They are active over a much wider range of voltages than other ion channels.

c) They allow Ca^{+2} ions to pass out of the cell.

d) They allow both Na^{+} and K^{+} through the same channel.