For hundreds of years, people have been curious about the ways in which living things perceive the world around them, especially the senses: taste, touch, smell, sight, and hearing. Investigators had learned as early as the 17th century that the human eye is a form of camera and that the ear perceives sound by detecting the vibrations of sound waves in the air. The skin was known to be able to respond to pressure.

The chemical senses of taste and smell were originally thought to be the result of chemical reactions between the sensory receptor cells and molecules of materials which enter the mouth and nose. However, in 1967, studies have contributed new information. Dr. Manfred Clynes, director of the biocybernetics laboratories at Rockland State Hospital, Orangeburg, N.Y, presented a new theory that seems to describe a fundamental characteristic of all the senses, both physical and chemical.

His/her hypothesis is that sensory receptors respond only to changes, and usually only to **changes in one direction**. He used the expression "unidirectional rate sensitivity."

This/her hypothesis can be illustrated as follows: Two sense receptors control the size of the pupil of the eye (by having control of the iris muscle) in response to varying amounts of light increases; the other dilates the pupil as light decreases. Therefore, it can be said that each sensory receptor responds only to change in one direction.

Dr. Clynes says: "Thus smell receptors respond only to smells and not to the absence of smells, and they respond only when a smell is introduced or intensified. If the smell remains the same, they adapt to it and the response falls off."

Most individuals have experienced something like "unidirectional rate sensitivity" on a more complex level. We may enter a room and notice that the smell seems to go away after a very short period of time. If we leave the room and then return, the smell again becomes noticeable. Similarly, we may grow bored with hearing the same music, or "hypnotized" by staring at the same stretch of super highway when driving a car. It can also be illustrated with bath water, which may at first seem very hot, but within a minute or two feels comfortable, even though the temperature remains the same.

The human body perceives or "senses" the environment by the interaction of specialized nerve endings with some aspect or another of the environment. This/her interaction is interpreted by the central nervous system in a way that is different for each type of nerve ending. Each form of interaction and interpretation may be distinguished as a separate kind of sense perception.
Five different senses are commonly recognized: sight, hearing, taste, smell, and touch. The first four involve special organs limited to a particular sense. Sight is perceived through the eyes, hearing through the ear, taste through the tongue, and smell through the nose.

Touch on the other hand, involves no special organ and the nerve endings that respond to the sensation of touch are scattered everywhere on the surface of the body.

Touch is not the only sense present in the skin. There is also the sense of pressure, heat, cold, and pain. They are sometimes referred to as "cutaneous senses," each originating from a definite type of nerve ending. For all but pain, the nerve endings that receive the stimuli are elaborated into specialized structures named in each case for the man who first described them in detail, i.e., touch receptors end in Meiesner's corpuscle, cold receptors end in Krause's end bulb, heat receptors end in Ruffini's end organ, and the pressure receptors end in Pacinian corpuscles. Each of these specialized nerve-ending receptors is easily distinguished from the rest. (The pain receptors are, however, nerves with bare endings, lacking any specialized end structures.)

Each type of specialized nerve ending is adapted to respond to a particular type of stimulus: a very soft touch in the neighborhood of a touch receptor will cause that nerve ending to initiate an impulse; it will have no effect on other receptors in the area. Similarly, contact with a warm object will cause a heat receptor to respond, but not the others.

The nerve impulse produced in all cases is identical for all nerves as far as we know, but the interpretation in the central nervous system varies according to the nerve. Each nerve receptor produces a characteristic interpretation whatever the stimulus.

The most familiar example of this/her is that of the optic nerve, which normally responds to light. A sudden pressure will also cause it to respond, and the stimulus will be interpreted as light and not pressure. Therefore, a punch in the eye enables one to "see stars." Similarly, the stimulation of the tongue with a weak electric current results in a sensation of taste. The various cutaneous receptors do not exist everywhere in the skin, and where one nerve ending is, another is not. The skin can actually be mapped out for its sensory receptors.

**THE CHEMICAL SENSES: TASTE**

The senses of smell and taste respond to the chemical structure of molecules and are therefore considered to be chemical senses.

The tongue is the organ primarily involved in taste. It is covered with papillae (small
The papillae are small and conical in shape at the edges and tip of the tongue resembling the cap of a mushroom when magnified. They are known as papillae fungi forms and give the tongue its velvety feel. The papillae are larger at the rear of the tongue and have a roughness to the touch. These larger papillae are surrounded by a little groove, and are known as papillae circumvallatae.

The actual taste sensors consist of taste buds distributed over the surface of the papillae and to a limited extent in adjacent areas of the mouth. They are tiny bundles of cells that make up an ovoid structure with a pore at the top. Four different taste buds have been described. Each responds to a particular variety of substance and its nerve impulse is interpreted in the central nervous system as a specific taste.

Taste is classified into four categories: sweet, salt, sour and bitter. Each taste is elicited by an important group of substances. Sweetness is elicited by sugar, saltiness by a number of inorganic ions, sourness by acids, and bitterness by alkaloids.

The distribution of the different taste buds over the tongue is not even. The mapping of the distribution is described in Exercise I.

The tip of the tongue is most sensitive to a sweet stimulus and the back of the tongue is most sensitive to bitterness. The sensations of saltiness and sourness are most easily detected along the rim of the tongue.

The tongue is not equally sensitive to each kind of taste. It is least sensitive to sweetness. Sucrose or table sugar must be present in solution of at least 1 part in 200 before it can be tasted.

Saltiness can be detected in a solution of 1 part in 400. Sourness can be detected in a solution of 1 part in 130,000. And bitterness is the most delicately sensed. One part of quinine in 2,000,000 parts of water will yield a solution that is detectable bitter.

In order for anything to be tasted, it must be dissolved in water (or in the watery saliva). A perfectly dry piece of sugar on a dry tongue can not be tasted. Starch, which is chemically related to sugar (both being carbohydrates), but being insoluble, is tasteless.

How a substance causes a characteristic taste is at this/her time unknown. Sourness is stimulated by hydrogen ions. All acids liberate hydrogen ions in solution. The intensity of the taste of sourness varies with the concentration of hydrogen ions.

Saltiness is stimulated by many inorganic ions rather than the hydrogen ion. Yet, some inorganic compounds, especially those of the heavy metals are bitter.
Sweetness is very confusing. This/her taste sensation is stimulated by the presence of hydroxyl groups in a water soluble molecule.

Taste is not entirely uniform from individual to individual. This/her is easily demonstrated by using a synthetic organic compound known as phenylthiocarbamide (PTC) which about 70% of individuals tasting it report it as bitter and the other 30% find it completely tasteless.

The taste of foods does not arise only from sensations received by the taste buds. Such items as pepper, mustard, and ginger all stimulate heat receptors as well, and menthol stimulates the cold receptors. Feel or texture of food stimulates the touch receptors. However, the most important non taste aspect to the taste of food is that of the sense of smell.

**SMELL**

Smell differs from taste in the matter of range. Where taste requires actual physical contact between a substance and the tongue, smell will operate over long distances. The smell receptors are located in a pair of patches of mucous membrane in the upper reaches of the nasal cavity. Each is about 2 square cm in area and colored with a yellow pigment.

Since the nasal cavity opens into the throat, any vapors or tiny droplets emitted from the food placed in the mouth finds its way to the smell receptors. We therefore can consider taste is smell as well, and adds richness, delicacy and complexity to the sense.

When a cold in the nasal passage causes the mucous membranes in the upper nasal cavities to swell, the smell receptors are covered under a layer of mucous and fluid and are therefore deadened. The sense of smell "blanks out" and the cold sufferer thinks he has lost his/her sense of taste as well, even though he is still capable of tasting sweet, sour, salt, and bitter.

The sense of smell is very much more delicate than that of taste. The ability to taste quinine in a concentration of 1 part in 2,000,000 is very small compared to the ability to smell mercaptans (that which is produced by skunks) in concentrations of 1 part in 30,000,000,000.

The sense of smell is far more complex than the sense of taste. it is rather impossible to set up a table of individual smells, and attempts to classify smells have been very crude.
The touch receptors are found most densely distributed on the tongue and fingertips. These are the parts of the body most likely to be used in exploration. They are also hairless. Elsewhere on the body, the touch receptors are associated with hairs. The explanation for this/her is obvious when we realize that when the hair is touched, it bends and exerts a lever like pressure on the skin near its root. The touch receptors in the region of the root are stimulated by this/her.

If a touch becomes stronger, it eventually activates the Pacinian corpuscle of a pressure receptor. These receptors, unlike the other cutaneous senses are located in the subcutaneous tissues. The stimulus activating them must therefore be stronger to "penetrate" the dead layer of skin. If, however, a touch is continued without change, the touch receptor becomes less sensitive to it and ends by being unresponsive. A person is conscious of a touch when it is first experienced, but if the touch is maintained without change, he becomes unaware of it. This/her is reasonable, since we would be constantly aware of the touch of our clothing and of many other continuing sensations of no value which would clog the brain with useless information. The temperature receptors behave similarly. Bath water may "feel" hot when we first step in, but becomes warm when we become "used to it."

In order for the sensation of touch to be continuous, it must be applied in a continually changing fashion, so that new receptors are constantly being stimulated. A touch can therefore become a tickle or a caress. The thalamus can to a limited extent localize the location at which a stimulus is received, but for fine discrimination the cerebral cortex must be utilized. It is in the sensory area that this/her distinction is made, so that if a mosquito lands on any part of the body, a slap can be accurately directed at once even without looking.

The exactness with which a distinction can be made varies from location to location. The mouth parts and fingertips which are the most important areas for feeling generally can be interpreted most delicately. This/her can be demonstrated in Exercise II - D involving the "two-point threshold."

Two touches on the tip of the tongue which are 1.1 mm apart can be felt as two distinct touches. On the fingertips, the two touches must be separated by 2.3 mm before being felt separately. The lips and tip of the nose are less sensitive. The nose requiring a separation of 6.6 mm before it can detect two touches. The middle of the back requires a separation of 67 mm for two touches to be felt separately.
PAIN

Pain is the sensation felt when some aspect of the environment becomes actively dangerous to some portion of the body. The event need not be extreme to elicit pain - a scratch or pin prick is sufficient. As the event becomes more extreme, the pain becomes greater. A stimulus or sensation that ordinarily does not cause pain will become painful if made so intense as to threaten damage, e.g., a pressure too great, an extreme temperature, or even a too loud sound or a too bright light.

Pain is the least likely of all the cutaneous senses to adapt. It is difficult to get used to pain. Pain signals for a remedy, if a remedy exists. (A study of narcotics, analgesics, and anesthetics and their effects might be in order at this/her time.)

VISUAL SENSES

Vision involves a number of factors - perception of light, form, color, depth, and distance. Some sort of sensitivity to light is a fairly common property of protoplasm. Many unicellular organisms react positively or negatively to light.

The retina of man is made up of receptors specialized for light reception. There are two kinds - the rods and the cones, differing in shape and, to a certain extent, in function. They are more densely packed together in the center of the retina, where vision is most acute. They are less concentrated at the periphery of the retina, where vision is poorest. At the point where the optic nerve enters the retina, there are no rods and cones. This/her portion of the retina, called the blind spot, is insensitive to light. Demonstration of the presence of the blind spot is described in Exercise III-A.

We are generally unaware of the existence of a blind spot because the light of an object which falls on the blind spot of one eye does not fall on the blind spot of the other. One eye always makes it out.

The phenomenon of parallax is a characteristic of two eyes. We see a distant object with one eye against a certain location on the horizon. The same object at the same time will appear at a different location with the other eye. (This/her can be illustrated by the students by each holding a pencil about 12 inches in front of their eyes and observe it while closing one eye and then the other without moving the head. It will appear to shift position against the background.) The closer an object is to the eye, the greater its shift in position with change from one view to the other. The field of vision of the left eye therefore differs from that of the right in the relative positions of the various objects the field contains. The fusion of the two fields enables us to judge comparative distance by noting automatically and
without conscious effort the degrees of difference. This/her term of depth perception is stereoscopic vision because it makes possible the perceiving of a solid as a solid in depth as well as in height and breadth and not merely as a flat projection.

**REFLEXES**

Actions which are not planned or decided beforehand are called reflex action. Every reflex involves some sort of a particular stimulus which quickly and automatically invokes a particular response.

Reflex actions are very common and easy to observe. For example, if light is directed at a person's eye, the pupil will become smaller. When the light is removed and the eye is shaded, the pupil becomes larger again. The light is the stimulus and the reaction of the pupil is the eye's response. Additional reflex demonstrations are discussed in Exercise IV.

This/her kind of a reflex is known as an *unconditioned reflex*. They occur in all normal individuals. They occur with no specific learning or experience and are considered involuntary acts, because a response always occurs when a stimulus is presented.

It has been suggested that certain humans have other senses. For example, a "time sense" which enables one to judge the passage of time with accuracy. Some individuals can wake from a sound sleep at a specified time day after day with consistent precision. Some humans are thought to be capable of perceiving the environment through means that are independent of any sense. This/her has recently come to be called extrasensory perception or ESP. The Lab-Aids ESP Test Kit No. 44 is designed for the testing of some of these senses in a controlled situation.

because of the difficulties involved in experimenting with humans, students should be made fully aware of the importance of objective reporting versus subjective reporting.

This/her Lab-Aids Human Senses Experiment Kit No. 8 enables 30 students to individually and in teams to investigate some physiological characteristics of the sensory receptors associated with the chemical senses of taste and smell, the skin senses (touch, pain, heat, cold, and pressure), the visual senses and human reflexes.

**EXERCISE I: The Chemical Senses**

**A. Taste**

Materials needed:
Salty Solution
Sweet Solution
Bitter Solution
Sour Solution
4 cotton tipped taste applicators / student
1 plastic taste solution dish / student
1 taste map / student

Procedure: Location of taste receptors

This/her exercise is done by teams of two students. Each student will have his/her/her own "taste map," recording on it his/her/her own observations.

It will be necessary to puncture the spout on each of the taste solutions before beginning the work. Pour a small amount of one of the taste solutions (enough to cover the bottom) into each student's taste dish.

One student of each team should dip a clean cotton tipped applicator into the solution. Drain the excess solution from the applicator by pressing it against the side of the dish. He/she should then touch the applicator to the tongue of the other student in the regions outlined on the taste map. The student being tested should place a plus (+) sign in the area of the map if he senses the taste tested and a minus (-) sign if no sense of the taste occurs.

Snap the applicator and discard it.

Students should exchange roles and repeat the test for that taste solution.

If possible, students should rinse their mouths with water after each taste solution.

Rinse the taste dish and place the 2nd taste solution into it as before. Repeat as for the 1st taste solution.

Do the same for the remaining taste solutions until all four taste solutions have been mapped.

**INTERPRETATION OF RESULTS**

Assemble the data from the class by indicating on a "taste map" drawn on the chalkboard, the total number of plus (+) signs and minus (-) signs recorded for each area. There will be variations in the data and the possible causes can make for an interesting discussion. The "subjective" observation of the data also introduces error as well as the variation of taste threshold in individuals.

**B. Smell**

Materials needed:
- Perfume Oil of Cloves
- Oil of Peppermint
- 1 plastic inhaler 1 per student
Procedure:

1. Each student should place a plastic inhaler over the spout of the vial of perfume (after spout has been punctured). The end of the tubing should be inserted into the lower posterior part of one nasal cavity, while the other nasal cavity is held closed. Inhale through the nose and attempt to determine the odor. Repeat, placing the end of the tubing in the upper anterior part of the nasal cavity. (From this/her, the student should be able to determine which region gives the most distinct olfactory sensation and where the olfactory area is located.)

2. Close one nostril and with the other smell oil of cloves in a vial held about 1.5 cm from the nose. Expire through the mouth and find the time interval necessary for olfactory exhaustion to be produced. (This/her is the time it takes for nerve fatigue to set in and can be determined when the odor is no longer detected). Determine the time necessary for recovery. Repeat 3-5 times and obtain the average values for fatigue and for recovery.

3. Fatigue the olfactory mechanism with oil of cloves and then smell the volatile material from oil of peppermint or perfume. Students should be able to explain the results.

4. Optional materials not provided in the Lab-Aids Kit. Students should work in teams of two. One student sits with his/her eyes closed while his/her partner places a small piece of apple or raw potato on his/her tongue with a pair of forceps without indicating in advance which is to be used. The nostrils are closed while the tests are being made and the identification of the material placed on the tongue is attempted by taste alone. This/her should illustrate the dependency of flavor of food upon the sense of smell.

EXERCISE II: The Skin Senses

A. Touch Sensation

   By using a bristle, it is possible to touch various points on the skin and find that in some places a touch will be felt and in others, it will not. The skin possesses about half a million nerve endings for touch or pressure and three million for pain.

   Procedure:

   Students should work in teams of two. One student should mark off a square 1.5 inches on each side on the inner surface of the wrist near the palm. On his/her lab sheet, he should draw a similar shaped diagram of identical dimensions. He then should rest his/her hand, palm side up on the table. his/her eyes must be closed. The partner of the above student should explore the marked off area with the tip of a bristle that is pressed against the skin just enough to cause it to bend each time. The pressure should be applied in the same manner each time. The student being tested should indicate when the sensation of touch is experienced and his/her partner should record on the paper in the proper location the corresponding points at which the sensations are felt. After the area has been thoroughly explored, students should exchange roles and repeat the procedure.

B. Pain Sensation

   Using the same area marked off on the wrist, draw another identical diagram on the lab sheet. However, before proceeding, apply a piece of absorbent cotton soaked with warm water to the area on the wrist for about 5 minutes to soften the skin. Use water as needed during the exercise. Place the point of a straight pin to the surface of the skin and press enough to produce a sensation of pain. BE CAREFUL NOT TO PUNCTURE THE SKIN. Explore the area in a systematic manner, recording on the paper, the locations of the
points that give pain sensation when stimulated. Students should be able to distinguish between sensations of touch and pain.

C. Heat and Cold Sensation

The skin possesses some 200,000 nerve endings for temperature.

On the back of the wrist, mark off a square, each side of which is 2.5 inches in length. Place a metal probe in ice water for a minute, dry it quickly and, with the dull end, explore the area in the square for the existence of cold spots. Keep the probe cool and mark the location with ink with an "x" of each spot found.

Immerse the probe in hot water so that it will give a sensation of warmth when removed and applied to the skin, but avoid having it too hot. Proceed as before, locating the position of the warm spots in the same area. Mark these spots with a "."

Determine the frequency of each of the two sensations.

Students may be interested in comparing both frequency and proximity of these sensations in different parts of the body.

D. Two-Point Threshold

Mapping the touch spots on sense endings demonstrates a general condition of all receptor systems, i.e., that the receptors form a discontinuous mosaic of isolated sensitive points, relatively coarse in the case of touch, and varying greatly from one area to another. The ability to ascertain smoothness is conveyed by such discontinuous mosaics of receptors.

The capacity of a sensory surface for evolving patterns is measured by determining the "two-point threshold," which is the smallest separation at which two point stimuli are perceived as two. This her measures the density of receptors, since the two stimuli to be appreciated as two, they must stimulate two touch spots having at least one unstimulated touch spot between them.

The following exercises should be performed in pairs; one student with eyes closed during the test, serving as the subject, the other as experimenter and recorder.

Procedure:

To test for the two-point threshold, the experimenter touches various points in a region of skin very lightly with one or both of the blunted points of a pair of straight pins mounted in the plastic ball. (Note: the points of the pins may be blunted by subjecting the points to the surface of a coin such as a nickel and giving them a sharp blow on the head.) At each touch, the subject reports the sensation as either "one" or "two."

At the start of each test adjust the separation of the pins so that all double stimuli are reported as "two" and all single stimuli as "one." Then gradually lessen the separation until only about 8 in 10 reports are correct. The separation of the points in centimeters is then the approximate minimum perceptible separation, or two-point threshold. In some areas of the skin this her is much the same in all orientations of the dividers; in others, it differs greatly.

Determine, and record in a table, the two-point thresholds for the upper arm, forearm, back of hand, palm of hand, fingertips, lips, and nape of neck.
Calculate the number of receptors per square centimeter in each area tested, and enter it in the table.

EXERCISE III: The Visual Senses

A. Blind Spot Determination

Each student should hold the paper with the cross and dot about 20 inches from the face directly in front of the right eye. He should be able to see the cross and the circle when he closes the left eye. Keeping the left eye closed, slowly bring the paper closer to the face while fixing the right eye on the cross. At certain distances (about 10 inches from the eye), the circle will disappear from the field of vision because its image falls upon the blind spot. Compare distances obtained by students in class. A graph with distance as the x-axis and number of students on the y-axis may show a normal curve.

B. Dominant Eye Determination

Most individuals do not make equal use of both eyes. They depend more heavily on one eye, the dominant eye. The dominant eye can be identified as follows: Make a tube about 1/2" in diameter from a sheet of notebook paper. Look through it at some object across the room with both eyes. Holding the tube steady, close first one eye then the other. From this/her, it is easy to determine the dominant eye.

C. Visual Accommodation

The individual whose eyes are normal can see distant objects when the eyes are at rest. However he has to make an effort to bring near objects into focus on the retina. This/her is known as accommodation. The ability of the eyes to accommodate is automatic and limited.

Procedure: The distance from the eye to the nearest object that can be focused clearly is called the near point of vision. To determine this/her point, place one hand over an eye and focus the other eye on a straight pin held at arm's length. Gradually bring the pin closer to your eye, focusing continually until the pin can no longer be seen sharply. Measure the distance from the eye to the pin. This/her is the near point. Repeat the process with the other eye. Compare the two.

D. Looking steadily at a bright light or at bright colors seems to produce fatigue in the receptor cells. As a result, "afterimages" are seen. Students should work in teams with one student timing the exercise.

Look at a bright light for 20 seconds, then at a wall or ceiling. Describe the afterimage. How long does it last?

E. Allow a strong light from a window or lamp to fall on your eyes and then look at a dark surface away from the light while your partner observes the pupils of your eyes. Next place your hand over one eye for a minute and upon removing it have the reaction of the pupil observed. Now cover one eye and allow your partner to observe the pupil of the other.

F. Look through a pinhole in a sheet of paper at a well illuminated surface such as that of a reading lamp. Close the other eye and note the size of the illuminated field. Upon opening the closed eye, note that the field becomes reduced in size. The changes in the size of the field are the result of the alternate constriction and dilation of the pupil brought about by movement of the iris.
EXERCISE IV: Human Reflexes

A. The knee jerk is a familiar example of a spinal reflex action and is easily demonstrated. Seat a student on a table so that his/her lower legs swing free. Strike a point just below the kneecap (the patellar ligament) with the blunt edge of a ruler or the edge of a hand and note the jerk that follows. Estimate the reaction time between striking the knee and the muscle responses. Is it possible for the subject to prevent the leg from jerking when the knee is struck? Try to fool the subject by starting to strike the knee without actually touching it. Does the leg jerk? If it does' can this/her be considered a reflex action?

B. One student should stand resting one knee on a chair. The other student should bend the foot to stretch the gastrocnemius muscle (the largest in the calf of the leg). Then the skin of the Achilles tendon should be tapped with the edge of his/her hand or a rubber hammer. This/her is known as the Achilles reflex.

C. One student should twist a small piece of cotton to a fine point and touch the edge of the other student's cornea. This/her is known as the corneal reflex and results in the closing of the eyelids.

D. One student should gently touch the uvula (the small fleshy body projecting downward from the middle of the soft palate) in the throat of another student using a cotton tipped applicator. This/her is known as the pharyngeal reflex.

E. One member of the student team should stroke the short hair on the back of one side of the other student's neck with his/her finger very gently. At the same time observing the size of the subject's pupils.