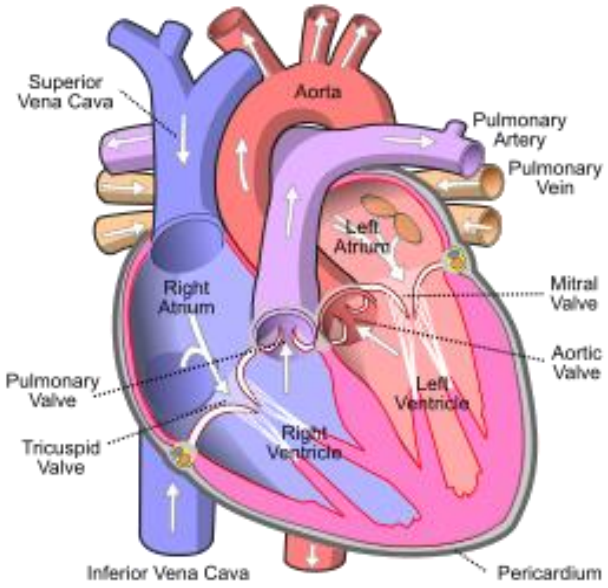
Four-Chambered Heart – "The Plumber"

In this project you will explore the circulatory subsystem within the heart by building a model of the human four-chambered heart. In addition to the biology concepts, you have an opportunity to build electrical circuits and use coding to write a program that blinks four LEDs in the order of the filling of each chamber. During the project you will explore:

- the anatomy of the heart chambers.
- blood flow through the circulatory system.
- the calculation or pulse rate in beats per minute.
- writing a program to control the model.
- LED electrical circuits.
- material conductivity.



Your Challenge:

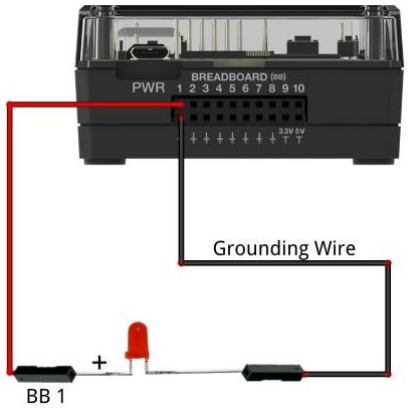
Build and code a model of the circulatory system of a four-chambered heart that responds to increased physical activity.

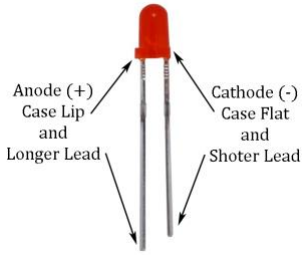
Activity Materials:

- TI Nspire CXII family calculator
- TI-Innovator Hub
- 4 x M/F Jumper Wires
- 1 x M/M Jumper Wires
- 4 x LED's
- 4 x Toothpicks with labels
- 3oz. A conductive compound such as Play-Doh. Modeling clay or plasticine will not work
- Print of the Model Heart Build Sheet
- Grove Temperature sensor

Project Challenges

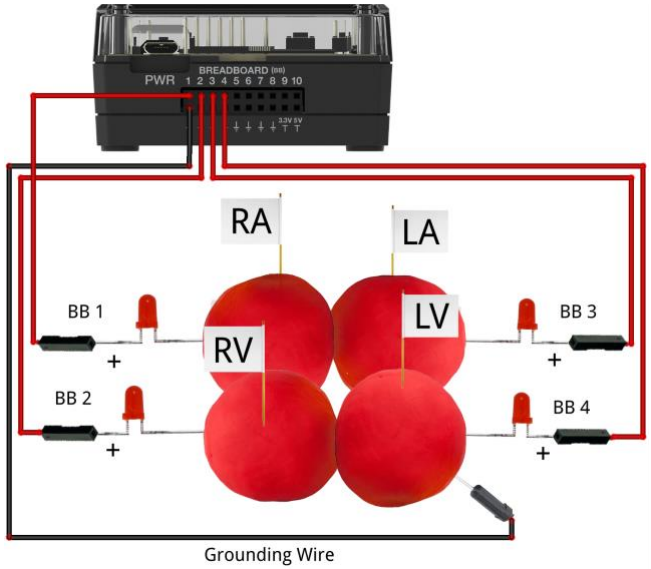
Challenge 1: Connect an LED to BB1 and blink at a rate of 2 Hz (flashes per second) for 10 seconds.





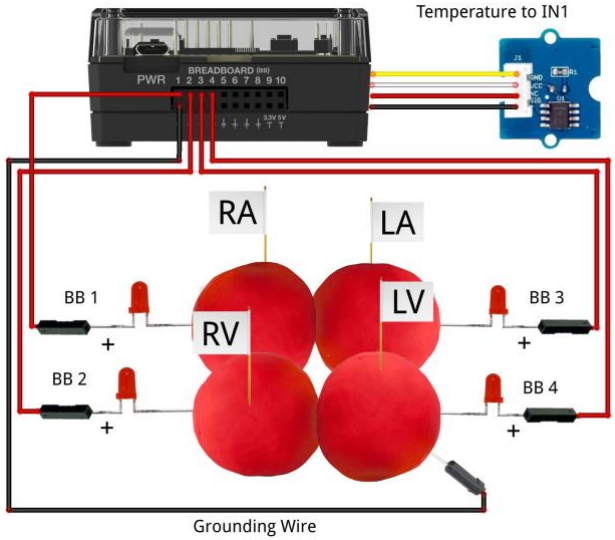
Challenge 2:

- Use four pieces of Play-Doh to model the four heart chambers.
- Place build sheet on the desk and place Play-Doh pieces on sheet.
- Label each piece of Play-Doh with the appropriate chamber name.
- Add three additional LEDs to the Hub connected to BB 2 thru BB 4.
- Insert the negative lead of each LED into each piece of Play-Doh.
- Add a single grounding wire from any of the pieces back into any ground on the BB connector of the Hub.
- Write a program to blink the four LEDs in sequence 1,2,3,4. Be sure to model the blinking order to match the blood flow order. The right atrium fills first while the left ventricle fills last.
- Add a beep to your program to sound like an EKG machine after each cycle of the heart. For example, the program should run for at least 30 seconds.
- What would you change in the program to speed up or slow down the flashing? Calculate the "heart rate" for this program.
- What happens when you separate the chambers? Can you explain your observation?



Challenge 3: The autonomic nervous system controls the human heart rate. When frightened, we do not need to think to make our heart beat faster. When our body becomes overheated, our heart rate elevates to try to cool us.

Use the Grove temperature sensor to modify the heart rate of the model. Change the program from Challenge 2 such that when body temperature goes up, heart rate goes up.



Example Programming Statements for the project

Example Code	Behavior
`from ti_hub import *`	Imports all the functions in the ti_hub module for use in the program. The ti_hub module includes all the necessary additions needed for project.
`# Define an external LED output device` `#  with variable name led1`	# at the beginning of a line denotes a comment. Comments are a "best practice" by programmers to annotate their code. Comment statements are ignored when the program is run. In the TI-Nspire CXII Python editor, [ctrl]+[T] toggles the statement of the current cursor location from a comment to a statement that will be run.
`led1=("bb1")`	Creates an LED object named **led1** connected to breadboard port 1, "bb1". led is available from the TI Hub > Add Output Device menu. The drop down menu for port does not include breadboard ports. It is necessary to escape from the menu and type in bb1, bb2, etc. Note: = is the Python operator for storing or assigning values to a variable.

`led1.on()`
`sleep(1)`
`led1.off()`
`sleep(1)`
	Turns on an LED object named **led1** then pauses the program for 1 second before turning **led1** off then pauses the program again for 1 second.
	Note: To see options for an object paste the object name from the var key menu then press the period key.

`sleep(.5)`	Pauses program for .5 seconds. sleep() is found on the Hub Commands menu.
`for n in range(10):` `  print(n)`	Repeats the statements in the block ten times, printing the value of the index variable, **n**, as 0,1,2,…9. The index variable n starts at 0 and increases by 1 with each loop. If **n** is less than the stop value, 10, the loop continues to repeat. Note: for index in range is found on the Built-ins>Control menu.

`for c in [led1,led2,led3,led4]:`
`  c.on()`
`  sleep(1)`
`  c.off`
`  sleep(1)`
	Loops through the elements of the list one at a time. The index variable **c** is replaced with the list element. In this example, the list elements are LED output objects that were defined earlier in the program. First led1 is turned on then off, then led2 the same and so one through all of the list elements. Note: for index in list is found on the Built-ins>Control menu. List elements are enclosed in square brackets. Values, text strings, objects are some of the data types that can be used in a list.

`sound.tone(440,1)`	Plays a tone through the TI-Innovator Hub speaker. In the example, plays the frequency 440 hertz (Hz) for 1 second. Note: sound.tone() is available from the Hub Built-in Devices>Sound Outputs menu.
`temp_sensor=temperature("IN 1")`	Creates a temperature sensor object named **temp_sensor** connected to port IN 1. temperature is available from the TI Hub > Add Input Device menu. Note: = is the Python operator for storing or assigning values to a variable.
`t=temp_sensor.measurement()`	Reads and stores the current measurement value of the **temp_sensor** object into variable **t**. Note: **.measurement()** returns the current measured value of a sensor object. To see options for an object paste the object name from the var key menu then press the period key.
`text_at(3,"temperature= " +str(t)+" °C","left")`	This text_at() function displays a text string on a specified row with an alignment of left, center or right. When variable **t** has a value of 26, the following is displayed on row 3, aligned to the left: temperature= 26 °C text_at() is available from the TI Hub>Commands menu. **Note:** The **str()** function converts a numeric value to a string. The + operator is used to join two strings. **str()** is available from the Built-ins> Type menu. **Note:** Degree, percent and other special characters are available from the ?! key menu in the lower right of the TI-Nspire keyboard.

`while get_key() != "esc":`
`  t=temp_sensor.measurement()`
`  text_at(3,"temperature= "+str(t),"left")`
	Defines a while loop that will continue until the escape key is pressed.
	While loops repeat the statements in the block if the condition at the top of the loop is true. In the example, looping continues until the escape key is pressed. Not pressing a key or pressing any key but escape means that get_key() will return a value that is not equal to "esc". The loop condition is true and looping continues. If the escape key is pressed, get_key() returns "esc". The condition will evaluate as "esc" not equal to "esc", which is false. A false result means that the loop statements are not repeated. Program execution skips to the statement just after the loop. Note: The block starts with a **colon** and includes the indented lines that follow. while get_key() != "esc": is available from the TI Hub > Commands menu.

`2+3==6 (result is false)`
`x+4>=y (if x=1 and y=3, the result is true)`
`"enter"!="esc" (result is true)`
	Boolean expressions evaluate to either true or false. The examples show some of the relational operators available from the Built-ins > Ops menu.
	Note: == is the Python operator to check equality. >= is the Python operator to check whether the value to the left is greater than or equal to the value on the right. != is the Python operator to check inequality.

`if t<=27:`
`  period=.15`
`else:`
`  period=.05`
	Checks to determine if the value of variable **t** is less than or equal to 27. If the statement is "true" then the statements in the **if** block are executed. If the statement is "false" then the statements in the **else** block are executed. In the example, when **t** is less than or equal to 27, the value .15 is stored to the variable **period**. When the value of **t** is or greater than 27, the value .05 is stored to the variable **period**. Note: **if..else..** is available from the Built-Ins > Control menu.

Calculator Notes:

- On the Home screen press 4:Current (or the Home key) 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 Python app program editor page. You run programs from a Python app Shell page.
- Use the [menu] key to see the options for your current app.
- ctrl-B is the shortcut from the Run menu to check the syntax and save changes to your program.
- In the Python editor ctrl-R is the shortcut from the Run menu to check the syntax and save changes and to run the program on the following Python Shell page.
- Use ctrl-R in the Shell to re-run a program.
- Press [enter] to run the statement entered on the line of a Python Shell page.
- Find your function names in the Python app by pressing the [var] (variables) key.
- To see options for an object paste the object name from the var key menu into the Python editor then press the period 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.