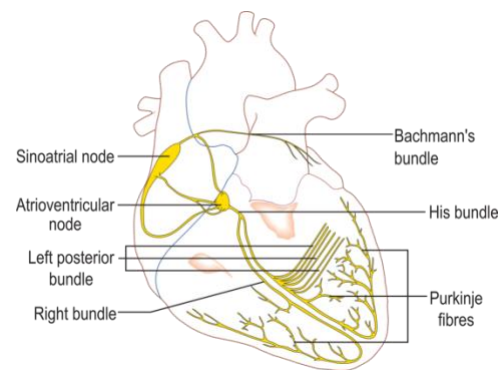## Four-Chambered Heart – "The Electrician"

"The Electrician" project extends The Plumber model and explores the electrical system of the heart by adding the sinoatrial (SA) and atrioventricular (AV) nodes. You will also learn how a pacemaker works in patients with heart disease. You will have the opportunity to build electrical circuits, explore material conductivity, and write code. Additionally, you are challenged to build a model of an automated external defibrillator (AED) for your model heart.

Your Challenge:

Build and code a model of the electrical system of a four-chambered heart.

Activity Materials: Build and code a model of the electrical system of a four-chambered heart.

- TI Nspire CX family calculator
- TI-Innovator Hub
- 4 x Male/Female (M/F) Jumper Wires
- 3 x Male/Male (M/M) Jumper Wires
- 4 x LED's
- Print of the Model Heart Build Sheet

- 4 x Toothpicks with labels
- 3oz. A conductive compound such as Play-Doh. Modeling clay or plasticine will not work
- 2 x small pieces of an alternate color of Play-Doh (teams may share)
- 2 x small square of aluminum foil

Setup Project Model:

The four separate chambers of the heart are formed using electrically conductive Play-Doh. Similarly, two small pieces of an alternate color of Play-Doh are used to form the SA and AV nodes. The heart's electrical stimulation is modeled using the Innovator Hub and four LEDs controlled by a TI-BASIC program. (note: see youtube video of heart electrical system animation at https://tinyurl.com/TI-HeartAnimation)

The model of the heart should include these events:
1. The firing of the SA node
2. The firing of the AV node
3. Conduction of SA node signal to the atria
4. Conduction of the AV node signal to the ventricles.

The model of the AED should include these events:
1. Detecting the presence of two AED paddles touching the heart
2. Reviving the heartbeat once the AED detects paddle on the heart

Project Challenges

Challenge 1: Use the hub with an ANALOG.IN and a DIGITAL.OUT to make a conductivity tester. The tester should make a tone on the speaker when the material is conductive and no tone when an insulator. As an extension, see if your tester will work across several balls of Play-Doh that are touching together.

Challenge 2: Build a model of the four-chambered heart's electrical system. Your model should be similar to the one used in The Plumber, but the wiring is different.

Be sure to insulate the upper from the lower heart using a piece of paper. The paper functions similarly to the non-conducting collagen fibers in the cardiac skeleton.

BB1 should deliver electrical signal to the SA node while BB2 will deliver signal to the AV node. Model each node with an alternate color of Play-Doh and an M/M jumper wire. Each node should bridge two chambers to model the function of Bachman's bundle and the His bundle.

Insert the LED (+) cathode into each Play-Doh chamber to illustrate the electrical activity in that chamber. The LED (-) anode is grounded. This circuit is opposite of The Plumber. Pay close attention to this difference in polarity.
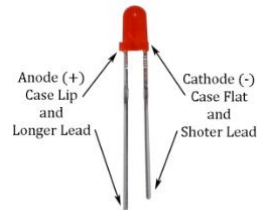
Write a program that blinks each node alternately. Comment your code with the different events represented in the PQRST wave.
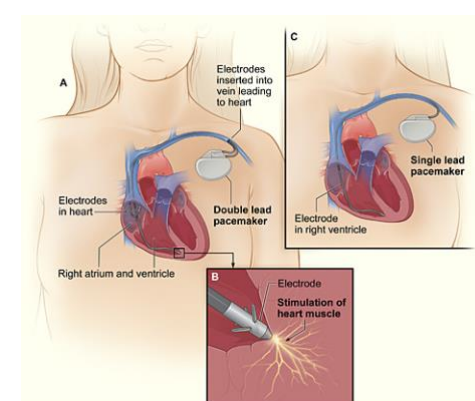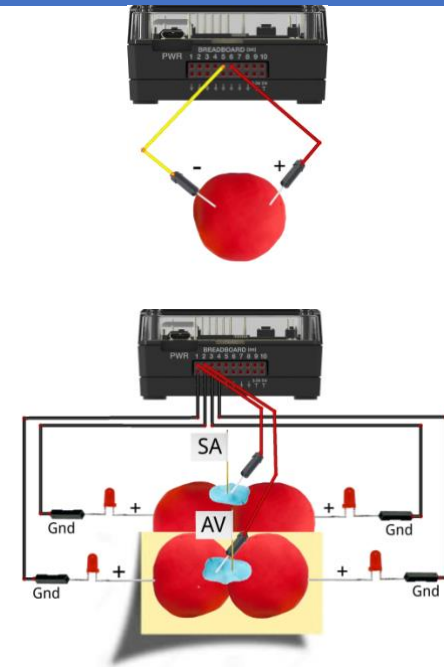
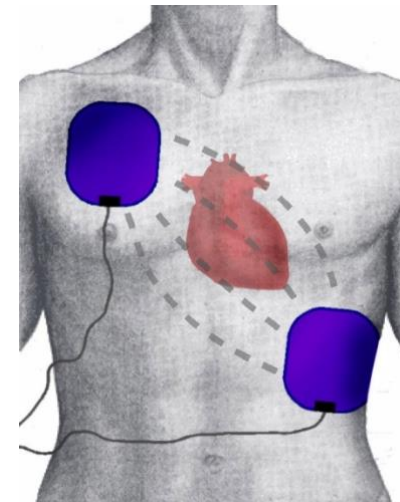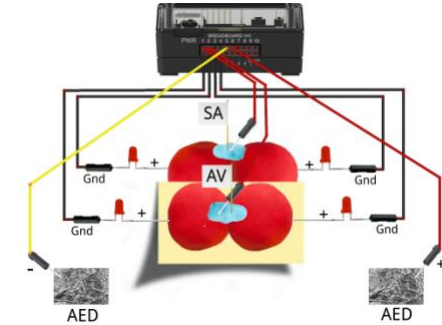**Challenge 3:** Build a model Automatic External Defibrillator to recover from a simulated heart attack.

For this challenge, modify the model built in challenge 2. Add two M/M jumper wires in BB5 and BB6 to model two AED paddles. You may choose to use aluminum foil on the ends of the jumper cable pins.

Use the concepts and code for detecting a voltage and material conductivity explored in challenge 1.

Use the concepts and code for a normal beating heart explored in challenge 2.

Your program should begin with several beats of the heart in sinus rhythm as done in challenge 2. Then, an attack is simulated by the absence of a heartbeat accompanied by a flatline tone. When the AED paddles are touched to the model and conductivity is detected, as in challenge 1, sinus rhythm resumes as in challenge 2.

Example Programming Commands for the project	
Example Code	**Behavior**
`Send "CONNECT DIGITAL.OUT 1 TO BB1"`	Associates BB 1 port with a software object named DIGITAL.OUT 1. Note: The DIGITAL.OUT object has more power than the LED object used in The Plumber project.
`Send "SET DIGITAL.OUT 1 TO ON"`	Switches the PORT associated with the corresponding "CONNECT DIGITAL.OUT 1 …" command to ON. The state may also be OFF.
`Send "CONNECT ANALOG.IN 1 TO BB5"`	Configures the port to measure the voltage on the associated port relative to the Hub ground. This object can only be used with IN1, IN2, IN3, BB5, BB6, and BB7
`Send "READ ANALOG.IN 1"`	Reads the analog voltage value associated with the corresponding "CONNECT ANALOG.IN 1 …" command in binary, ranging in value from 0 to 2^{14}. A Get command must immediately follow the READ command.
`Get a`	Gets the value returned from the Hub from the previous READ command and stores the value into the variable named "a".
`Send "SET SOUND 440 TIME 3"`	Sets the speaker on the Hub to make a 440 Hz tone for 3 seconds.
`key:=getKey()`	getKey() returns the name of the last key pressed as a text string (e.g. "esc"). In this example the key name is stored to a variable named "key".

Calculator Notes:

- On the Home screen press 4:Current to return to your document file.
- On the Home screen Press 1:New to create a new document file.
- You create and edit programs in a Program Editor app. You run programs from within a Calculator app.
- Use the [menu] key to see the options for your current app.
- ctrl-b is the shortcut from the Check Syntax and Store menu to store changes to your program.
- ctrl-r is the shortcut from the Check Syntax and Store menu to store changes to your program and paste the name to a Calculator app
- Press [enter] to run a program named on a Calculator app entry line.
- The Calculator app "remembers" the last command entered. Press Enter after a program has run to run the program again.
- Find your program names in a Calculator app by pressing the [var] (variables) key.
- Move from page to page by using ctrl-left arrow and ctrl-right arrow or by using the touchpad pointer to click on the desired page tab.
- ctrl-doc (+page) will add a blank page to your document.
- ctrl-z will undo your last action.
- To stop ("break") a program press and hold the ON key until you receive a dialogue box.

- ctrl-s is the shortcut for saving your entire document file. Do this periodically to save your work.