Science Unit: *Biology Inquiry*

Lesson 4: *Human Physiology Experiments*

Lesson Summary

In three activities, students do physiological tests on themselves, all involving neural pathways: 1. pitch frequency perception, 2. touch sensitivity and 3. reaction time. Students collect data from each and analyze the data with averages and graphing.

School Year:	2016/2017
Developed for:	Britannia Elementary School, Vancouver School District
Developed by:	Ingrid Sulston (scientist); Kevin Dwyer and Pascal Spino (teachers)
Grade level:	Presented to grades 4-6; appropriate for 3-7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes

Objectives

a) Practice repeated and consistent data collection and recording.
b) Gain experience in graphing and averaging numbers.
c) Understand the extent of neural connections required for even the simplest response or task.
d) Appreciate how other animals have wider hearing ranges than us, and what they use them for.

Background Information

Students enjoy using themselves in an experiment, and our body provides a rich source of physiological processes to study and collect data on.

Pitch frequency perception varies among individuals, and adults in particular are less able to hear higher frequencies that young people are able to hear, demonstrating how our hearing works and how it can fail as we age. Other animals have different hearing ranges from us: some can hear higher e.g. bats, and some lower e.g. elephants.

Touch sensitivity varies on different regions of our body, correlating with the variation in density of touch-sensitive receptors in our skin. Students are able to map which areas of the human body have the greatest and lowest density of touch receptors with a simple test.

Catching a falling ruler to measure reaction time engages a multi-step neural pathway from our eyes to our brain to our hand muscles. The process only takes milliseconds. Reaction times vary greatly between trials for one individual, and average reaction times vary greatly between individuals. Some individuals have very fast reaction times, so are able to take on jobs such as ice hockey goalie or fighter pilot.

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Vocabulary

frequency — How fast a vibration moves back and forth. Hertz is the unit used for sound (as well as other kinds of) vibrations.

pitch — How low or high a note is, determined by the vibration frequency of the molecules that are transmitting the sound.

receptor — A molecule in a biological system that receives signals (e.g. touch, a chemical, light) from outside a cell, and in turn passes a signal to other components inside the cell.

neuron — A kind of cell in animals that transmits information with electrical and chemical signals. There are 100 billion neurons in the brain, which are hugely interconnected. Neurons can be very short (less than a millimetre) or very long (1 metre is the length of a neuron from our spinal cord to foot).

Materials for Sound Detection activity

- tone generator on a phone (e.g. "Tone Generator" by lifegrit.com)
- speaker to connect to phone to increase the volume (for lower frequencies that can be quiet)

Materials for Touch Sensitivity activity

- paperclip bent into a U-shape, with points 1cm apart, one per student pair
- student worksheet
- ruler for each student pair

Materials for Reaction Time activity

- 30cm ruler for each pair of students
- paper and pencil for students

In the Classroom

Introductory Discussion

Tell students that they will be doing experiments on themselves, and that they will be collecting data to share with the class. Demonstrate each activity before running it.

Brief description of science activities in this lesson:

1. Sound Detection: as a class, record the highest and lowest frequencies that students and adults can hear. Compare to other animals.
2. Touch Sensitivity: students record how many points of a paperclip they can perceive on different parts of their skin.
3. Reaction Time: students record how quick they are to catch a falling ruler, and average their results.

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Processes of science that the students will focus on: exploration, mechanical manipulation, accurate measuring, collecting data, classifying and comparing data, recording results, graphing data, interpreting graphs, inferring, concluding.

Science Activities

(A) Sound Detection

1. Introduce this activity with a discussion on what sound is: molecules vibrating back and forth, which bump the next-door molecules, passing the vibration through the air (or liquid or solid). When those molecule vibrations reach your ear, they cause your eardrum to vibrate, which transmits the vibrations through the bones of the middle ear to your inner ear, where tiny hairs (in the cochlea) move. The moving hairs initiate an electrical signal which gets sent via nerves to the auditory section of your brain. Only then do you perceive the sound. Use a diagram of the ear structure to show this pathway (e.g. Ref. 1).

2. Explain how low or high a note is (its “pitch”) depends on the frequency (or speed) of the vibrations. Faster vibrations sound higher, and slower vibrations sound lower. The rate of the vibrations are measured in Hertz, or Hz.

3. Tell students that different people can hear different frequencies - some can hear higher than others, and some can hear lower. This activity collects data on the frequencies that students and adults in the classroom can hear. Demonstrate to students what kind of sound they will be hearing, by turning on the tone generator and the connected speaker, and running up and down the frequencies.

4. Then start data collection. Start the tone generator at the highest frequency, then slowly lower the frequency, and ask students to put their hand up when they start to hear the sound. If at any point, it is hurting students' ears, lower the volume (it may hurt students while adults cannot hear it at all). When students raise their hands, write down the frequency you are at on the board. Keep lowering the frequency, and keep writing frequencies down, until all present in the class can hear the sound. (It is good to start high, so that students are less likely to feel inadequate at not hearing it - adults will likely be the last to hear.)

5. Then collect data on the lowest frequency humans can hear. Continue to lower the frequency and ask students to raise their hands when they no longer hear it. Note that the sound may get very quiet, so be sure to raise the volume on the phone and speaker, and if necessary, move the speaker around the classroom so that students can put their ear to it. Record the lowest frequencies perceived on the board. (Note that the limits of the speaker may define the lowest note that can be played.)

6. Discuss the results. There is a range of frequencies that students can hear, due to variability in their ear physiology. Show students a diagram of the inside of the ear and the path that the sound takes, to show the complexity of sound perception. Adults are usually unable to hear the higher frequencies that students can hear, as during aging humans lose the inner ear hair cells that are sensitive to high frequencies.

7. Compare to other animals. Show students a diagram of animals’ hearing range compared to humans (ref. 2). Humans are able to hear frequencies ranging from 19,000Hz (19KHz) down to 30Hz. Bats can hear higher frequencies than humans (called ultrasound), up to 115KHz, and use these frequencies for echolocation. Elephants can hear lower frequencies than humans (infrasound), down to 17Hz.

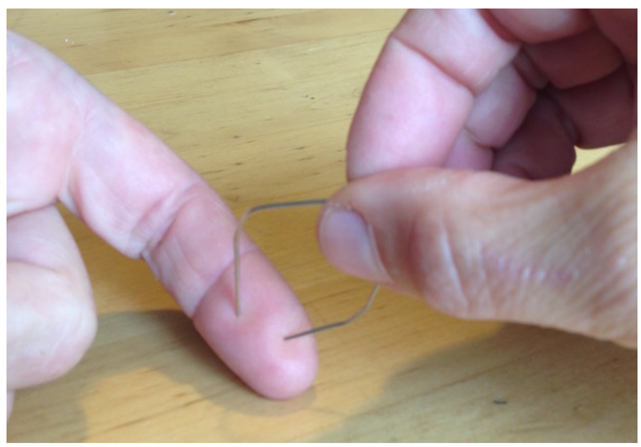
(B) Touch Sensitivity

1. Explain to students that when you touch something, a touch receptor in your skin is activated, which makes a neuron fire to send a message to the sensory part of your brain. Once the brain receives the message you are able to perceive the touch. Some parts of your skin have a greater density of touch receptors and some have the touch receptors spaced further apart. By using the points of a bent paperclip [show students] to touch the skin, we can map the density of touch receptors in different regions of our skin.

2. Pair up the students and distribute a bent paper clip to each pair, and a worksheet to each student. Ask them to use their rulers to check that the points of the paperclip are spaced 1cm apart.

3. Demonstrate to students how to run the touch test and use the worksheet. They will practice on the forearm first. One student should lay their forearm on the table and turn their head away, so that they cannot see themselves being touched. The other student of the pair gently touches the forearm with either one or two points of the paper clip, making sure that two points contact the arm at the same time. The student being touched tells their partner how many points they thought touched them (but does not look or find out if they were right yet). The student doing the touching then records whether the answer was correct or not (but without telling their partner if they got it right yet).

   Then continue with the next touch, recording again if it was correctly perceived or not. This first run with the forearm can be used as practice, to make sure all students are touching gently but clearly, and that they know how to record the data. For this practice run, students can follow the order of one- or two-point touches indicated on the worksheet.

   Once the forearm row of touches has been completed for one student, they can look at how "well" they did (though they are not "good" or "bad" n their success, but are mapping their body for touch). Students switch roles to record the forearm results for the second student on a second worksheet.

4. After ensuring that all student pairs understand the procedure, they can move on to testing different parts of the body. For the following tests, students should randomize the order that they touch with one or two points (so that the order cannot be learned). For each body part, they should still touch with one point five times and two points five times. If students have more time, they can add their own body parts to test and record. Ask students to tally the total "correct" for each body part, then together graph the class results.

5. Explain what the students have mapped and why. Where touch receptors are more closely spaced than the 1cm paperclip, one can sense each point independently and determine if it is one or two points. Where the receptors are more sparse, sometimes the two point touch will only stimulate one touch receptor, so it will feel like one point, and be incorrectly reported. So from the number of correct responses we can predict the relative density of touch receptors for various body parts.

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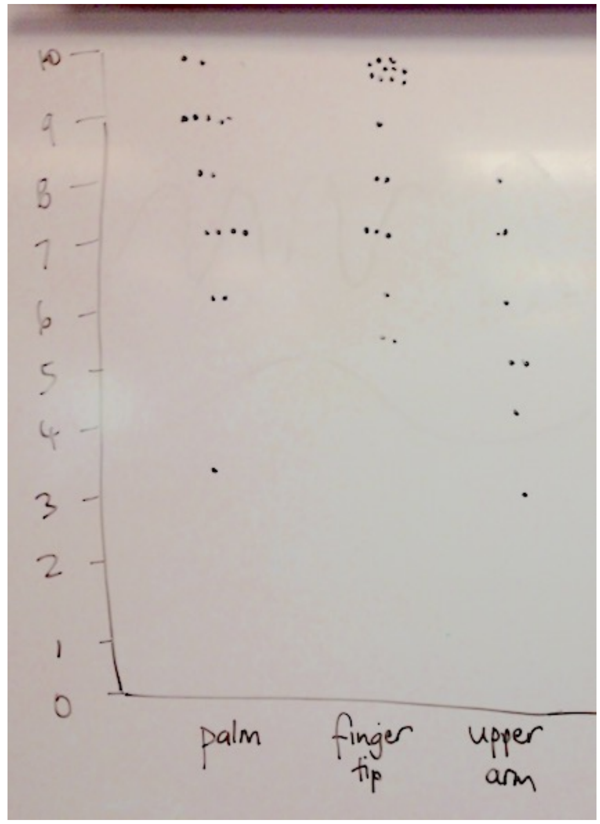
6. Hence, the parts of the body that reported the correct number of touches more of the time would be predicted to have touch receptors closer together, and those that reported incorrectly more of the time would be predicted to have touch receptors further apart. From their results, students are likely to conclude that fingertips and palms have more touch receptors, whereas the forearm and upper arm have fewer (though the forearm was a practice run so may have some errors and variation).



7. Share with students the "threshold distances" (distances between touch receptors) for different parts of the skin, and discuss how they correlate with the students' results:

   Index Finger 2-3mm, Cheek 6mm, Nose 7mm, Palm 10mm, Forehead 15mm, Shoulder 37mm, Forearm 40mm, Upper arm 45mm, Thigh 45mm, Calf 47mm (from Ref. 3). Body parts with shorter threshold distances should have been better at detecting one versus two points.

8. Show image of a sensory homunculus - a man drawn with the size of his body parts scaled to the density of touch neurons they have (Ref. 4). Fun to look at, and to induce further experimentation.

(3) Reaction Time

1. Explain to students that they will be measuring how fast their neurons can transmit information in this activity. They will be using their neurons that allow them to see and neurons that contract their muscles, as well as neurons that send messages between these two processes.

2. Give each pair of students a ruler. Demonstrate how one student rests their arm on the edge of a table their hand hanging over the edge, and holds their thumb and index finger a couple of cm apart. The other student of the pair holds a ruler so that the 0cm mark is between the thumb and finger. (See images in Ref. 5) Without warning, the ruler is dropped and the partner closes their fingers on the ruler to stop it as quickly as they can.

3. Students should record the catch distance each time, doing 10 trials before switching roles with their partner, and record their results.

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4. Ask students to find the mean of their data, and record their average catch distance. Convert catch distances to reaction time (from Ref. 5):

catch dist. (cm)	reaction time (secs)	catch dist. (cm)	reaction time (secs)	catch dist. (cm)	reaction time (secs)	catch dist. (cm)	reaction time (secs)	catch dist. (cm)	reaction time (secs)	catch dist. (cm)	reaction time (secs)
1	0.05	6	0.11	11	0.15	16	0.18	21	0.21	26	0.23
2	0.06	7	0.12	12	0.16	17	0.19	22	0.21	27	0.24
3	0.08	8	0.13	13	0.16	18	0.19	23	0.22	28	0.24
4	0.09	9	0.14	14	0.17	19	0.2	24	0.22	29	0.24
5	0.1	10	0.14	15	0.18	20	0.2	25	0.23	30	0.25

5. Students will have a range of catch distances likely from 10-25cm, making their reaction times between 0.14 seconds and 0.23 seconds (or 140 and 230 milliseconds). Discuss how hockey goalies, and other people in high-speed sports need to have very fast reaction times.

6. Discuss how with any reaction time, it is amazing how fast the processing happens. The order of events starts with the eye seeing the ruler drop and sending a message along a neuron to the visual cortex in the brain. Then other neurons pass the signal to the motor cortex region of the brain. The next neuron connects the motor cortex to the spinal cord, and another from the spinal cord down the arm to the finger muscle. This last neuron signals the finger muscle to contract.

References

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