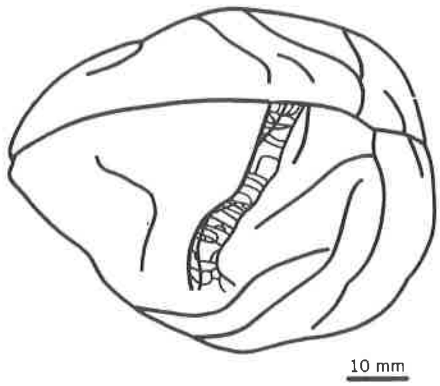
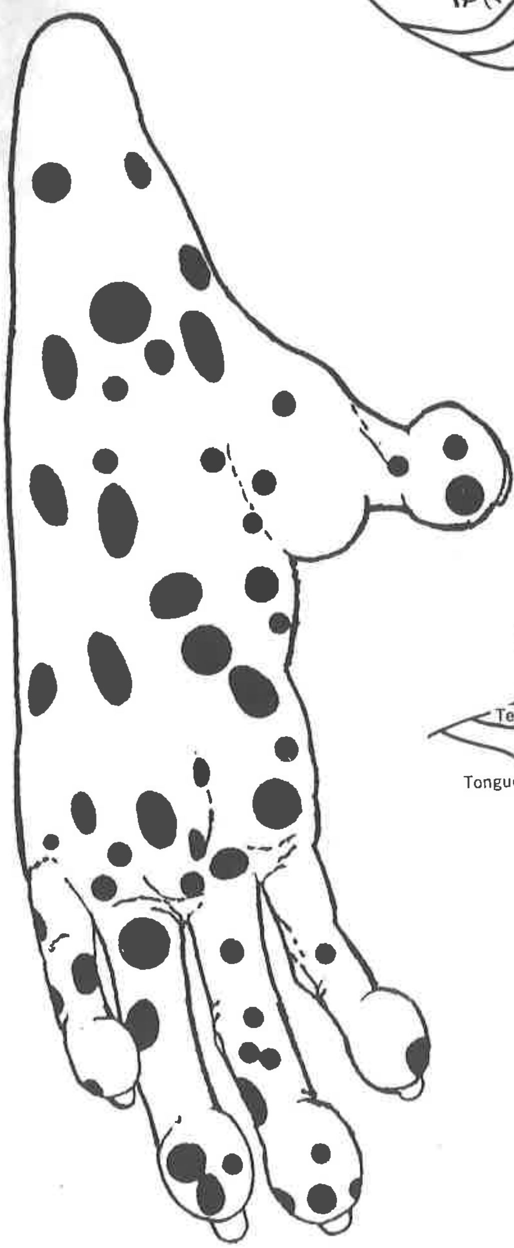
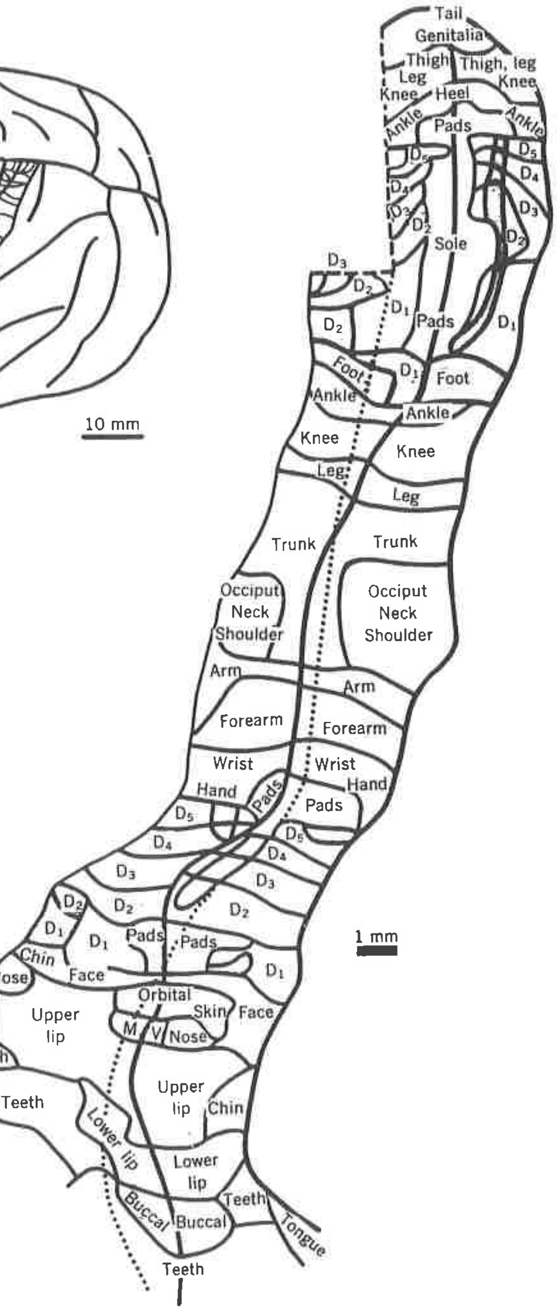
TOUCH AND TEMPERATURE SENSES







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Background About Skin Receptors

All the sights, sounds, odors, tastes, touch, and other stimuli that we sense in the world around us are detected by special kinds of cells called sense cells. Some sense cells (such as those that detect light) are grouped together to form a sense organ (as the retina of the eye). Other sense cells, such as those that detect touch and temperature, are not grouped into organs, but are arranged as separate sensory neurons. The cell bodies of these neurons are located in the dorsal root ganglia near the spinal cord. One branch from each neuron extends into the spinal cord and another extends to the skin, where it branches into tiny terminal endings called receptor endings. Receptor endings from any one sensory neuron are highly sensitive to just one type of stimulus, such as touch. Endings from other neurons are sensitive to other stimulus types, such pressure, heat, or cold, etc. (See Figure 1).

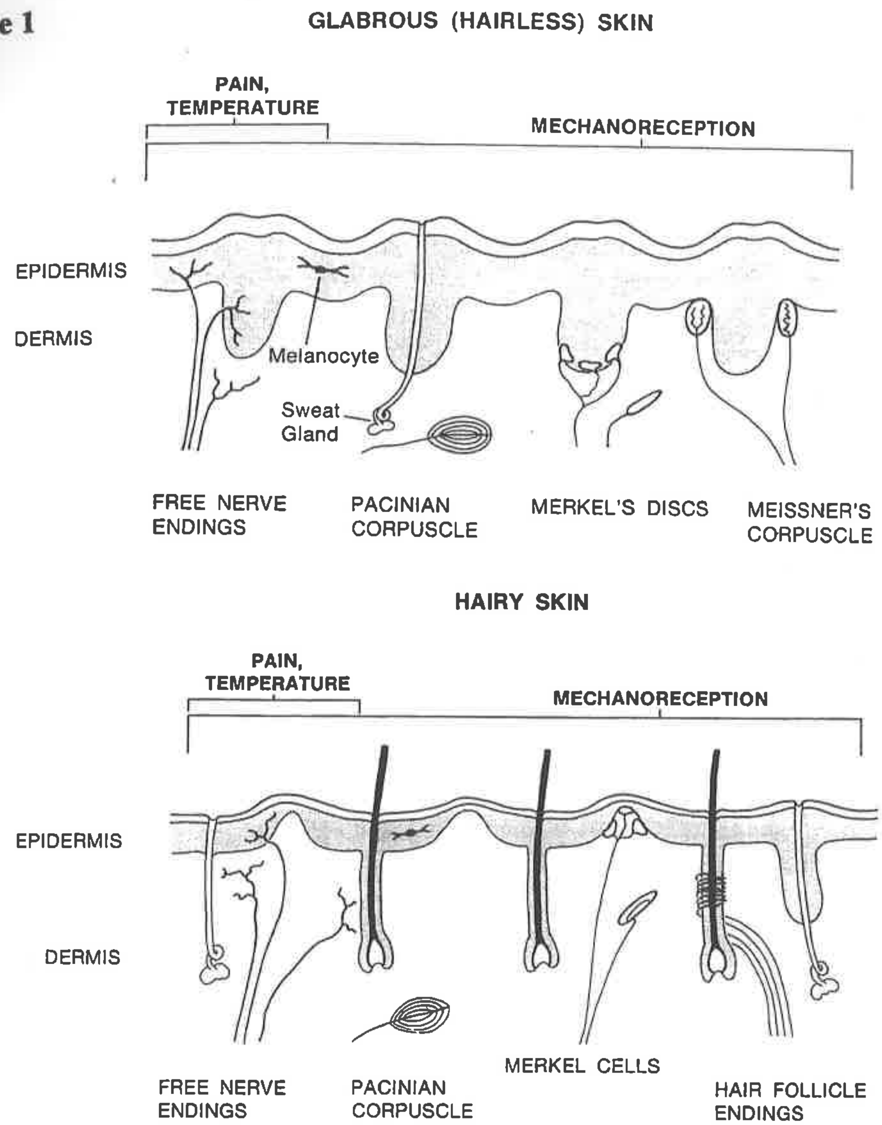
Once a touch stimulus is detected by receptor endings in the skin, the neuron responds by producing electrical impulses (action potentials) that are carried into the spinal cord. Impulses are then relayed to other neurons in the spinal cord and to the thalamus of the brain. From there, the impulses are transmitted to neurons in the somatosensory cortex of the cerebrum (see Figure 2).

It is important to remember that although detection of touch occurs at the receptor endings in the skin, the actual perception (that is, conscious realization or awareness) of the stimulus occurs only when certain neurons in the somatosensory cortex of the brain receive the incoming sensory impulses from that part of the body. Furthermore, each part of the body has a corresponding part of the brain devoted to perceiving its touch. This results in a very specific organization of the somatosensory cortex in which the body surface is represented in an upside-down fashion on the surface of the cortex (see Figure 2 and COVER). Note in these illustrations that some body parts have a greater brain space devoted to the perception of their touch than other parts. For example, large areas of the cortex are devoted to the perception of touch in very sensitive areas, such lips and fingers.

In summary, high sensitivity to touch in areas of the skin such as lips and fingers results from two factors: (1) the large brain space devoted to perception of touch in those skin areas, and (2) the high density of touch sensory nerve fibers and receptor endings in those skin areas. In contrast, low sensitivity to touch in areas such as the trunk and back results from less brain space in the cortex and a lower density of sensory fibers and receptor endings.

This laboratory exercise will focus on the physiology and psychophysics of touch and temperature receptors in human skin. Both quantitative and qualitative features of receptor functions will be explored.

Figure 1



Types of receptor endings for sensory nerve fibers in skin:

<u>Free nerve endings</u>: some are touch-sensitive; some are pain-sensitive; some are cold-sensitive; and some are heat-sensitive. They are found in hairy and smooth skin, cornea of the eye, pulp of teeth, mucous membranes, and many other locations.

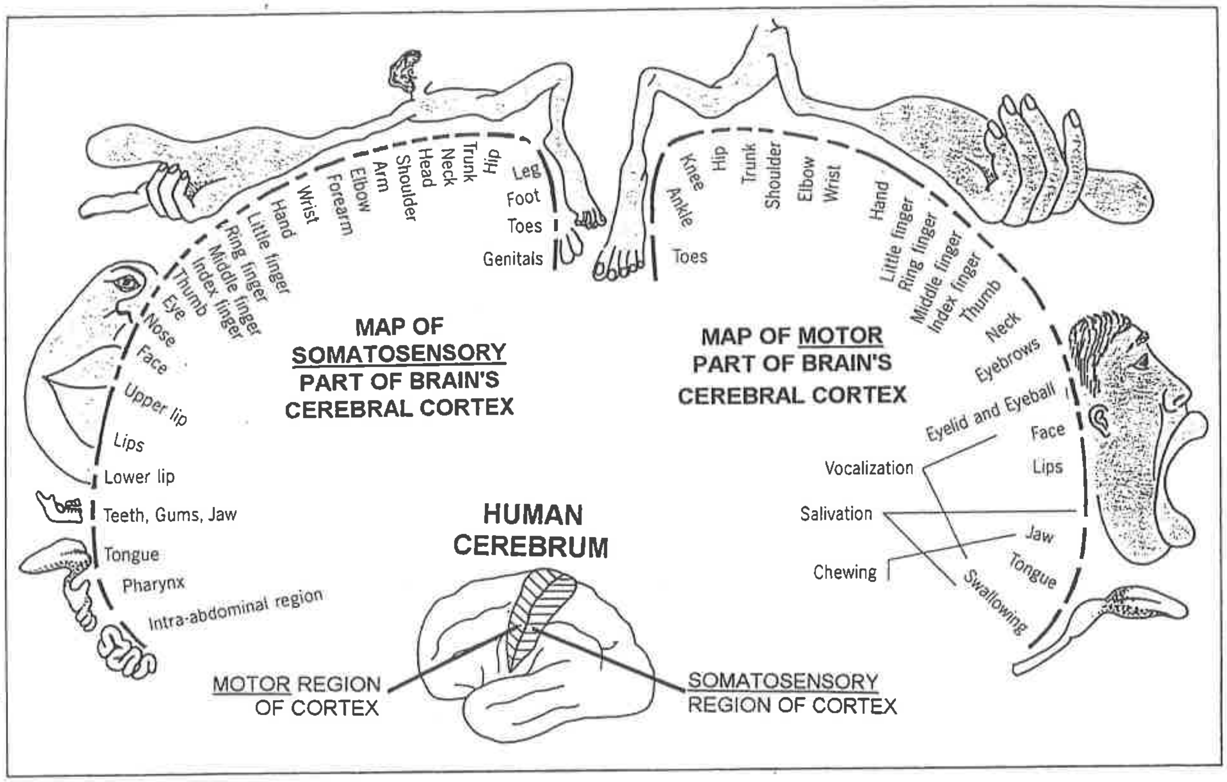
<u>Pacinian corpuscles</u>: sensitive to pressure and vibration.

<u>Merkel's discs and cells</u>: sensitive to touch and pressure. They are important in localizing touch sensation to different areas of the body. These are found in hairy and smooth skin.

<u>Meissner's corpuscles</u>: very sensitive to touch. These are abundant in smooth skin of toes, fingertips, palms, and soles of the feet. They are very important in touch localization and texture discrimination.

<u>Hair follicle endings</u>: very sensitive to movement and touch.

Figure 2



The LOWER diagram in the center shows the positions of the somatosensory cortex and motor cortex of the LEFT SIDE of the human cerebrum.

The two semi-circles show expanded maps of the two cortex regions and the locations where different body parts are represented on these maps. Note that very large areas of each map are devoted to sensory and motor functions of the face and fingers.

Two-point Threshold for Touch

In order for touch at two points on the skin to be perceived by the brain as two separate stimuli, the following prerequisites must be met:

(a) in the skin, stimulation of at least two separate touch sensitive nerve endings must occur;. This is more likely when touching occurs in sensitive areas of the skin that contain a high density of sensory endings; it is less likely in insensitive area that contain fewer endings.

(b) in the spinal cord, nerve impulses triggered by the two stimuli must be carried in two separate pathways leading to two different locations in the somatosensory cortex of the brain. Without activity occurring in two separate spinal cord and brain pathways, the ability to discriminate or resolve separate points of touch would be lost.

Materials:
Calipers with bristles attached
Ruler with mm scale

Procedure

1. Work in groups of two or three, with one person as the subject and the other(s) as examiner and data recorder. The subject should be seated with eyes closed.
2. Starting with the caliper bristles about 80 mm apart, the examiner should lightly touch the two bristles, at the same time, to the back of the subject's hand. The subject should state whether he/she felt the touch as one single point or two separate points.
3. Reduce the spacing between bristles by 10 mm and repeat step 2. Repeat testing again and again with gradually smaller spacings each time. Occasionally, and without the subject knowing, the experimenter should touch the subject with only one bristle. This will help prevent the subject from second-guessing whether a double-point stimulus, in fact, was given.
4. Eventually, a spacing between the two bristles will be found which the subject reports as one rather than two points. This is the two-point threshold distance for that part of the body. Find this value in mm for the back of the hand and record it on the data sheet.
5. Now move to the next area of the body, as listed on the data sheet, and repeat steps 2 through 5. Depending on the size of the area being tested, you may need to begin with smaller spacing. Also, when testing body areas with small two-point threshold distances, changes in bristle spacing with each test will need to be quite small (1 mm, for example) to assure measurement precision and reliability.
6. Switch roles and repeat the procedures and data collection for each group member.

Data Sheet

Body area tested:	Subject 1	Subject 2	Subject 3	Subject 4
Back of hand				
Palm of hand				
Index fingertip				
Forearm (non-hairy side)				
Upper arm (outer side)				
Shin				
Back of neck				

Questions:

1. Assuming that small values for two-point threshold occur in areas with a high density of touch receptor endings, which areas of the body have the highest density of endings?
2. Which areas have the lowest density? Compare your values of two-point threshold distances to values shown in Appendix A.
3. Explain why it would be beneficial to an animal's survival to have different touch receptor densities in different regions of the body.
4. Based on data you collect, try to predict the density of touch receptor endings in the following body areas: lips, thigh, back, toes, and forehead.

Tactile Localization

Tactile localization is the ability to relocate (by memory) a spot on the skin which has just been touched. Generally, the ability to accurately relocate the site of stimulation increases in body areas with the greatest density of touch receptor endings and the greatest amount of brain space devoted to that body area.

Materials:
Blunt metal probe
Metric ruler

Procedure

1. Work in groups of two or three, with one person as the subject and the other(s) as examiner and data recorder. The subject should be seated with eyes closed and his/her hand resting, motionless on a flat surface.
2. The examiner then positions the probe over a selected point on the palm and touches that point so that the subject feels it. [IMPORTANT: The experimenter must keep track of the exact point where the touch was made, but not let the subject see or know.]
3. Next, give the probe to the subject and, with eyes now open, have the subject touch the spot where he/she thinks the touch was made. The subject should hold the probe in that spot.
4. Measure and record the distance in mm between the spot of the original touch, selected by the experimenter, and the relocated spot, selected by the subject. Record this result as the error of localization for trial 1 on the data sheet.
5. Repeat steps 2-4 three times. Then, calculate an average error of localization.
6. Now, repeat the procedure and obtain an average error of localization for the fingertip and inside of the forearm.
7. Switch roles and repeat the procedure for a different subject.

Data Sheet

PALM

	Trial # 1	Trial # 2	Trial # 3	Average Error of Localization
Subject 1				
Subject 2				
Subject 3				

FINGERTIP

	Trial # 1	Trial # 2	Trial # 3	Average Error of Localization
Subject 1				
Subject 2				
Subject 3				

INSIDE FOREARM

	Trial # 1	Trial # 2	Trial # 3	Average Error of Localization
Subject 1				
Subject 2				
Subject 3				

Questions

1. Which area(s) had the lowest average error of localization?
2. Did areas with the lowest average error of localization also have the smallest two-point threshold? Why would you expect these two results to coincide closely? (Hint: Think about the number of touch receptors in these areas and the brain space devoted to perceiving touch in each area.)

Mapping Temperature Receptors

Besides touch sensory nerve fibers, the skin contains other kinds of sensory nerve fibers whose receptor endings are sensitive to temperature. Some of these respond to warmth and others to cold. The endings for each cold-sensitive or warm-sensitive nerve fiber are located under the skin and form a discretely sensitive point that is separate from the points of other fibers nearby. The area of skin occupied by the receptor endings of a single temperature-sensitive nerve fiber is only about 1 mm in diameter. Also, the density of points in different body areas varies greatly. For example, there are as many as 15-25 cold points per square centimeter in the lips, 3-5 cold points per square centimeter in the finger, and less than 1 cold point per square centimeter in some broad areas of the trunk. In most areas of the body there are three to ten times as many cold-sensitive points as warm-sensitive points. It is well established from physiological and psychological testing that warm-sensitive nerve fibers and cold-sensitive fibers are distinctively different structures. Both kinds of fibers seem to terminate as free nerve endings in the skin.

Materials:

Metric ruler
Paper
Tissue
Permanent marker
Masking tape
Drywall joint tape (mesh type)
Blunt metal probes
Cold source to cool probes (e.g., probe tips lay on metal pan in contact with crushed ice)
Hot source to heat probes (e.g., probes stuck in hot sand contained in heated coffee can)
Hot plate

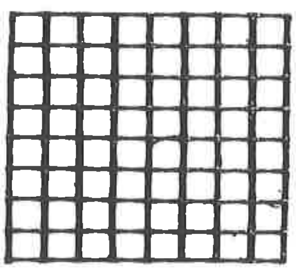
Procedure

1. Work in groups of two or three. One person will be the tester. With a group of two, the second person is both the subject and data recorder (the subject uses one arm to write with, while the other is used for testing). With a group of three, the second person is subject and third is data recorder.
2. Cut off a 2 inch by 3 inch rectangle of drywall tape and place it on a piece of paper. Using the marker, outline the boundaries for an 8x8 grid, as shown on the data sheet diagram. Now, transfer the piece of drywall tape to the ventral (inside) surface of the subject's lower arm. Make sure the adhesive surface of the tape is pressed flat against the arm and that the subject does not move the arm during testing. If needed, secure the edges of the drywall tape to the arm with masking tape.
3. The tester should remove a probe from the cooling source and insulate the probe handle by quickly wrapping it with a paper towel or other material. By holding onto the probe through the insulation, it will not heat up so quickly.
4. With the subject's eyes closed and arm resting motionless on a flat surface, the tester should briefly touch the probe tip to the upper left corner square in the 8x8 grid. Have the subject report whether he/she feels cold or touch. The data recorder should immediately record the result as a *dot* for touch, or *C* for cold, in the corresponding square of the data sheet.

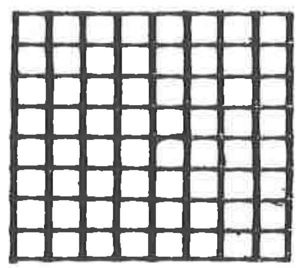
5. Quickly repeat step 4 for each square, working from left to right across the first row of squares, and then doing the same for the second row, and so on, until all 64 squares have been touched. If the team is properly communicating and coordinating, the test sequence should take less than 5 minutes and only a single probe will be needed. If testing is delayed, the probe may become too warm and it may be necessary to obtain another cold probe. Replace the probe in the cold source for later use.
6. Next, remove a probe from the hot sand. Insulate the handle. Then, repeat steps 4-5, keeping the grid in the same location. This time the subject should report whether he/she feels touch or warm. The data recorder should record the result as a *dot* for touch or *W* for warm, as before. (Note: the metal probe cools quickly, so it will probably be necessary to use more than one heated probe for testing all 64 squares.)
7. Repeat the entire testing for cold or warm receptors on another subject, as time permits.

Data Sheet

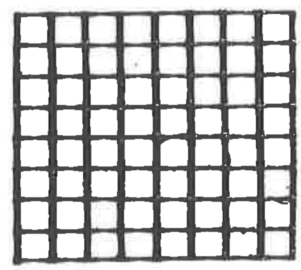
Subject 1



Subject 2



Subject 3



C = cold
· = touch
W = warm

Questions

1. Compare the number of cold spots to hot spots in each subject. Were the locations of these different? Were there some areas of the skin that had neither warm nor cold spots?
2. Measure the length and width of the 8x8 test area on the drywall tape. Multiply length by width to find the area, and express in units of square centimeters. Then divide the number of cold spots for each subject by the grid area to find the density of cold spots. Give units for your values.

<u>Hot point density</u>
Subject 1 ____________________
Subject 2 ____________________
Subject 3 ____________________

<u>Cold point density</u>
Subject 1 ____________________
Subject 2 ____________________
Subject 3 ____________________

Temperature Adaptation

Many sensory nerve fibers respond well to the sudden onset of a stimulus, but then respond less, or stop responding altogether, when the stimulus remains constant. This decrease in the level of response despite continued stimulation is called sensory adaptation. One result of sensory adaptation is that we feel much colder when the temperature of the skin is in the process of falling than when the temperature is held constantly cool. Similarly, we feel warmer when the temperature is rising than when it remains constantly warm. As an example, the water in a swimming pool feels much colder when we enter it than after we've been in it a while. Likewise, hot water in a tub feels hotter at first than after we've been in it a while. Thus our sensations of temperature are more influenced by relative changes (in one direction or another) than by the absolute temperature.

Materials:

3 large bowls or 1000 ml beakers (with ice water in one bowl, room temperature water in the second bowl, and very warm (not hot) water in a third bowl (about 44 degrees C).
Hot plate

Procedure

1. Place the bowls in the following order on a table (left to right): cold, room, and warm.
2. Have the subject place one hand in warm and other in cold water for 1 minute.
3. After one minute, the subject should place both hands in the room temperature water and immediately report the sensation in each hand.
4. Does the sensation change after keeping both hands in room temperature water for 1 min?

Questions

1. Explain what temperature change occurred in each hand when it was moved to the room temperature water. Which sensory receptors were most likely responding in the left hand when it was put in room temperature water? Which in the right hand?

Touch Adaptation

Touch sensory nerve fibers show rapid sensory adaptation to a constant touch stimulus. It is important that touch sensory fibers respond in this way so that we do not feel touch stimuli that constantly exist but are unimportant. For example, we feel our clothes as we put them on or move, but we do not feel them once they are on and we are motionless.

Materials:

Stacks of four pennies and two pennies, held together with double stick tape
Clock with second hand

Procedure

1. Work in groups of two, with one subject and one experimenter.
2. The subject should be seated, with eyes closed and one arm bent (palm facing up).
3. The examiner should place a coin on the forearm. The subject should report when he/she can no longer feel the coin. Record this time, in seconds, on the data sheet.
4. Repeat the measurement with the coin placed in another location on the forearm.
5. Once adaptation has occurred with one coin, place another on the first and determine the time it takes for adaptation to the new touch stimulus caused by addition of the second coin.
6. Using another site on the arm, determine how long it takes for adaptation to a stack of four coins placed on the arm all at once.

Data Sheet

	Time for adaptation to one coin (seconds) Trial 1	Trial 2	Time for adaptation after adding second coin (seconds)	Time for adaptation to four coins at once (seconds)
Subject 1				
Subject 2				
Subject 3				

Questions

1. Compare the time it took for adaptation to one coin to the time it took for adaptation to four coins. Do you think complete adaptation would occur if a hundred pounds of weight was placed on the arm? Explain.

References:

Guyton, A. C. (1987) *Basic Neuroscience: Anatomy and Physiology*, W. B. Saunders, Philadelphia.

Ross, H. E. (1978) *E. H. Weber: The Sense of Touch* (translated from *De Tactu* by E. H. Weber), Academic Press, New York.

Schmidt, R. F. (1978) *Fundamentals of Sensory Physiology*, Springer-Verlag, New York.

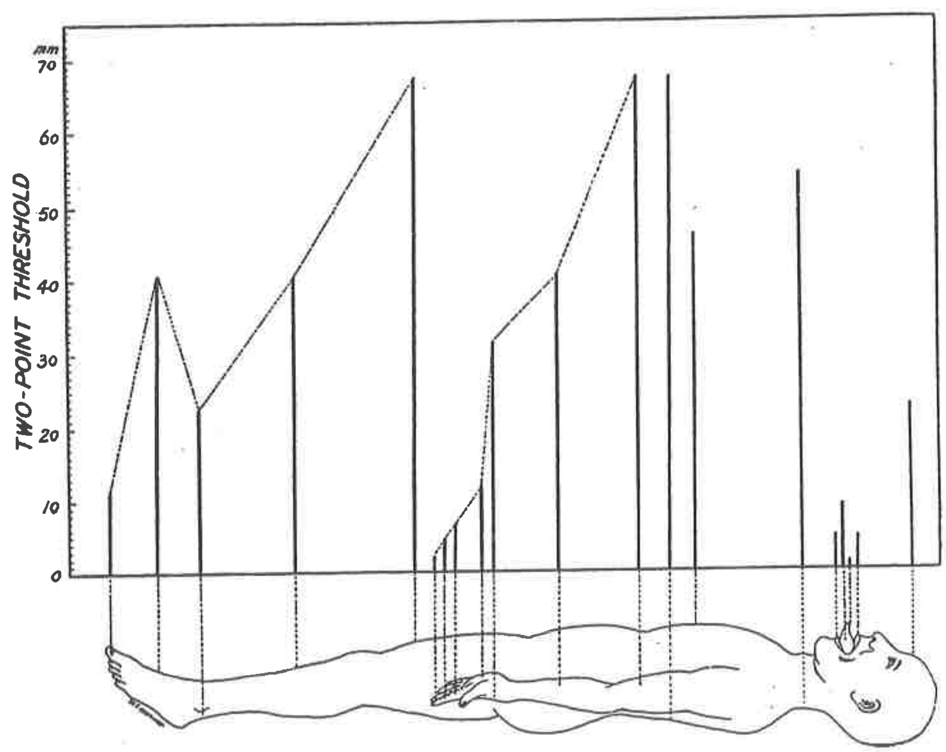
Shepherd, G. M. (1988) *Neurobiology*, Oxford University Press, New York,.

Appendix A. Examples of regional variation in two-point threshold

Two-point threshold values for human skin
(from E. H. Weber's *De Tactu*, 1834)

Values here are converted from original units (Paris lines) to millimeters.

tip of tongue	2 mm	side of stomach	47 mm
lower lip	4 mm	mid upper arm	36 mm
upper lip	4 mm	forearm undersurface	23 mm
tip of nose	7 mm	palm of hand	13 mm
skin on cheekbone	18 mm	back of knuckles	16 mm
mid forehead	22 mm	tip of second finger	1 mm
ear	20 mm	front of mid thigh	41 mm
back of neck	27 mm	mid shin	27 mm
midback	29 mm	mid calf	40 mm
lower shoulder blade	61 mm	upper foot surface	27 mm
side of chest	34 mm	sole of big toe	13 mm
mid front of back	40 mm	tips of toes	9 mm



from: Patton, H. D. et al. (Introduction to Neurology), 1976.