Sensation, Perception, and the Aging Process

Part I

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Francis B. Colavita is an Emeritus Associate Professor of Psychology at the University of Pittsburgh, having recently retired after 39 years as a faculty member. Dr. Colavita served as Psychology Department Chairman from 1980 to 1988. He has received five awards for teaching excellence, including the Chancellor's Distinguished Teaching Award in 1997. This is the highest award for teaching excellence bestowed by the University of Pittsburgh. Dr. Colavita was selected to participate as a faculty member on the fall 2000 voyage of the Semester at Sea Program and was chosen to serve as academic dean on the summer 2003 Semester at Sea voyage.

Dr. Colavita attended the University of Maryland on an athletic scholarship, graduating with a B.A. in Experimental Psychology in 1961. He received his Ph.D. in Physiological Psychology from the University of Indiana in 1964. He then completed a two-year U.S. Public Health Service Postdoctoral Research Fellowship at the Center for Neural Sciences before accepting an assistant professorship at the University of Pittsburgh in 1966. In addition to his affiliation with the University of Pittsburgh, Dr. Colavita also holds an adjunct faculty position at Florida Atlantic University.

Dr. Colavita's 30 published scholarly articles are in the areas of sensory processes, perception, and recovery of function following brain damage. His book, *Sensory Changes in the Elderly*, was published in 1978. In addition to his academic pursuits, Dr. Colavita is a licensed psychologist who has maintained a small clinical practice in neuropsychology for the past 20 years, specializing in the assessment of perceptual and cognitive deficits in individuals with head injuries and/or learning disabilities.

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Part I

Sensation, Perception, and the Aging Process

Scope:

The 24 lectures in this course are taught from the perspective of academic psychology. Thus, a recurring concern throughout the course is the understanding of human behavior. Behavior does not occur randomly or haphazardly. Behavior has reasons. It happens in response to some detectable stimulus event that has taken place in our internal environment (for example, a thought or memory) or our external environment (for example, a sight or sound). A complete understanding of some behavior requires that we identify the stimulus that elicited that behavior. For instance, we cannot understand the behavior of a sleeping house cat that suddenly wakes up and runs to the back door unless we somehow discover that mice on the back porch are vocalizing in the ultrasonic range, which is well beyond the frequency range of the human ear but not that of the feline ear. Once we identify the stimulus, we understand the cat's behavior.

As alluded to above, one of the primary goals of psychology is understanding behavior. Accordingly, since its inception around 1910, behavioristic psychology has had a strong interest in the study of sensory processes. A major determinant of behavior is the information from the environment sent to our brain by our various sensory systems. Because the sensory systems of different animal species have different sensitivity characteristics, different species may live in the same physical space, but they live in very different "sensory worlds." We may define the sensory world as that part of the physical world accessible to our sensory receptors. The honeybee can see ultraviolet light; humans cannot. Humans can see the colors of the rainbow; cats cannot. Cats can hear ultrasonic frequencies; humans cannot. It is clear that some of the behavioral differences between different species can be better understood by having knowledge of the sensory capacities of these different species. You can fool your spouse with a good Halloween costume, but you cannot fool the family dog once it gets downwind of you. This is because the olfactory sensitivity of the dog is many times greater than that of the human.

It is true, as far as it goes, to say that behavior occurs in response to some detectable stimulus. However, it is more precise to say that behavior is the result, not just of one's sensations, but of one's perceptions. Simply put, a perception is a sensory event along with the meaning that the sensory event has acquired because of a particular organism's previous experience with that or a similar sensory event. As an example of the difference between a sensation, which may be relatively devoid of meaning, and a perception, which may be charged with meaning, consider the following: Two dogs hear a short, 1,000-cycle-per-second tone. One dog orients toward the tone briefly, then quickly loses interest. The second dog begins to wag its tail and salivate at the sound of the tone, showing obvious excitement. The behavioral differences between these dogs make more sense if we are told that the year is 1900 and that the latter animal has spent time as a subject in the classical conditioning laboratory of Dr. Ivan P. Pavlov. The meaning that the tone has acquired for this animal, namely, that dried meat powder is about to be blown into its mouth, is an example of a perception. To employ a human example of the difference between a sensation and a perception, imagine the following hypothetical situation: Two people are standing in a crowd in Vatican Square, one a devout Catholic who lives in Rome and the other an Asian tourist who knows nothing of Catholicism or its rituals. Suddenly a puff of white smoke is emitted from the upper level of the Sistine Chapel. The meaning that this visual stimulus will have for these two individuals is the difference between a sensation and a perception. We see that for different dogs or humans or what have you, the same sensory events can and do acquire different meanings, leading to different perceptions. Thus, it is not simply our sensory world that determines our behavior but our "perceptual world," which is determined by our unique life experiences.

This course describes how our sensory systems respond to the energy from our physical environment and how, based upon our past experience with a particular sensory event, the brain creates the perceptions that determine our behavior. Another important component of the course is a consideration of the way the aging process influences both our sensations and our perceptions. Unavoidable changes occur in the sensitivity and acuity of our sensory systems as we age, resulting in young people and older people actually living in different sensory worlds. It is also the case that young people and old people have generally had different life experiences, which is how stimuli acquire meaning and result in our perceptions. The aging process has implications for one's sensory world and one's perceptual world. The first 12 lectures in this course will expand on the difference between a sensation and a perception and elaborate on the concept of the perceptual world. The functioning of the visual, auditory, and cutaneous systems, and the changes in functioning associated with the aging process, will also be discussed in these 12 lectures. The last 12 lectures will deal with the senses of pain, taste, smell, vestibulation, and kinesthesis. Special categories of human perception, such as speech perception, face recognition, and person perception, will also be addressed. As in the initial 12 lectures, attention will be paid to the role of the aging process. All lectures are presented at a level that does not presume previous coursework in sensory processes.

Lecture One
Sensation, Perception, and Behavior

Scope: The study of sensory processes has been an important part of academic psychology for more than 100 years. The school of psychology known as *behaviorism*, which was the dominant school of psychology until at least 1970, emphasized the fact that the ability to understand a particular behavior required knowledge of the stimulus that elicited that behavior. In time, psychologists found that identifying the eliciting stimulus was of some help in making sense of behavior but that a complete understanding of an instance of behavior required knowledge of what particular meaning the eliciting stimulus had for the behaving organism. This led psychologists to the study of perception, the process by which sensory stimuli acquire their meaning.

Our behavior is determined both by the sensory input we receive and by the meaning for us that those sense data have acquired through our previous experiences. It is now clear that some behavioral differences between young people and old people are due to the fact that the aging process results in changes both in sensory systems and in perceptual processes.

In this lecture, after establishing course goals, we present a brief introduction to psychology in general and to behaviorism in particular. We also distinguish among the physical world, the sensory world, and the perceptual world. We close with a brief overview of what the course will cover and establish a distinction between a sensation and a perception.

Outline

I. This course has three instructional goals.

- **A.** The first goal is to show how our sensory systems collect data from the world around us and translate that information into a language that the brain can understand.
- **B.** The second goal is to describe how perceptions are created in the brain by integrating basic sense data with our past experiences.
- **C.** The third goal is to point to examples of how the aging process can alter both our sensory and our perceptual worlds.

II. This course will include a good amount of hard science balanced with examples drawn from scientific experimentation and clinical observations. The perspective of academic psychology, that is, a behavioral perspective, will be maintained throughout the course.

III. In 1879, Wilhelm Wundt founded the first psychological laboratory at the University of Leipzig.

- **A.** Wundt defined *psychology* as the "scientific study of mind," which doomed the new science to failure. Science must deal with things that are public, repeatable, and measurable, and the "study of mind" is none of these.
- **B.** In the United States, a competing school of academic psychology was established at the University of Chicago to study the "function of mind." Again, with "mind" as the subject matter, this school of functionalism was doomed to failure as well.

IV. Since the founding of behaviorism by John B. Watson in 1913, the goal of academic psychology has been the prediction and understanding of behavior.

- **A.** Watson replaced the experimental methods used previously and adopted Pavlov's method of classical conditioning.
- **B.** The school of behaviorism has been historically referred to as *S→R psychology*. This seemingly simple representation, in which *S* stands for "stimulus" and *R* stands for "response," actually makes three important points about behavioristic psychology.
  1. Psychology accepts the principle of determinism, which is the basic assumption of all science.
  2. Behavior has causes; it does not occur randomly. It does not operate under the premise of free will.

3. A complete understanding of a behavior requires knowledge of the eliciting stimulus.

V. An organism's (human or otherwise) behavior is determined by its sensory world, not by its physical environment.

- **A.** Psychology studies sensory processes in order to understand an organism's sensory world.
- **B.** Behavioral differences between species are better understood when we understand the differences in their sensory worlds.
  1. Cats can hear ultrasound; humans cannot.
  2. Humans can see colors; cats cannot.
  3. Dogs can smell things at concentrations 1,000 times weaker than humans can.
  4. Bees can see ultraviolet light; humans cannot.
  5. Likewise, some snakes can see infrared radiation; humans cannot.
  6. Some behavioral differences among bees, cats, and humans are directly attributable to the fact that these species live in different sensory worlds while living in the same physical world.

VI. The aging process results in changes in the sensitivity characteristics of human sensory receptors. Young people and old people live in different sensory worlds.

- **A.** Unavoidable changes occur in all our sensory systems as we age.
- **B.** These changes affect our behavior.
- **C.** Some behavioral differences between young and old people are due to the fact that their sensory worlds are different.

VII. In this course, we will cover all the sensory systems.

- **A.** We will start with the visual, auditory, and cutaneous systems.
- **B.** We will then study the chemical senses (taste and smell).
- **C.** We will examine the vestibular and kinesthetic systems.
- **D.** We will give special attention to pain as part of the skin senses.
- **E.** In all instances, we will see how aging affects the senses.

VIII. Psychology makes the distinction between a sensation and a perception.

- **A.** A sensation occurs when some physical energy (sound waves, light waves, touch, and so on) impinges on a receptor at a super-threshold intensity.
- **B.** A perception is more complicated than a sensation.
  1. A perception is a sensation plus its unique meaning for an individual.
  2. The brain is the organ of perception; it gives meaning to our sensory experiences.
  3. The brain stores as memories our past experiences with a given sensory event so that when that sensory event recurs, the brain integrates the sensation of the new physical stimulus with our previous experience to form a perception.
  4. Different people can have different perceptions of the same sensory event.
  5. Our physical world does not define our reality. Instead, our perception and our brain's interpretation of it define our reality.
  6. Perceptions can be changed if we change the meaning associated with a particular sensory experience.

Suggested Reading:

Leahey, *A History of Psychology* (6th ed.), chapter 12.

Thorne and Henley, *Connections in the History and Systems of Psychology* (2nd ed.), chapter 11.

Questions to Consider:

1. What do you think of behaviorism's position on free will and human behavior?
2. Can we ever have a complete understanding of another person's perceptual world?

Lecture Two

Sensation and Perception—A Distinction

Scope: Predicting and/or understanding an animal's behavior is sometimes difficult for us because people and animals live in different sensory worlds. We don't always know what an animal is responding to. This same phenomenon occurs in predicting and/or understanding some instances of human behavior, in that all people do not live in the same sensory world. Further complicating the prediction and understanding of human behavior is the fact that the same stimulus may have different meanings for different people as a result of their previous life experiences.

The meaning a stimulus has for us defines our perception of that stimulus. It is ultimately the meaning of a stimulus, not the stimulus per se, that determines behavior. In this lecture, we will treat in greater detail the difference between a sensation and a perception.

We will see that the brain is the organ of perception and that experiences stored in our brains beginning in infancy actually determine the meaning that sensory events will have for us. The eye may see something or the ear may hear something, but it is the brain that gives these sensory events their meaning, which ultimately determines behavior. Two people may be exposed to the same sensory display, but their differing personalities, cultural backgrounds, expectations, motivational and emotional states, family histories, and life experiences will determine how similar or different their perceptions of that sensory display will be.

Outline

I. Our sensory world is defined by attentional factors, as well as the sensitivity range of our receptors.

- **A.** Not all detectable stimulus energies are given equal weight in determining our sensory world.
  - **1.** We have a finite attentional capacity.
  - **2.** We would experience sensory overload if we attended to all sensory inputs.
- **B.** The mechanism of selective attention permits us to tune out irrelevant stimuli.
- **C.** Selective attention is critically important for our everyday functioning.
  - **1.** Those who have difficulty with selective attention are at a disadvantage in everyday life.
  - **2.** Such difficulties include attention deficit hyperactivity disorder and some forms of schizophrenia.

II. Human behavior is determined by our "perceptual world," not our sensory world.

- **A.** Perceptions, not sensations, determine our reality; thus, different people may have different realities.
- **B.** The importance of the perceptual world in determining behavior was recognized by the Gestalt psychologists in the early 1900s.
  - **1.** Max Wertheimer, the founder of Gestalt psychology, realized that apparent movement and real movement could result in the same perception.
  - **2.** The Gestaltists' distinction between the geographical environment (our physical world) and the behavioral environment was the first formal statement of the distinction between the sensory world and the perceptual world.

III. Because the brain is the organ of perception, any experience that affects brain functioning can influence our perception.

- **A.** Drugs can alter brain functioning, and drugs can significantly affect perception.
- **B.** Our emotional experiences alter brain function, and emotional state is known to influence perception.
- **C.** Individual conditioning histories are stored in the brain and can result in unique perceptual experiences.
  - **1.** Ivan Pavlov's dogs had unique conditioning histories.

2. Certain stimuli produced perceptions in Pavlov's dogs that were (and are) unlikely to occur in most dogs.

D. Our expectations and our motivational states also affect our perception.

E. Different cultures indoctrinate their members with beliefs and attitudes that are stored in the brain and influence perception.

   1. Direct eye contact in the United States is perceived as a sign of honesty and forthrightness.
   2. Direct eye contact in Japan is perceived as aggressive and intrusive to the point of rudeness.

F. Personality traits are stored in the brain, and our personalities most certainly affect our perception.

IV. The aging process can influence perception in several ways.

A. Although not guaranteeing it, old age increases the likelihood that we will have acquired wisdom.

B. Different generations hold different beliefs that can influence perception.

C. The aging process frequently leads to personality changes that influence perception. For instance, we tend to become more conservative with age because our sensory systems begin to decline in their sensitivity and acuity. We become more cautious about dealing with the environment in order to avoid injury or embarrassment.

Suggested Reading:

Leahey, *A History of Psychology* (6th ed.), pp. 252–258.

Thorne and Henley, *Connections in the History and Systems of Psychology* (2nd ed.), chapter 14.

Sekuler and Blake, *Perception* (4th ed.), chapter 1.

Questions to Consider:

1. Is "reality" an absolute or a relative concept?
2. How might we go about changing our perceptual world?

Lecture Three

Vision—Stimulus and the Optical System

Scope: In this lecture, we begin an examination of the process by which our sensory systems do their job of transducing the various forms of energy from the physical world into a language that the brain understands, namely, electrochemical activity. The brain can analyze only electrochemical events. It is insensitive to light, sound, taste, smell, touch, even pain. It is the function of our sensory receptors to change these forms of energy into electrochemical events so that the brain can be aware of them and give them meaning (or not).

We will begin our exploration of the human senses with the visual system. The two goals of this lecture will be, first, to describe some of the physical properties of the energy we call light and, second, to describe some of the ways the visual system's supporting structures, including the optical instruments of the eye, the cornea and lens, prepare light to maximize our awareness of it.

Outline

I. With this lecture, we begin an examination of the different sensory systems and how they do their job of transducing the various forms of energy from the physical world into a language that the brain understands, namely, electrochemical activity.

- **A.** The brain can analyze only electrochemical events.
- **B.** It is insensitive to light, sound, taste, smell, touch, even pain, because the brain itself has no receptors.
- **C.** Our receptors act as the transducers between the physical world and the brain.

II. The human visual system responds to that portion of the electromagnetic energy spectrum ranging from 400 nanometers (nm) to 700 nm, known as the *visible spectrum*, or light.

- **A.** This is a small portion of the full spectrum of electromagnetic radiation, which ranges from 1 nm (x-rays) to 100 m (radio broadcast waves).
- **B.** Light has seemingly inconsistent physical properties.
  1. The color of light is best understood if light travels in continuous transverse waves.
  2. The brightness of light is best understood if light travels in discrete packets of energy.
  3. The visible spectrum, from the long (700 nm) to the short (400 nm) wavelengths, is red, orange, yellow, green, blue, indigo, and violet.
- **C.** The speed of light is 186,000 miles per second. By contrast, the speed of sound is much slower: only 1,110 feet per second.

III. The visual supporting structures include the pupil at the front of the eye, the choroid coat at the back of the eye, and the cornea and lens. The supporting structures do not directly respond to light but, rather, facilitate the job of the visual receptors that do respond to light. (Figure 3a)

- **A.** If we shine a beam of light into the eye, the first supporting structure it encounters is the transparent cornea.
- **B.** The next supporting structure the light encounters is the pupil.
  1. The pupil is actually a hole in the iris, which is the color portion of the eye. The iris automatically changes the size of the pupil to protect the sensitive visual receptors. The pupil becomes larger in dim light and smaller in bright light.
  2. A researcher named Eckhard Hess also discovered that a person's pupils widen when shown something attractive or appealing and shrink when shown something unappealing or repulsive.

IV. The optical instruments of the eye are the cornea and the lens, which cooperate to bring visual stimuli to a precise focus on the visual receptors.

- **A.** The cornea is called a *fixed optical instrument* because it cannot change its optical properties.

- **B.** The lens is known as a *variable optical instrument* because it can change its optical properties.
  - **1.** The elasticity of the lens gives it the ability to alter its focal properties through shape changes.
  - **2.** The lens assumes an elongated, thin shape (the default shape) to appropriately focus distant objects and a short, thick shape to focus near objects.

V. The choroid coat at the back of the eye absorbs stray light to prevent blurred vision.

- **A.** It gives us greater acuity.
- **B.** Some nocturnal animals trade acuity for sensitivity, and their choroid coats reflect light instead of absorbing it.

VI. Problems with the eye's optical instruments—the lens and the cornea—typically result in blurred vision.

- **A.** *Presbyopia*, blurred vision for near objects, occurs in most people by the mid-40s and is the result of loss of elasticity in the lens. Near objects are brought to a focus behind the retina, causing blurred vision. The lens's ability to alter its shape is known as *accommodation*.
- **B.** *Myopia*, a less common optical problem, occurs when the eyeball becomes elongated and objects are brought to focus in front of the retina, resulting in blurred vision.
- **C.** Both presbyopia and myopia are easily corrected by eyeglasses, contact lenses, or in some cases, LASIK surgery.
- **D.** People who were myopic as children may not have to wear reading glasses as adults thanks to accommodation.

Suggested Reading:

Sekuler and Blake, *Perception* (4th ed.), chapter 2.

Questions to Consider:

1. Can you think of any practical value in knowing about the physical properties of light?
2. What information would you seek before donating your eyes to an eye bank?

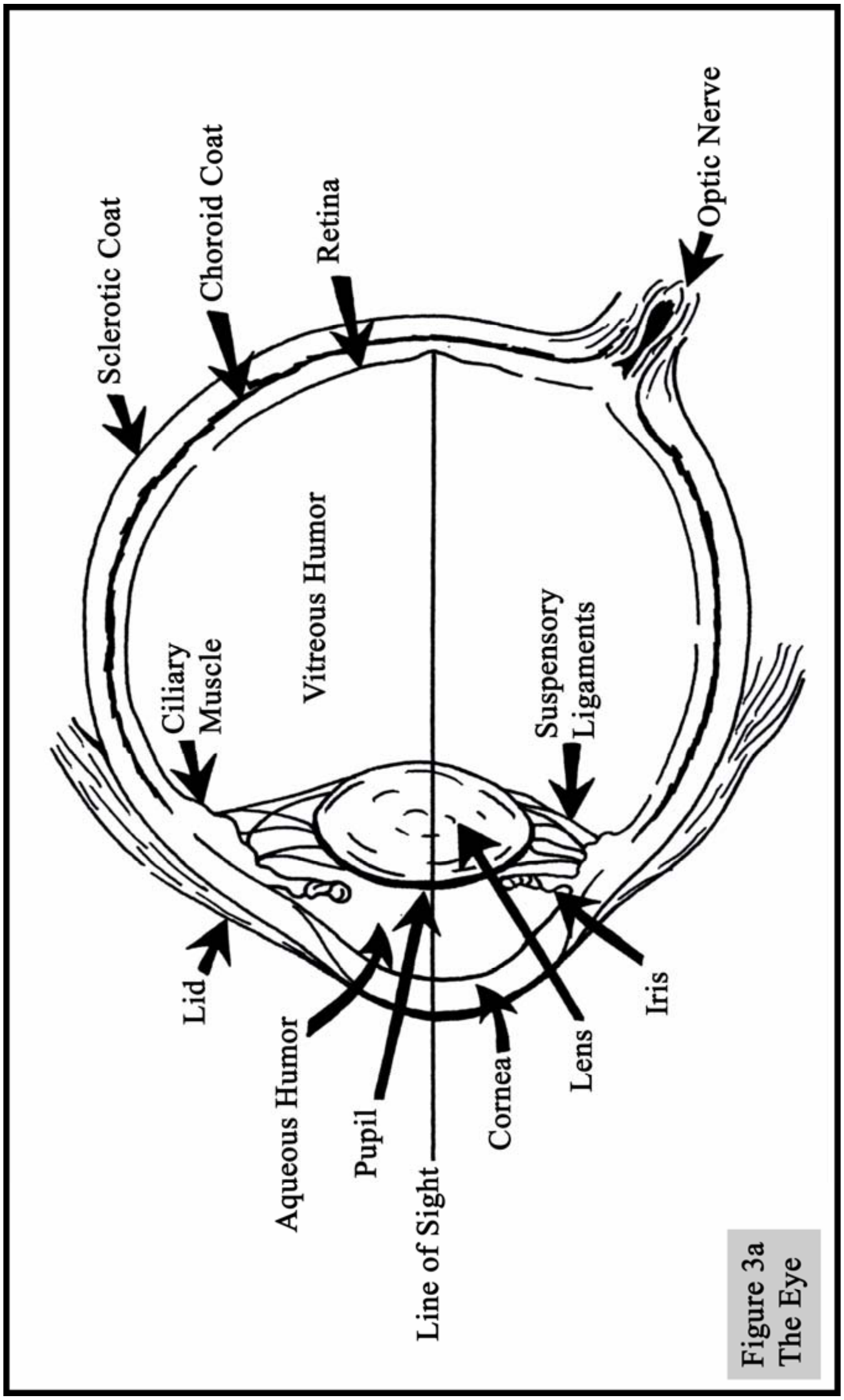

Figure 3a
The Eye

Lecture Four

Vision—The Retina

Scope: The human retina is called a *duplex retina* because it contains two types of receptors, known as *rods* and *cones*. Between them, rods and cones give us the ability to see in black and white under low levels of illumination and in vivid color under normal levels of illumination. Having a duplex retina also provides the human visual system with both sensitivity and acuity. These are actually quite different but equally important visual abilities.

This lecture explains the contributions that rods and cones make to normal vision. It also describes the fundamentals of the human trichromatic color vision system, which permits us to see a wide array of hues as mixtures of the three visual primary colors, red, green, and blue. In addition to being called a duplex retina, the human retina has also been described as an *inverted retina* because of what appears to be a serious design flaw. In actuality, the design of the human retina is not flawed but represents a necessary compromise due to the high energy needs of the visual receptors.

Outline

I. The receptors and neural elements on the retina at the back of the eye make vision possible.

- **A.** The human retina is called a *duplex retina* because it contains two types of receptors, *rods* and *cones*.
  - **1.** Rods outnumber the cones by a ratio of around 20:1, with 120 million rods to 6.5 million cones.
  - **2.** Rods are found in the periphery of the retina, while cones are found in and around the *macula* (the center of the retina) and are lacking in the periphery of the eye. The *fovea*, which is the center of the macula, is 100 percent cones.
  - **3.** Rods mediate our vision in dim light and do not perceive color. They detect movement better than cones.
  - **4.** Cones provide high-acuity vision under normal illumination and have the ability to perceive different colors. They do not work well in dim light, nor do they detect movement in the periphery.
- **B.** Both rods and cones contain chemical photopigments that are altered (bleached) by light. Bleaching of photopigments leads to the generation of electrical impulses.
  - **1.** All rods contain the same photopigment, rhodopsin, which is maximally sensitive to light of 500 nm; cones would see this light as bluish-green. Because they contain only a single pigment type, rods cannot perceive color.
  - **2.** There are three types of cone photopigments with overlapping spectral sensitivity ranges. One cone pigment is maximally sensitive to light at 419 nm (blue); one cone pigment is maximally sensitive to 531 nm (green); and the remaining cone pigment has a peak sensitivity at 558 nm (red). This visual system is called a *trichromatic color system*.
  - **3.** Color vision is possible because the overlapping sensitivity ranges of the three pigments permit "color mixture" to occur in the brain.
  - **4.** Color blindness or color weakness occurs when one (or, rarely, more than one) of the cone photopigments is absent or deficient.

II. The human retina is organized such that the foveal area has the highest acuity, while the retinal periphery has the greatest sensitivity.

- **A.** An example of sensitivity is the ability to detect a faint movement in dim light (the rods are best at this).
- **B.** An example of high acuity is the ability to read the small print on a warranty card (the cones are best at this).
- **C.** These factors have been applied in many situations, from laboratory studies of nocturnal animals to nighttime military maneuvers.

III. In addition to the rods and cones, there are two layers of retinal neural elements, the *bipolar cells* and the *ganglion cells*. (Figure 4a)

A. The human retina is referred to as an *inverted retina* because light must pass through the ganglion cell layer and the bipolar cell layer before it reaches the receptors.

1. This design, known as an inverted retina, has been called flawed and has been used as an argument against "intelligent design."

2. The design of the retina is actually a good and necessary compromise, in that the receptors must be in physical contact with their blood supply in the pigment epithelium layer in order to function properly.

B. The 126 million receptors—120 million rods and 6.5 million cones—that are stimulated by light pass this information on to 50 million bipolar cells, which in turn, send the information on to 1 million ganglion cells.

C. The axons of the ganglion cells form the optic nerve, which creates a small "blind spot" as it pushes some receptors aside on its way from the eyeball to the brain.

D. Most of the bipolar and ganglion cells are located in the fovea, where the cones are found, while relatively few bipolar and ganglion cells are located in the retinal periphery, where the rods are located.

1. In the periphery, as many as 10,000 rods may be feeding their information to a single ganglion cell; thus, we have enormous spatial summation in the periphery.

2. In the macula, particularly in the fovea, there may be a 1:1 relationship between a cone and a ganglion cell.

3. The ratio of receptors to ganglion cells in the periphery provides the opportunity for spatial summation, giving the rods high sensitivity for movement at the expense of good acuity.

4. This arrangement of receptors to neural elements maintains a precise coherence between a point in the visual field and a point on the fovea, giving the fovea good visual acuity at the expense of sensitivity.

IV. It is not possible to stare fixedly at an object until our receptors bleach, thereby making the object disappear, because our eyes engage in three kinds of movement.

A. Our eyes drift, flick, and engage in tremors to prevent such a disappearance from occurring.

B. Breakdown and regeneration of photopigments occur continuously.

C. Snow blindness is an example of what happens to vision when the photopigment regeneration process cannot keep up with the bleaching process.

Suggested Reading:

Carlson, *Physiology of Behavior* (8th ed.), chapter 6.

Goldstein, *Sensation and Perception* (6th ed.), chapter 2.

Questions to Consider:

1. Why do visual afterimages occur?

2. In what ways would you expect the behavior of an animal with an all-rod retina to differ from the behavior of an animal with an all-cone retina?

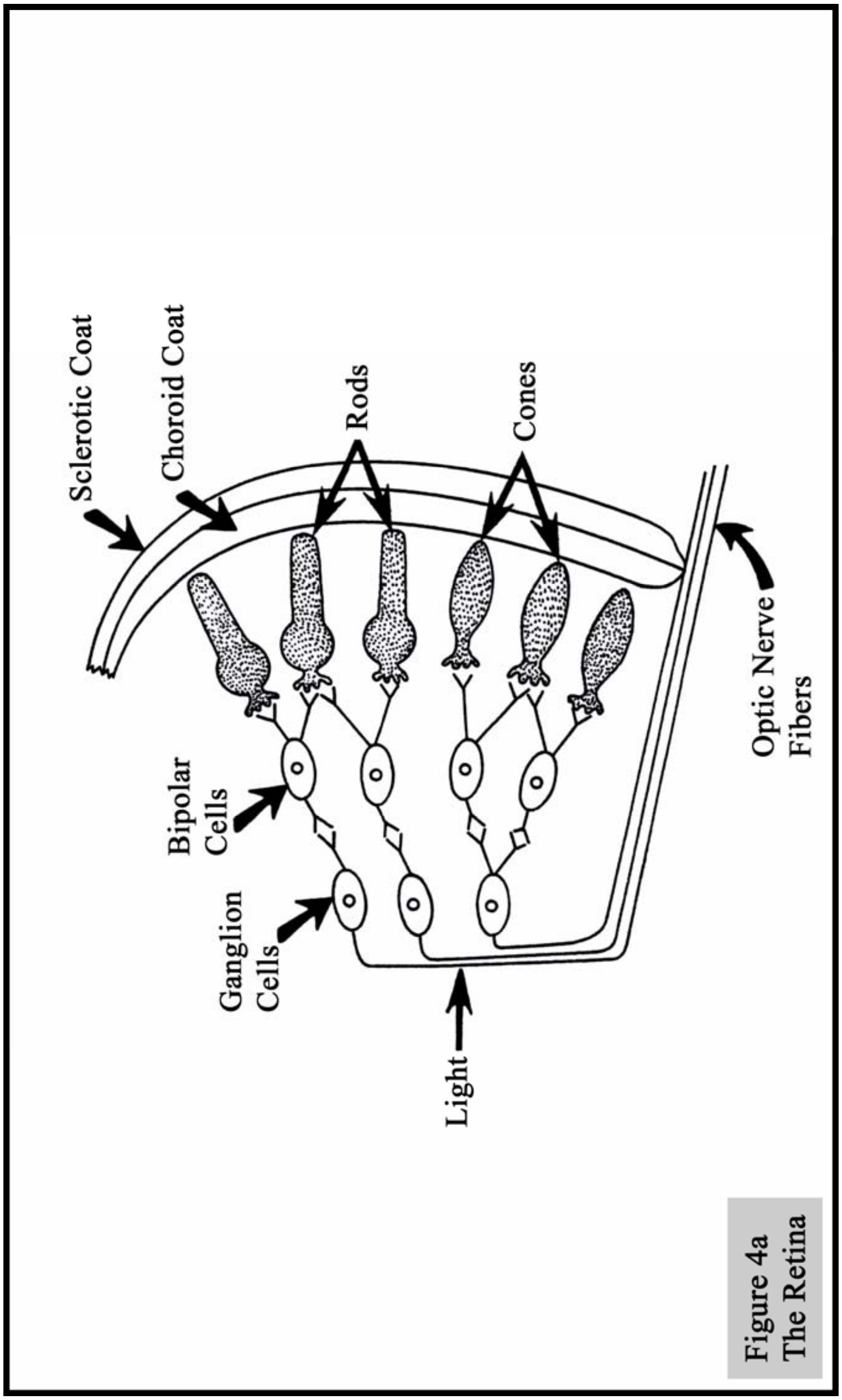

Figure 4a
The Retina

Lecture Five

Vision—Beyond the Optic Nerve

Scope: Signals from the rods and cones are transmitted by way of the optic nerve to visual information processing regions in the midbrain, then on to the cerebral cortex. Information about the location of objects in space relative to our position in space appears to be analyzed by a midbrain region known as the *optic tectum*. The optic tectum can activate automatic orienting reflexes or avoidance reflexes so that we can begin to react to the movement of objects in visual space even before we are aware of what these objects are. The type of visual analysis done by the optic tectum is called *object location*. This is the most primitive level of visual analysis and is present in animals lacking a visual cortex. In humans, information from the retina continues beyond the midbrain, where another type of visual analysis, known as *object identification*, takes place in the visual cortex. Here, information about shape, form, color, and size gives us knowledge of exactly what kind of object we have just oriented toward or away from. In humans with damage to the visual cortex, the unusual phenomenon of *blindsight* illustrates the fact that, in special circumstances, object location can be dissociated from object identification. Depth perception is also an important aspect of both object location and object identification.

Outline

I. After leaving the eyeball by way of the optic nerve, different aspects of the visual stimulus are analyzed at different levels of the brain. The two broad general categories of visual perception are *object location* and *object identification*.

- **A.** Object location refers to the awareness of the position occupied by an object in the visual field relative to our location and changes in the position in space relative to our position.
  - **1.** A midbrain structure known as the *optic tectum* has been shown to be important to the awareness of object location.
  - **2.** The optic tectum mediates our primitive awareness of where things are in space with regard to our own location.
  - **3.** It is also makes us sensitive to sudden movements in the visual field and causes a reflex orientation to visual stimuli.
  - **4.** As well, defensive reactions to moving objects in the visual periphery (duck-and-cover) are initiated by midbrain circuits.
- **B.** Object identification refers to the ability to perceive the precise characteristics of objects in the visual field, such as size, shape, color, and movement. It is learning based. We will discuss this topic further in Lecture Twenty-Three.

II. Dissociation of object location from object identification can be observed in humans with damage to the occipital lobe and in animals where the visual system does not ascend beyond the level of the midbrain.

- **A.** The phenomenon of *blindsight* demonstrates that people with visual cortical damage can still point to objects in the visual field even though they have no visual awareness of these objects.
- **B.** Laboratory work with blind cats has also shown the phenomenon of blindsight.

III. An important aspect of both object location and object identification is depth perception.

- **A.** In the case of object location, the importance of depth cues in locating an object's position in space is obvious.
- **B.** Depth cues are also important in object identification, as a toy car held at arm's length may be the same size on the retina as a real car 70 yards away. Depth perception tells us that one car is real and one is a toy.

IV. There are two categories of depth perception cues; one type is known as *binocular depth cues*, and the other type is known as *monocular depth cues*.

- **A.** Binocular depth cues are innate and require the use of both eyes simultaneously. These cues are based on the slight disparity in the images that are seen by each eye.

1. The brain can compare the degree of overlap of the images seen by each eye, such overlap decreasing as an object is moved farther and farther away.
2. Laboratory studies suggest that infants as young as 3 ½ months can use binocular depth cues to determine how far away some object is located.
3. Another binocular depth cue is *convergence*, the feedback from the eye muscles as we focus on objects no more than 8 to 10 feet from us.
4. The ability to utilize binocular depth cues appears to be unlearned, depending upon maturation of prewired neural circuits in the brain.

B. Monocular depth cues are cues that can be used with a single eye.

1. Monocular cues appear to be the result of learning and experience.
2. Monocular cues are sufficient to permit people who are blind in one eye to perform normal functions, such as driving a car.
3. Artists use monocular depth cues, such as relative size, overlapping/superposition, haziness, texture gradients, and linear convergence, to create an appearance of depth in paintings that can be appreciated even if the viewer closes one eye.

Suggested Reading:

Goldstein, *Sensation and Perception* (6th ed.), chapters 3 and 8.

Sekuler and Blake, *Perception* (4th ed.), chapter 4.

Questions to Consider:

1. People have a dominant eye just as they do a dominant hand. Do you have a dominant eye? If so, how do you know this? If not, you can determine your dominant eye by identifying which eye you use when you look through a telescope.
2. What requirements must an animal’s visual system meet in order to use binocular disparity as a depth cue?

Lecture Six

Vision—Age-Related Changes

Scope: The supporting structures, receptors, and neural elements of the visual system all undergo progressive physical changes related to the aging process. As a consequence of these changes, vision is affected in predictable ways as we grow older. We can expect to experience deficits in near vision and in night vision, and we will perceive more glare in bright sunlight and in direct artificial lighting. With age, we will become less sensitive to the blue range of the visible spectrum, and our peripheral vision will become less extensive.

As we age, we also become more likely to experience medical conditions of the eye, such as cataracts, glaucoma, detached retina, macular degeneration, and "ministrokes" involving the vascular supply to the retina. All of these conditions can have serious debilitating consequences for vision.

Outline

I. The aging process includes physical changes in the structures of the eye that, in turn, produce changes in the way the visual field is perceived. The supporting structures, receptors, and neural elements all undergo age-related changes that alter our visual capacities as we grow older.

II. Visual supporting structures that exhibit age-related changes include the iris, pupil, cornea, and lens.

- **A.** With age, the iris, which gives the eye its color, loses pigment granules. Thos granules float around in the aqueous humor or intraocular fluid and help create conditions that can lead to glaucoma.
- **B.** A swelling of the tissue of the iris around the pupil occurs with age, preventing the pupil from opening to its full extent in dim light. This change is especially detrimental to night vision in the elderly.
- **C.** By age 50, an opaque ring known as the *arcus senilis* begins to form around the outer boundary of the cornea, although the completed ring may not be seen until the mid- to late 60s. This condition produces a minor shrinkage of peripheral vision.
- **D.** With age, the cornea of the eye becomes more susceptible to infections and wart-like growths that can impair corneal transparency. A badly scarred cornea can be corrected by a corneal transplant.
- **E.** The lens of the eye exhibits three different age-related changes.
  - **1.** By the mid 40s, the lens has usually lost enough of its elasticity that the ability to focus on near objects is adversely affected, and an optical correction, such as reading glasses, is necessary.
  - **2.** Opaque particles begin to form in the lens, leading to the condition known as *cataract*. By age 60, some degree of cataract formation is the rule, not the exception.
  - **3.** Aging also causes the lens to take on a yellowish hue. This somewhat diminishes color sensitivity across the entire visible spectrum, with the deficit being greatest for the short-wavelength (blue-violet) colors.

III. The visual receptors have also been shown to exhibit age-related changes.

- **A.** The metabolic processes needed for regeneration of visual photopigments slow down, resulting in the older eye taking longer to regain full sensitivity following exposure to bright light.
- **B.** With age, the vitreous humor, a transparent collagen gel that gives the eyeball its shape and holds the retina against the back of the eye, can pull away from its attachment in the back of the eye, causing the retina to detach.
- **C.** The condition known as macular degeneration appears to be age-related.
  - **1.** In *wet macular degeneration*, abnormal blood vessels begin to grow under the receptors in the macular region. These vessels leak blood and create a bulge so that, to a person with this problem, straight lines appear wavy.
  - **2.** *Dry macular degeneration*, which brings about deterioration of the macula, progresses more slowly, is more treatable, and is more common than wet macular degeneration.

D. Receptor death due to "ministrokes" in the pigment epithelium can produce "blind spots" on the retina.

IV. The neural elements of the visual system are clearly affected by the aging process. Degenerative changes occur in the ganglion cells and in the optic nerve, which is composed of the axons of ganglion cells.

A. Age-related visual changes are more serious in the periphery of the eye than in the central portion because there are fewer ganglion cells in the periphery in the first place. The loss of even a small number of ganglion cells in the periphery can adversely affect peripheral vision, the ability to detect movement, and night vision.

B. Conduction speed in the optic nerve is reduced by as much as 25 percent in the elderly, as can be demonstrated by measuring critical flicker frequency (CFF) in people of different ages.

V. Although detached retinas and cataracts are typically age-related illnesses, repeated blows to the head, as seen among young boxers and soccer players, can greatly increase the likelihood that these athletes will develop such problems.

Suggested Reading:

Colavita, *Sensory Changes in the Elderly*, chapter 2.

Goldstein, *Sensation and Perception* (6th ed.), pp. 546–565.

Questions to Consider:

1. Are you aware of any animals besides humans that develop cataracts? What might be the behavioral consequences of cataracts in animals?

2. Can you imagine a time when it might be possible to perform a complete eyeball transplantation? Why or why not?

Lecture Seven

Hearing—Stimulus and Supporting Structures

Scope: Striking a tuning fork sets up vibrations in the tuning fork's arms. These vibrations produce pressure variations in the adjacent air molecules that travel through the air until they reach a listener's ear. What we call sound is actually the brain's response to small, rapid, in-and-out movements of the eardrums produced by pressure variations in air molecules. In the absence of background noise, a healthy young human can hear a 1,000 cycle-per-second (CPS) tone if the eardrum is vibrated 1,000 times per second, with each vibration moving the eardrum a distance less than the diameter of a hydrogen atom. The auditory system is extremely sensitive, which causes it to be extremely delicate and vulnerable to damage due to overstimulation.

The ear can detect three attributes of a sound: its pitch (*frequency*), its loudness (*amplitude*), and its *location* in space. Pitch is determined by the frequency of vibration of the eardrum. The human ear can perceive frequencies from (approximately) 20 to 20,000 cycles per second. Loudness is determined by the amplitude of the in-and-out movement of the eardrum. We are able to localize the source of a sound in space because we have two ears. The supporting structures located in the outer and middle ears contribute to the hearing capabilities of the human ear in important ways.

Outline

I. The auditory system is an exquisitely sensitive touch system. When we hear something, we are responding to a series of faint, rapid touches of air molecules on our eardrums.

- **A.** The auditory system has found clever ways to amplify faint stimuli.
- **B.** It is so sensitive that it is vulnerable to damage through overstimulation.
- **C.** Sound waves usually travel through air.
- **D.** Sound waves can travel through media other than air.
- **E.** There is no sound in a vacuum.

II. The three attributes of the auditory stimulus are *frequency*, *amplitude*, and *location* in space.

- **A.** A healthy, young human listener can hear frequencies between 20 and 20,000 cycles per second (CPS). The unit of measurement for frequency (CPS) is Hertz (Hz).
  - **1.** The physical dimension for frequency corresponds (approximately) to the psychological dimension of pitch.
  - **2.** The human ear is most sensitive to frequencies between 2,000 Hz and 4,000 Hz.
  - **3.** Many important speech sounds occur in this frequency range.
- **B.** The physical dimension of amplitude corresponds (approximately) to the psychological dimension of loudness.
  - **1.** The amplitude of sounds is measured in decibels (dB), a unit of pressure.
  - **2.** Because the decibel notation is logarithmic, 0 dB is not silence; instead, it is the threshold for hearing in a normal young listener. The point where sound becomes painfully loud is around 120 dB.
  - **3.** Prolonged exposure to sounds of 80 dB (about the loudness level of heavy traffic) or more can lead to permanent hearing loss.
- **C.** The ability to localize the source of a sound in space depends upon our having two functioning ears.
  - **1.** Nerve cells in the brain compare the time of arrival of a sound at the two ears and calculate the location in space of the source.
  - **2.** Sound sources along the body's midline axis are the hardest to localize.
  - **3.** With practice and motivation, people can more or less learn to *echolocate*, that is, to determine the location of walls and other obstacles by listening for the echo from the object.

III. The three anatomical divisions of the ear are the *outer ear*, the *middle ear*, and the *inner ear*. (Figure 7a)

A. The outer ear extends from the *pinna* (the flap of skin we call the ear) through the *external auditory meatus* (the ear canal) to the *tympanic membrane* (eardrum).

1. The pinna serves to capture sound waves. We enhance its ability when we cup a hand behind the pinna.

2. The external auditory meatus actually amplifies sounds between 2,000 Hz and 4,000 Hz because of its resonance properties.

3. The tympanic membrane can follow vibrations in air molecules between 20 Hz and 20,000 Hz.

B. The middle ear is an air-filled chamber extending from the tympanic membrane to the cochlea. The middle ear contains three tiny bones, known collectively as the *ossicles*, and two tiny muscles, known as the *intra-aural muscles*.

1. Sound waves are transmitted through the middle ear to the inner ear by the three ossicles, called the *malleus* (hammer), *incus* (anvil), and *stapes* (stirrup).

2. The intra-aural muscles, known as the *stapedius* and *tensor tympani*, contract reflexively in response to loud sounds and dampen the movement of the ossicles. This contraction, called an acoustic reflex, serves as some protection from the harmful effects of loud sounds.

C. The inner ear is made up of bony structures known as the *cochlea*, the *semicircular canals*, the *utricle*, and the *saccule*.

1. The cochlea is part of the auditory system and contains the auditory receptors.

2. The semicircular canals, utricle, and saccule are components of the vestibular system and will be discussed in Lecture Nineteen.

IV. The auditory and vestibular systems have several things in common.

A. They share a common cranial nerve.

B. Their receptors are hair cells.

C. They both require the presence of *endolymph*, an incompressible fluid, for proper functioning.

D. Diseases that affect one system typically affect the other system.

Suggested Reading:

Carlson, *Physiology of Behavior* (8^{th} ed.), pp. 202–207.

Goldstein, *Sensation and Perception* (6^{th} ed.), pp. 331–343.

Questions to Consider:

1. With your eyes closed, try pointing toward some sound sources around you. Why are you less accurate at locating sources along the body's midline axis?

2. Most animals can hear sound frequencies much higher than the human ear can experience. Can you think of some reasons why this is the case?

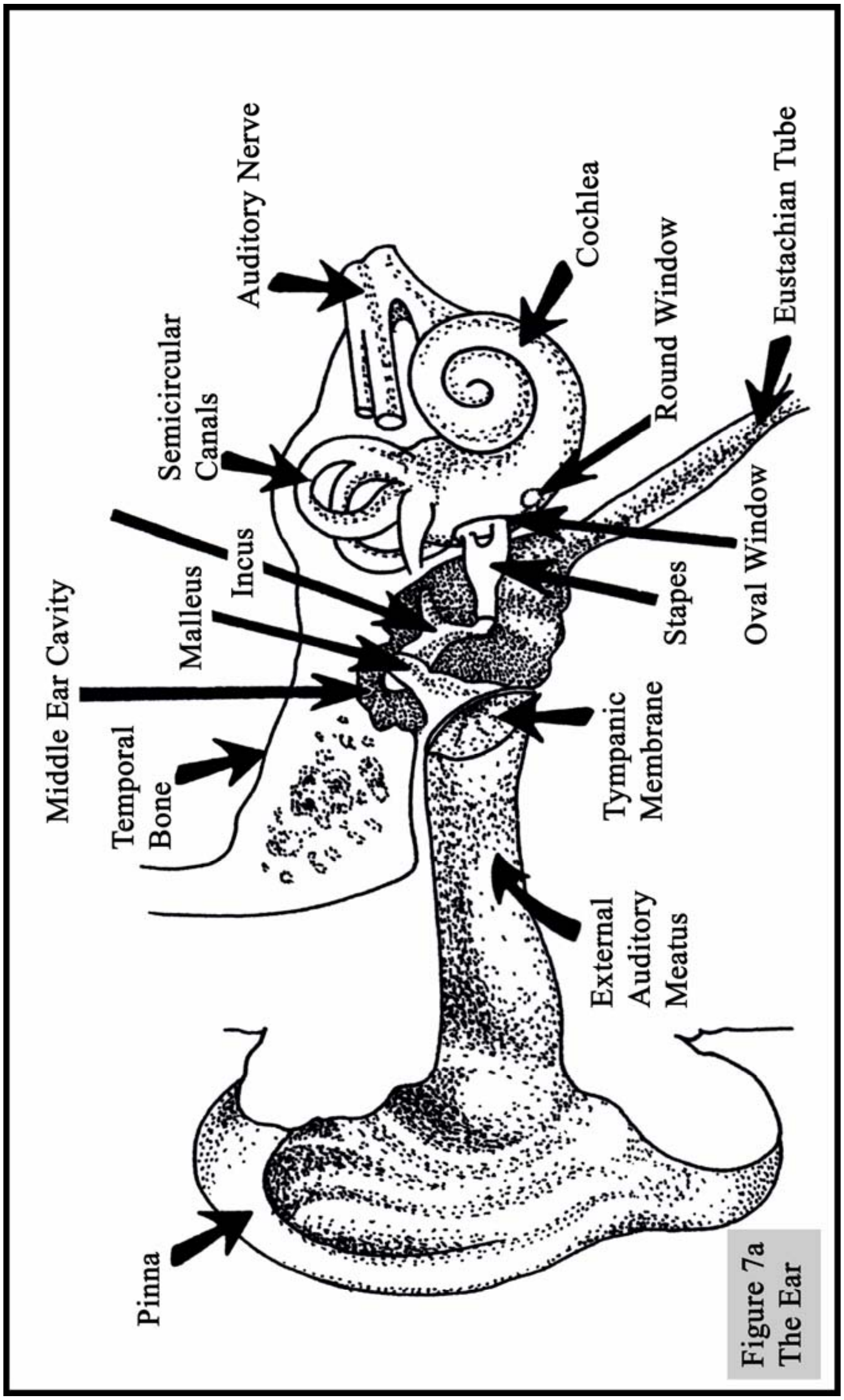

Figure 7a
The Ear

Lecture Eight

Hearing—The Inner Ear

Scope: In this lecture, we will see how the transduction process is accomplished by the auditory receptors, which are known as *hair cells*. The auditory hair cells (there are also vestibular hair cells) are housed in a bony protective structure known as the *cochlea*. The hair cells sit atop a remarkable inner-ear structure in the cochlea called the *basilar membrane*. Not only is the basilar membrane central to the transduction process, but because of its unique physical properties, the basilar membrane is also responsible for the ability of the cochlea to perform sound frequency analysis even before any information is sent to the brain.

This lecture also explains the difference between the two mechanisms by which sounds from the environment reach the hair cells. These two mechanisms are called *air conductive hearing* and *bone conductive hearing*. These two modes of hearing have clinical significance in that they can be used to diagnose different types of hearing loss. For instance, conductive hearing loss can be identified by comparing bone conductive loss with air conductive loss. We elaborate on conductive hearing loss in this lecture instead of Lecture Nine because conductive loss is the only category of hearing loss that occurs with equal or greater frequency in children than in the elderly.

Outline

I. The auditory portion of the inner ear is the cochlea, a coiled, bony structure. Sound waves that vibrate the eardrum are transmitted across the middle ear by the ossicles. The footplate of the stapes introduces these vibrations to the cochlea. (Figure 8a)

- **A.** The cochlea is made up of an upper canal (the *scala vestibuli*) and a lower canal (the *scala tympani*).
- **B.** The scala vestibuli and the scala tympani are separated by a flexible membrane, known as the *basilar membrane*, that travels down the length of the cochlea.
- **C.** The scala vestibuli and the scala tympani are filled with *perilymph*, a thick substance.
- **D.** The scala vestibuli has a membrane-covered opening, known as the *oval window*, while the membrane-covered opening of the scala tympani is known as the *round window*.
- **E.** The two canals are connected to each other by a small opening called the *helicotrema*.
- **F.** The footplate of the stapes fits into the oval window.
  - **1.** Inward movement of the stapes produces inward movement of the oval window.
  - **2.** Displacement of the perilymph results in outward movement at the round window.

II. The characteristics of sounds are analyzed in the cochlea by the hair cells.

- **A.** The 15,500 auditory receptors, known as *hair cells*, are evenly spaced along the length of the basilar membrane.
- **B.** The tips of the hair cells are in physical contact with a stiff, inflexible structure called the *tectorial membrane*, which extends the length of the cochlea.
  - **1.** In-and-out movement of the stapes produces back-and-forth movement of the perilymph between the oval window and the round window.
  - **2.** Back-and-forth movement of the perilymph produces up-and-down movement in the basilar membrane.
  - **3.** Up-and-down movement of the basilar membrane produces physical shearing of the hair cells against the tectorial membrane. When the hair cells are physically sheared, they release a neurotransmitter that in turn produces electrical impulses that travel to the brain, and the brain experiences what it interprets as sound.

III. As we learned in Lecture Seven, sound has three attributes: localization, loudness, and frequency.

- **A.** Recall that sound localization occurs because we have two ears to capture sounds, and our brains use time-of-arrival information to determine where a sound is located.

B. Loud sounds produce a greater extent of movement in the perilymph, producing more movement of the basilar membrane and greater shearing of the hair cells against the tectorial membrane.

1. The greater the extent of shearing in the hair cells, the greater the electrochemical response in the auditory nerve and the greater the perceived loudness.

2. That is, loudness is coded in the brain by the number of electrical impulses that are, in turn, determined by the force with which hair cells are sheared against the basilar membrane.

C. The shearing of different populations of hair cells is translated by the brain into different sound frequencies.

1. Because of the differential stiffness and width along its extent, different parts of the basilar membrane are maximally affected by different frequencies of movement in the perilymph.

2. The basilar membrane is only .04 mm in width at the basal end of the cochlea and .5 mm in width at the apical end.

3. The basilar membrane is 100 times stiffer at the basal end of the cochlea (the end of the cochlea near the oval and round windows) than it is at the apical end (the end near the helicotrema).

4. The basal end of the basilar membrane is maximally displaced by high frequencies; the middle of the basilar membrane is maximally displaced by mid-range sound frequencies; and the apical end of the basilar membrane is maximally displaced by low sound frequencies.

IV. German scientist George von Bekesy discovered how the ear analyzes sounds by studying cadavers of a number of species, from mice to elephants to humans.

A. He used a method called the *traveling wave model* and found that the inner ear of all species he studied analyzed frequencies in the same way.

B. In 1961, he won the Nobel Prize in Physiology and Medicine for his discoveries.

V. The *olivocochlear bundle* (formerly named the bundle of Rasmussen for its discoverer) is a cluster of around 500 nerve fibers found in the auditory nerve traveling from the brain to the hair cells, rather than from the hair cells to the brain.

A. Nerve fibers that come from the periphery of the body into the brain are called *afferent nerves*; nerve fibers that carry information from the brain out to the periphery of the body are called *efferent nerves*.

B. Of the auditory nerve fibers, 15,500 are afferent nerves, but the 500 in the olivocochlear bundle are efferent nerves.

C. Activation of the olivocochlear bundle has a desensitizing effect on hair cells.

D. The olivocochlear bundle appears to contribute to the phenomenon of selective attention.

VI. Hair cells on the basilar membrane are stimulated by two mechanisms, one referred to as *air conduction* and the other referred to as *bone conduction*.

A. Air conductive hearing involves transmission of sound waves by air molecules that starts at the eardrum, passes by way of the ossicles through the middle ear, and ends with the footplate of the stapes producing vibrations at the oval window.

B. Bone conductive hearing occurs when vibrations are transmitted directly to the temporal bone in which the cochlea is housed.

C. Conductive hearing loss, which occurs in children with equal or greater frequency than it does in the elderly, can be diagnosed by comparing air conductive hearing with bone conductive hearing.

1. Obstructive hearing loss occurs when such objects as beans or small toys are stuck in the ears and obstruct the sound waves entering the ear.

2. Otitis media is a medical condition that causes the accumulation of fluid in the middle ear, thus impairing the ability of the ossicles to vibrate freely and loosely. It can afflict animals as well as humans.

Suggested Reading:

Goldstein, *Sensation and Perception* (6^{th} ed.), pp. 343–350.

Questions to Consider:

1. How many functions can you think of for the outer ear?
2. Helen Keller, who was both deaf and blind, felt that deafness was worse than blindness. Why do you think she felt this way? Do you agree with her?

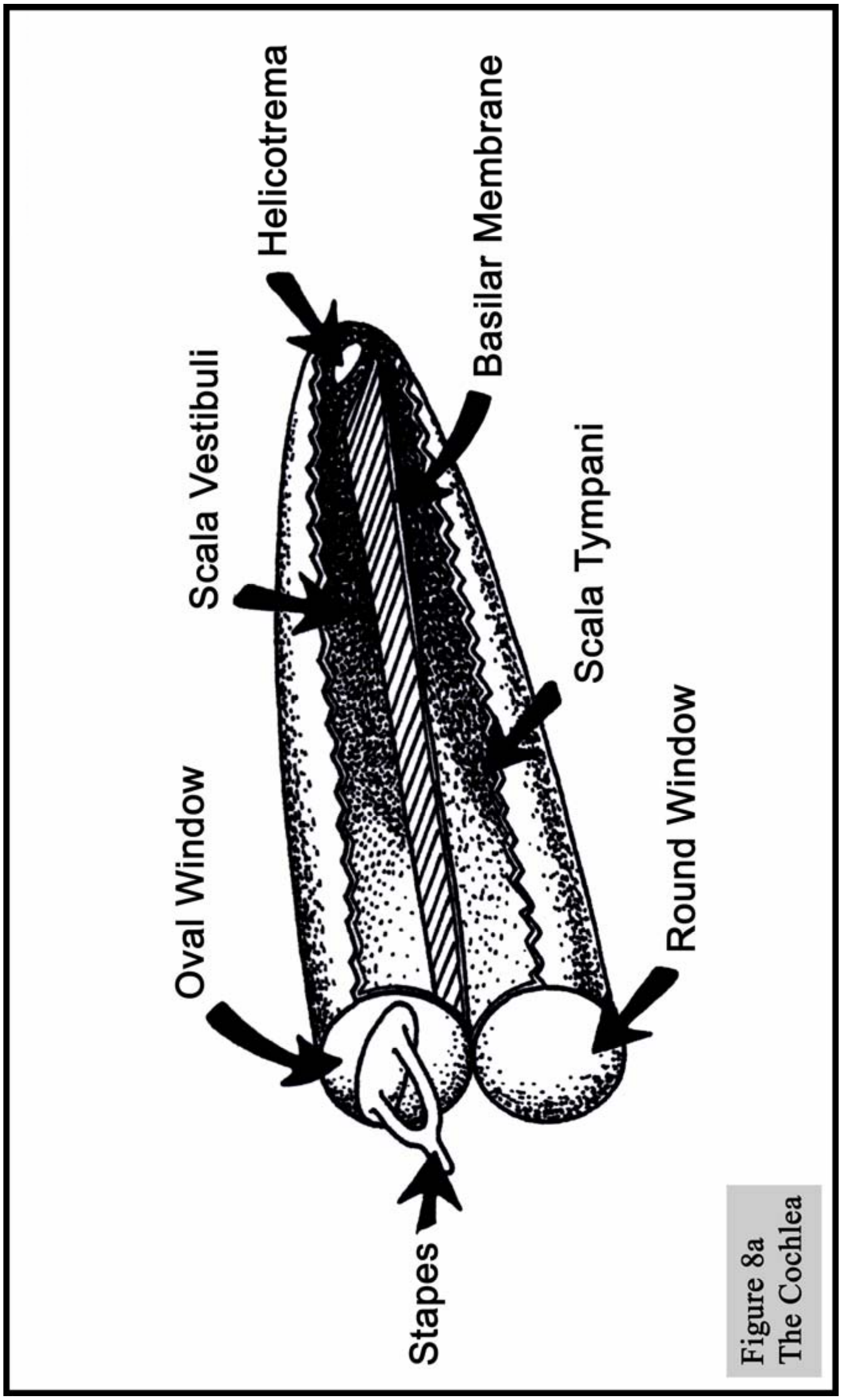

Figure 8a
The Cochlea

Lecture Nine

Hearing—Age-Related Changes

Scope: Some degree of hearing loss as we age is unavoidable. Small deficiencies can be measured in the teens, especially in societies such as ours with a great deal of noise pollution. However, in the absence of pathology, significant hearing loss is usually not noticed until the late 50s. Hearing loss typically occurs slowly and may go unnoticed until it is commented on by others.

There are multiple causes for age-related hearing loss, including physical changes in the ear canal and the eardrum, degeneration of the temporal bone, progressive death of hair cells beginning at the basal end of the cochlea, reduced electrical output in an amplification source in the cochlea known as the *stria vascularis*, and age-related degenerative changes in the auditory nerve. Age-related hearing loss occurs in all societies, but it is greatest in industrialized societies because of noise pollution. Although noise-induced hearing loss is a danger at any age, the elderly auditory system is far more susceptible to noise than the young auditory system.

Some drugs have also been found to put hearing ability at risk. Such substances are referred to as ototoxic drugs (harmful to hair cells). The elderly typically require more medication than the young and should be cautious about taking any medication that produces a ringing in the ears.

Outline

I. There is no question that age-related decreases in auditory sensitivity occur. However, these changes are not quite as great as were once believed.

- **A.** As we age, we tend to become more conservative, valuing accuracy over speed out of greater concern for making errors.
- **B.** In audiometric tests, young people are more likely to say, "I hear it," even when they are not quite certain that a tone was present, while older people tend to wait until they are certain before reporting, "I hear it."

II. Although personality variables lead to a slight overestimation of age-related hearing loss, there is ample evidence that significant age-related loss does, in fact, occur. Structural changes occur in the outer ear, middle ear, inner ear, and auditory nerve.

- **A.** We will look first at air conductive hearing loss, in which age-related degenerative changes in the ear canal and the eardrum have been documented.
  - **1.** Degenerative changes in the cartilage that forms the wall of the ear canal alter its resonance characteristics.
  - **2.** The eardrum becomes thicker and stiffer with age, distorting its vibrational characteristics.
- **B.** Both air conductive and bone conductive hearing loss occur as the aging process produces changes in our bones. We first look at air-conductive hearing loss.
  - **1.** Physical changes in the ear canal and the eardrum can cause air-conductive hearing loss.
  - **2.** Otosclerosis impairs air conductive hearing as a result of a bony growth that fuses the footplate of the stapes to the oval window.
- **C.** Now we come to bone conductive hearing loss, where we see that the inner ear is also affected by the aging process.
  - **1.** The temporal bone becomes more brittle and porous with age, resulting in decrements in bone conductive hearing.
  - **2.** A phenomenon referred to as *presbycusis* is defined as a progressive loss of hearing for high frequencies as a function of age.
  - **3.** At age 60, our auditory frequency range is less than half of what it was in our teens.
  - **4.** Cross-cultural studies show that presbycusis affects people in all cultures, not just noise-polluted societies.

5. Presbycusis causes progressive hair cell loss, which starts at the basal end of the cochlea and moves over time toward the apical end of the cochlea.

III. A highly vascularized tissue layer in the cochlea, the *stria vascularis*, can generate a +80-millivolts (mv) direct current that acts as a battery and amplifies the electrical output of the auditory hair cells.

- **A.** With age, the stria vascularis shows degenerative changes, and its electrical output is decreased.
- **B.** Animal experiments indicate that when the blood supply to the stria vascularis is decreased, the animal's hearing sensitivity declines.
- **C.** The implication is that human hearing sensitivity declines as age-related changes in the stria vascularis occur.

IV. Certain drugs can injure or kill hair cells. Such drugs are called ototoxic drugs.

- **A.** Streptomycin, an antibiotic once used to treat tuberculosis, was found to result in progressive, permanent hearing loss due to hair cell death.
- **B.** Other mycin drugs and many diuretics have also been found to have ototoxic properties.
- **C.** In general, the elderly take more medication than young people and are at greater risk of encountering a drug with ototoxic properties.

V. Noise-induced hearing loss is a serious problem in industrialized societies where noise pollution is unavoidable.

- **A.** The older ear is more susceptible to noise-induced hearing loss than the younger ear.
- **B.** Ear protection (that is, ear plugs or ear covers) should be used whenever listening for an extended period of time to any noise louder than a power lawn mower.
- **C.** Any situation that produces a ringing in the ears (tinnitus) is harmful to hearing. Medication that causes a ringing in the ears should be used with caution. Even large doses of aspirin can reduce hearing sensitivity, although in the case of aspirin, the effect is reversible with dosage reduction.

VI. The nerve fibers in the auditory nerve exhibit degenerative changes with age. These changes result in slower conduction speed, which leads to intelligibility and comprehension problems when listening to rapid speech.

VII. Most forms of conductive hearing loss can be corrected, and many instances of sensorineural hearing loss can be reduced with the use of a hearing aid.

Suggested Reading:

Colavita, *Sensory Changes in the Elderly*, chapter 2.

Goldstein, *Sensation and Perception* (6th ed.), pp. 564–578.

Questions to Consider:

1. What do you know about cochlear implants? Why are they less beneficial for the elderly than for children?
2. Noise pollution is an increasing problem in modern society. In addition to hearing loss, what other harmful consequences of noise pollution can you think of?

Lecture Ten

The Cutaneous System—Receptors, Pathways

Scope: The cutaneous system, or skin senses, provides us with information about events on the surface of the body. Experiments going back more than 150 years indicate that cutaneous stimulation is experienced by discrete receptors located in a layer of the skin known as the *dermis*. These receptors, known collectively as the *encapsulated end organs*, are not uniformly distributed over the body. As a result, we find that different parts of the body are differentially sensitive to warm, cold, light touch, pressure, or vibration (pain will be considered in later lectures because of its special nature). Complications arose in the scientific understanding of the cutaneous system when experimenters could find no encapsulated end organs for such sensations as itch, tickle, and wetness. An encapsulated end organ for the perception of hot was also lacking, although the experience of hot was later shown to result from simultaneous activation of warm and cold receptors. The workings (and importance) of the cutaneous system turned out to be significantly more complicated than the original experiments tended to suggest.

Outline

I. The cutaneous system provides us with information about stimulus events on the surface of the body, rather than about events at a distance, as in the case of vision or hearing.

- **A.** The most commonly experienced cutaneous sensations are warm, cold, light touch, pressure, and vibration.
- **B.** Pain differs from the other skin senses in a number of important ways and will be considered separately.

II. The skin is the largest sense organ of the body, containing millions of receptors spread over approximately 2.5 square meters. Skin is composed of four layers.

- **A.** The outermost layer of skin is the dead-cell layer, which acts as some protection against invading microorganisms and harmful wavelengths of electromagnetic energy.
- **B.** The epidermis is a thin layer of live cells that produces new cells to replace cells from the dead-cell layer that are constantly being sloughed off.
- **C.** The next layer of skin is the dermis, which contains the cutaneous sensory receptors, known collectively as the *encapsulated end organs*.
- **D.** The innermost skin layer is the subcutaneous fatty layer.

III. Experiments going back more than 150 years demonstrated that human skin possesses *punctate sensitivity*. That is, not all points on the skin are equally sensitive to the different categories of cutaneous stimulation. (Figure 10a)

- **A.** In the late 1800s, anatomical studies of human skin identified several types of encapsulated end organs in the dermis, which turned out to be receptors.
- **B.** Follow-up anatomical studies suggested that each encapsulated end organ was responsive to a particular form of stimulation.
  1. *Meissner corpuscles* were thought to be the receptors for light touch.
  2. *Pacinian corpuscles* served as receptors for deep touch, pressure, and vibration.
  3. *Krause end bulbs* were considered to be cold receptors.
  4. *Ruffini cylinders* were the warm receptors.
  5. *Free nerve endings* in the skin were, by default, considered pain receptors.

IV. Punctate sensitivity experiments conducted with human subjects in the late 1800s and early 1900s permit some general statements to be made.

- **A.** Touch sensitivity is greatest in the periphery of the body, becoming less precise moving toward the body's midline axis.

B. Pain sensitivity is greatest along the midline axis, where the vital organs are, decreasing toward the periphery of the body. The two parts of the body that have the greatest representation of pain receptors are the corneas and the eardrum.

C. Some parts of the body may deviate from the norm.
   1. The brain has no pain receptors; it only receives pain signals.
   2. Connective tissue surrounding organs is full of pain receptors, while the organs themselves are not.
   3. The mucous lining of the cheeks is also largely devoid of pain receptors.

D. "Cold spots" on the body are more numerous than "warm spots."

E. There do not appear to be any punctate "hot spots" on the body.
   1. Cold receptors are located more superficially in the skin (.1 mm deep) than warm receptors (.3 mm deep).
   2. The experience of hot requires simultaneous stimulation of warm and cold spots.
   3. One can now make sense of the phenomenon of paradoxical cold, in which a hot stimulus may be initially and briefly perceived as cold before the hot sensation is experienced.

V. Up until the 1950s, the association of a particular encapsulated end organ with a specific cutaneous experience (known as *specific receptor view*) was generally accepted. However, several troubling issues were raised at this time.

A. Where are the receptors for such cutaneous experiences as itch, wetness, and tickle?

B. How is it possible that the cornea of the eye, which possesses only free nerve endings, can be shown (with care) to perceive light touch, as well as warmth and cold?

C. How are points on the skin containing no encapsulated end organs capable of perceiving cutaneous sensations?

VI. It is now known that free nerve endings have a primitive (nonspecific) ability to respond to all categories of cutaneous stimulation.

A. Free nerve endings transmit cutaneous information to the brain via a more primitive pathway (the spinothalamic tract) than that used by the encapsulated end organs.
   1. Cutaneous perception is more complicated than originally conceived in the traditional specific receptor position.
   2. The brain apparently analyzes input from the free nerve endings and from the patterns of input from various encapsulated end organs before creating a perception.

B. An example of how the brain analyzes multiple inputs to create a cutaneous perception can be seen in the case of tickle.
   1. One cannot tickle oneself, although the physical stimulus may be exactly the same as when someone else is doing the tickling.
   2. A highly ticklish person can tolerate a doctor probing the rib (or any other traditionally ticklish area) if the patient holds the doctor's palpating or probing hand and presses and palpates with the doctor's hand according to the doctor's directions.

C. Experiments have revealed how best to tolerate drinking very hot liquids: Taking a sharp "sip" of air before drinking cools the oral cavity and enables one to transfer the liquid to the back of the throat, which is relatively devoid of pain receptors.

Suggested Reading:

Sekuler and Blake, *Perception* (4^{th} ed.), pp. 497–512.

Questions to Consider:

1. Are perceptions we feel through the skin as important to survival as those provided by vision and hearing?
2. Can you think of common examples of "selective attention" operating in the cutaneous system?

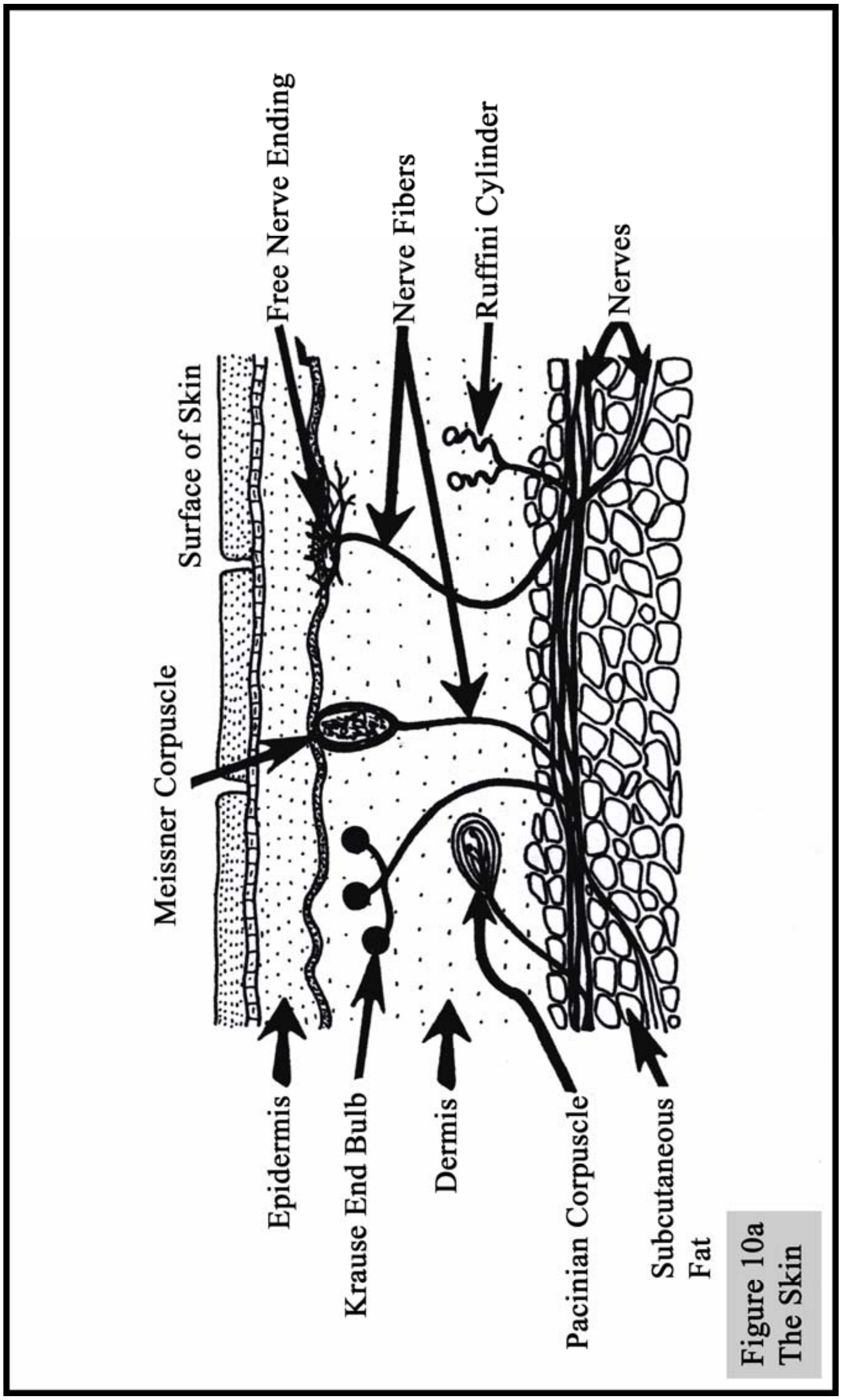

Figure 10a
The Skin

Lecture Eleven

The Cutaneous System—Early Development

Scope: This lecture presents an overview of the literature indicating the importance of cutaneous stimulation, especially tactile stimulation, for normal growth and development. Animal experiments conducted in the 1960s demonstrated that infant rats and monkeys deprived of tactile stimulation exhibited serious developmental deficiencies, from which they never recovered. These deficiencies were in the areas of learning capacity, physical size, socialization, appropriate reactions to stress, and exploratory behavior. More recent experiments indicated that animals raised in isolation and deprived of tactile stimulation, either from humans or from conspecifics, showed differences in brain growth and endocrine functioning when compared with animals raised with conspecifics or given daily handling and gentling by human researchers. Observations made in orphanages around the world suggest that human infants who do not receive sufficient tactile stimulation from caregivers also exhibit developmental deficiencies, including a lack of the capacity to exhibit trust.

Within the past decade, it has been demonstrated that the standard treatment for premature babies needs to be reconsidered. Traditionally, "preemies" spend much time in isolation to minimize exposure to antigens. New research suggests that the reduced level of tactile stimulation from caregivers may cause more harm than good. Preemies actually flourish when given regular tactile stimulation by caregivers.

Outline

I. Animal research conducted over the past 40 years indicates that tactile stimulation is critically important for normal maturation and development.

- **A.** Numerous studies with young rats indicate that animals receiving daily holding, handling, and stroking by laboratory technicians exhibited developmental advantages over animals that did not receive such treatment.
  - **1.** Infant rats receiving daily handling and gentling grow larger than ignored animals.
  - **2.** Handled animals have smaller adrenal glands, making them less reactive and more resistant to stress.
  - **3.** Handled animals learn mazes faster, are less timid, and exhibit more exploratory behavior.
- **B.** Psychologist Ronald Melzack studied puppies isolated from their parents and siblings and found that such animals exhibited highly abnormal behavior.
- **C.** In the 1960s, psychologist Harry Harlow demonstrated that infant monkeys deprived of touch stimulation from parents and siblings exhibited gross abnormalities.
  - **1.** The animals exhibited behaviors similar to those seen in severely autistic children.
  - **2.** In extreme cases, the behavioral abnormalities were irreversible.

II. Observations made of children raised in orphanages in different countries indicate that physical contact with caregivers is necessary for normal development.

- **A.** Normal social and cognitive development can be impaired if a human infant does not receive sufficient holding and cuddling.
- **B.** Related studies have been made of animal imprinting, which is the formation of a strong attachment to a mother object during a critical period.
- **C.** Evidence suggests that infants who do not experience a warm, affectionate physical interaction with a caregiver during the first year of life are restricted in their ability to develop trust.

III. The precautions taken by hospitals to provide a near sterile environment for premature babies ("preemies") preclude these babies from receiving normal levels of tender loving care (TLC). Dr. Tiffany Field of the University of Miami's Touch Research Institute (TRI) has conducted studies to compare the developmental progress of preemies given structured TLC with that of preemies treated in the standard fashion.

- **A.** Senior citizen volunteers were trained in massage techniques, then assigned a preemie to whom they would give gentle back rubs and limb massages.

B. Preemies receiving regular tactile stimulation were more alert and responsive and were able to be released from the hospital on an average of six days earlier than traditionally treated preemies.

C. Follow-up studies eight months later again showed dramatic results.

1. Preemies in the TLC group were larger and had fewer illnesses.
2. They also exhibited fewer instances of sleep apnea, a risk factor for SIDS.
3. The TLC group gained weight much faster.
4. When compared with traditional preemies, the TLC preemies also showed faster development of the myelin sheath, which is the layer of fatty insulation that keeps nerves endings from short-circuiting.

IV. Certain categories of children, such as those with seizure disorders, may be placed at risk developmentally by being excluded from group activities, such as gym classes, playground recreational activities, and games during school recess periods.

V. Society has become less accepting of appropriate touch in schools and daycare facilities because of concerns about inappropriate touch.

A. Caring people are reluctant to display affection and attention.

B. The harm done to children directly by the predations of molesters is painfully obvious.

C. Molesters harm even more children indirectly by creating a climate in which genuinely caring and affectionate people who work with children are afraid to touch them.

Suggested Reading:

Ackerman, *A Natural History of the Senses*, pp. 65–122.

Field, *Touch Therapy*.

Questions to Consider:

1. How can tactile stimulation (or its lack) have an effect on nervous system development?
2. Does being raised in an orphanage necessarily place an infant at greater developmental risk than being raised by biological parents?

Lecture Twelve

The Cutaneous System—Age-Related Changes

Scope: Far fewer studies of the human skin senses have been conducted than on vision or hearing. However, sufficient data exist to make the general statement that there are decrements in cutaneous sensitivity with age. One reason is that aging skin loses its elasticity, requiring more pressure to experience light touch or vibration. Also, at the anatomical level, fewer encapsulated end organs are found in aged skin. Further, age-related degenerative changes take place in the sensory nerves that carry cutaneous information from the skin to the brain. One consequence of this is that people in their 80s have extreme difficulty in perceiving two discrete light touches presented simultaneously to two different body parts. This phenomenon is called *sensory suppression* by neurologists and neuropsychologists.

In the absence of neural pathology, such as multiple sclerosis, most age-related changes in cutaneous sensitivity require laboratory conditions to measure. They actually have little effect on normal daily living. This fact is of great significance, in that tactile stimulation is as important to young and old adults as it is to infants and children. A touch on the arm, a pat on the shoulder, hand holding, or a hug produce measurable positive physiological changes in people at any age. Young or old people in deep comas show reductions in blood pressure and heart rate when someone holds their hands.

Outline

I. The aging process causes changes in cutaneous sensitivity.

- **A.** Human skin loses its elasticity with age, requiring more mechanical pressure to produce sensations of light touch or vibration.
- **B.** The number of encapsulated end organs in the skin decreases, leaving only the free nerve endings, which are less precise in their responses to stimulation.
- **C.** As we age, our skin also becomes less sensitive to vibration, because of changes in the Pacinian corpuscles.
- **D.** Experiments underscore the fact that our sense of touch does not decline until about the age of 50.

II. Sensory nerves that carry cutaneous information from the skin to the brain show degenerative changes with age.

- **A.** Older nerves conduct more slowly, resulting in slower reaction time.
- **B.** Sensory suppressions (failures to perceive both of two simultaneously presented tactile stimuli delivered to two body sites) are common in the elderly.
  - **1.** Sensory suppressions are common in children between the ages of 3 and 6 and in adults over the age of 70.
  - **2.** Sensory suppressions are a sign of brain dysfunction in young adults.

III. Age-related deficits in cutaneous sensitivity are easily demonstrated in the laboratory. In the absence of neural pathology, such as multiple sclerosis, these deficits are not of a sufficient magnitude to have a great effect on normal daily activities.

IV. Tactile stimulation, known to be important for the well-being of infants and children, continues to be important for the rest of our lives.

- **A.** The senior volunteers in the TRI preemie study appeared to benefit from the interaction as much as the babies did. During the training period, the volunteers practiced their technique by massaging each other.
  - **1.** Volunteers reported less depression and feelings of loneliness as the study progressed.
  - **2.** Volunteers had reduced levels of stress hormones and made fewer trips to their physicians.
  - **3.** Volunteers became more socially outgoing and reported increased quality of life.
- **B.** Touch is a significant part of interpersonal relationships.

1. **1.** Shaking hands, holding hands, kissing, hugging, linking arms, and so on are common practices in different life situations.
2. **2.** Waitresses who place a hand on a customer's arm or shoulder when bringing the check or returning change get larger tips.
3. **3.** People in an anxious state show reductions in heart rate and blood pressure when someone puts a hand on their shoulder or holds their hand.
4. **4.** People in deep comas show beneficial heart rate changes when their hands are held.
5. **5.** Massage therapy has been shown to bring about positive medical benefits, including increase of the efficiency of the immune system, stress reduction, speedier healing of surgical incision, and reduction of severity of asthma attacks.

V. Cultural differences in touch frequency may have developmental significance.

A. Studies show that the United States is a nontactile society.

B. French parents touch their children three times as often as American parents do, and French teachers touch their students significantly more often than their American counterparts.

C. Some researchers believe that in cultures with higher touch rates, there are lower rates of adolescent aggression.

VI. There are two broad categories of touch that are important throughout life. These categories are called *passive touch* and *active touch*.

A. Passive touch refers to a situation in which the person being touched remains stationary.

B. Active touch refers to the use of touch to explore and manipulate objects in the environment.

1. **1.** It is through active touch that we learn how the physical world works.
2. **2.** Visually guided grasping responses are not automatically accurate; such accuracy is acquired through practice with active touch.

C. With advancing age, our touch discrimination declines.

D. On the other end of the spectrum, babies develop their "view" of the world through tactile stimulation.

Suggested Reading:

Colavita, *Sensory Changes in the Elderly*, chapter 7.

Field, *Touch Therapy*.

Questions to Consider:

1. **1.** Should those of us who have reached adulthood as "non-touchers and non-huggers" reconsider our position on this issue? Why? Why not?
2. **2.** When one is stroking a dog or cat, which do you think is experiencing greater pleasure, the one stroking, or the one being stroked?

Glossary

A-delta fibers: Rapidly conducting nerve fibers that carry information from encapsulated end organs in the skin to the central nervous system.

Accommodation: The ability of the lens of the eye to alter its focal properties by changing its shape.

Active touch: Exploration and identification of objects in the environment through actively touching them.

Air conductive hearing: Auditory experiences resulting from sound waves transmitted from the eardrum through the ossicles to the cochlea.

Alzheimer's disease: A form of senile dementia resulting in widespread neural degeneration in the brain, an early sign being memory loss.

Anosmia: Inability to perceive odors.

Aphasia: A disorder of the associative aspects of language.

Arcus senilis: An opaque ring just inside the border between the cornea and the sclerotic coat, usually apparent by the mid- to late 60s.

Automaticity: The process by which repetition and practice permits an individual to perform a coordinated sequence of motor movements without conscious thought.

Axon: The elongated portion of a neuron that transmits the action potential from the cell body to the terminal end branches.

Ayurvedic medicine: The holistic system of health care that was in use in India 10,000 years ago and is still in use today.

Basilar membrane: The flexible membrane located in the cochlea upon which the auditory hair cells are located.

Bed spins: A vestibular phenomenon experienced by individuals who drink too much alcohol and lie on their backs in bed.

Behaviorism: The school of psychology founded by John B. Watson around 1913 that stated that the subject matter of psychology should be behavior, not the mind.

Binocular depth cues: Depth cues that depend on the simultaneous use of both eyes.

Blindsight: The ability, following damage to the visual cortex, to point to an object in the visual field with no awareness of seeing it.

Blind spot: A small area on each retina where the receptors are pushed aside by the optic nerve leaving the eyeball on its way to the brain.

Bone conductive hearing: The perception of sound through vibrations in the temporal bone that are transmitted directly to the cochlea without the involvement of the eardrum and ossicles.

Broca's area: The brain region in the left (usually) frontal lobe necessary for the expression of speech.

C fibers: The small-diameter, slow-conducting nerve fibers that transmit pain information from the free nerve endings to the central nervous system.

Cataracts: Clouding of the lens of the eye, usually due to aging.

Central tendency error: The perceptual error of seeing people as more consistent than they actually are.

Cerebral cortex: The outer mantle of cell bodies that covers the subcortical parts of the brain.

Choroid coat: The retinal layer at the back of the eye that absorbs stray light.

Cochlea: The bony inner-ear structure that contains the auditory receptors.

Conductive hearing loss: Hearing loss caused by interruption or dampening of sound waves before they reach the receptors.

Cones: The centrally located visual receptors responsible for detailed color vision in normal levels of illumination.

Critical flicker frequency (CFF): The highest rate of visual flicker an individual can perceive before the flicker turns into a steady light.

Decibel (dB): A unit of pressure used to measure sound waves.

Deep pain: Dull, aching, throbbing pain.

Determinism: The basic assumption of science asserting our belief in a lawful universe where cause and effect are in operation.

Echolocation: The ability to locate objects in space by emitting high-frequency pulses and using the two ears to sense the location in space from which the object reflects back those pulses.

Encapsulated end organs: The general term used to refer to the various types of cutaneous receptors found in the skin.

Endorphins: Morphine-like substances produced in the brain that can have analgesic effects.

Forebrain: A subcortical brain region involved in emotional reactivity and the expression of the primary drives.

Fovea: The central portion of the retina that contains only cones and has the greatest visual acuity.

Free nerve endings: The primitive receptors in the skin (and other regions of the body) primarily responsible for pain sensations.

Gate-control theory: Melzack and Wall's theory that our perception of pain is determined by the ratio of A-delta to C fibers that a stimulus excites.

Gestalt psychology: An early school of psychology that is best remembered today for its phenomenological approach to perception and perceptual organization.

Glaucoma: A medical condition in which increased fluid pressure in the eyeball can damage the retinal elements and the optic nerve.

Golgi organs: Receptors in the tendons that respond to the amount of tension generated by a contracting muscle.

Halo effect: The tendency to form an overall positive impression of someone from a single positive trait.

Hertz (Hz): A unit of measurement for the number of cycles a sound wave (or any continuous wave) completes in one second.

Hindbrain: The primitive portion of the brain that controls vital functions, such as breathing and heart rate.

Hippocampus: A forebrain structure known to be involved in the consolidation of short-term memory into long-term memory.

Infrared: The portion of the electromagnetic energy spectrum just above the red end of the visible spectrum, invisible to the human eye.

Inner ear: The cochlea, semicircular canals, utricle, and saccule.

Intra-aural muscles: The two tiny muscles located in the middle ear, known as the stapedius and the tensor tympani muscles.

Kinesthetic sense: The sense that responds to the position and motion of our limbs.

Krause end bulbs: One of the encapsulated end organs in the skin, thought to respond to cold.

Learned taste aversion: The tendency for humans and other animals to develop an aversion to a taste that is temporally contiguous with feelings of illness, even if the taste is unrelated to the illness.

Ligaments: The tough connective tissue that attaches bones together at a joint.

Lobes of the brain: The human brain is composed of the frontal, parietal, occipital, and temporal lobes.

Logical error: A perceptual error resulting from the faulty belief that certain personality traits (such as politeness and honesty) always go together.

Long wavelengths of light: Colors located toward the red end of the visible spectrum.

Macular degeneration: Degeneration in the central 5 mm of the retina that surrounds and includes the fovea.

McClintock effect: The phenomenon whereby college coeds who live on the same dormitory floor frequently have menstrual periods that start around the same time.

Meissner corpuscle: An encapsulated end organ in the skin that responds to touch.

Midbrain: Subcortical brain region responsible for reflex orientation to sensory stimuli.

Middle ear: The air-filled space between the eardrum and cochlea, containing the ossicles and the intra-aural muscles.

Monocular depth cues: Depth cues, such as those used by artists in a painting, that can be perceived with one eye.

Muscle spindles: Receptors located in muscles that respond to the degree of contraction.

Myopia: Nearsightedness; an inability to see distant objects clearly due to a focal error in the eye.

Object identification: The higher-order aspect of visual perception requiring the integrity of the visual cortex.

Object location: The lower-order aspect of visual perception mediated by neural circuits in the midbrain.

Olfactory bulbs: Structures located under the frontal lobes that receive information from the smell receptors.

Olfactory epithelium: The area of tissue at the top of the nasal cavity, measuring 2.5 square centimeters, where the smell receptors are located.

Olivocochlear bundle: A bundle of nerve fibers going from the central nervous system back to the auditory receptors in the cochlea, thought to be involved in selective attention.

Optical instruments of the eye: The cornea and the lens are the optical instruments of the eye.

Optic tectum: The midbrain region responsible for reflex orientation to abrupt changes in the visual field.

Ossicles: The chain of three tiny bones in the middle ear known as the malleus, incus, and stapes.

Otitis media: A middle-ear infection.

Otoliths: The tiny calcium carbonate particles found in the utricle and saccule.

Otosclerosis: A hereditary condition resulting in partial or complete immobilization of the stapes.

Ototoxic drugs: Drugs that can be harmful to auditory and vestibular hair cells.

Outer ear: The portion of the auditory system from the ear to the eardrum.

Pacinian corpuscle: One of the encapsulated end organs in the skin, known to be sensitive to pressure and vibrations.

Passive touch: The situation in which a person remains passive while tactile stimulation is applied to the skin.

Perceptual world: The meaning that a sensory array has for a particular individual as a result of that individual's unique history with that or a similar stimulus array.

Perilymph: The liquid having the consistency of blood that fills the cochlea and the semicircular canals.

Personal space: In public situations, the distance maintained from another person or persons with which one feels most comfortable.

Phenylketonuria: An inherited metabolic disorder that can cause retardation; PKU produces a characteristic odor in those who have it.

Phenylthiocarbamide (PTC): A synthetic substance that some people (called *tasters*) can taste and others (called *nontasters*) cannot.

Phenylthylamine (PEA): A substance found in chocolate and thought to contribute to chocolate cravings.

Pheromones: Odorous chemicals released by some species that produce physiological responses in conspecifics.

Phonemes: The smallest distinguishable utterances in a language.

Phonemic perceptual maps: Dedicated connections between auditory receptors and cells in the auditory cortex are created in children who repeatedly hear phonemes spoken by caregivers, with each phoneme having a different spatial location in the auditory cortex.

Pigment epithelium: The retinal layer containing the blood supply that provides nutrients for the receptors.

Placebo effect: The ability of an inert substance to reduce symptoms if the recipient believes in its efficacy.

Plasticity: The ability of the brain to compensate for damage.

Presbycusis: A progressive loss of hearing for high frequencies as a function of age.

Presbyopia: A deficit in near vision resulting from age-related loss of elasticity and accommodation.

Prosopagnosia: A form of visual agnosia characterized by an inability to recognize human faces.

Pyramidal tracts: The nerve fiber bundles that carry instructions from the motor cortex to the peripheral muscles.

Rods: The visual receptors mediating noncolor vision in dim light.

Ruffini cylinders: One of the encapsulated end organs in the skin thought to be sensitive to warm stimuli.

Saccule: Part of the vestibular system found under the semicircular canals; a protuberance, slightly smaller than the utricle, that responds to changes in the head's orientation.

Semicircular canals: The portion of the vestibular system that responds to angular acceleration and deceleration.

Sensorineural hearing loss: Hearing loss due to damage or degeneration of receptors and/or auditory nerve fibers.

Sensory supporting structures: Structures such as the ossicles or the hairs on the skin that make a stimulus more accessible to the sensory receptors.

Sensory suppression: The inability to perceive both of two touch stimuli delivered simultaneously to different body areas.

Sensory world: Those portions of the physical environment to which an organism's sensory receptors are responsive.

Short wavelengths of light: The blue-violet end of the visible spectrum.

Specific gravity: The weight of an object in air divided by the weight of an equal volume of water.

Speed of light: The speed of light is 186,000 miles per second.

Speed of sound: The speed of sound is approximately 1,110 feet per second in air at normal atmospheric pressures.

Stria vascularis: The highly vascularized tissue layer inside the cochlea that appears to act as a DC battery, amplifying the electrical output of the hair cells.

Substantia gelatinosa: A nucleus in the dorsal horn of the spinal cord, proposed as the "gate" in the gate-control theory of pain.

Superficial pain: "Bright," sharp, surface pain.

"Sweet-tooth" phenomenon: Refers to the unlearned preference for the taste of sweet seen in humans and many other species.

Sylvian sulcus (or sylvian fissure): The upper boundary of the temporal lobe.

Taste bud: A goblet-shaped cluster of cells below the surface of the tongue.

Taste papilla: One of the visible bumps on the surface of the tongue, surrounded by moat-like trenches containing the taste buds.

Taste receptor: Each of the 10,000 taste buds on the tongue contains a taste receptor.

Tectorial membrane: A stiff membrane in the cochlea against which the auditory hair cells rub when vibrations from sound waves are initiated in the basilar membrane.

Tendons: Strong bands of connective tissue that attach muscles to bones.

Traditional Chinese medicine (TCM): A holistic health care system used in China for more than 5,000 years, which includes acupuncture as a component.

Tympanic membrane: The technical term for the eardrum.

Ultraviolet: The frequency of electromagnetic energy just below the blue-violet end of the visible spectrum, invisible to the human eye.

Utricle: Part of the vestibular system found under the semicircular canals; a protuberance, somewhat larger than the saccule, that responds to changes in the head's orientation.

Visible spectrum: That portion of the electromagnetic energy spectrum visible to the human eye, ranging from approximately 400 nm to 700 nm.

Visual agnosia: A condition usually caused by brain injury in which different aspects of the visual field are unrecognizable to the individual.

Wernicke's area: A brain region in the upper portion of the left temporal lobe important for speech comprehension.

Biographical Notes

Tiffany Field, Ph.D., University of Massachusetts, 1976, developmental psychology. Founded the Touch Research Institute (TRI) at the University of Miami School of Medicine in 1992, where she remains as director. Dr. Field studies the relationship between touch and health (both physical and psychological health). She is well known for her studies of high-risk infants.

Eleanor Gibson (1910–2002), Ph.D., Yale, 1938, psychology. Studied perceptual development in children and is best known for her work with the *visual cliff*, demonstrating that babies can perceive depth. In 1992, Dr. Gibson became one of only 10 psychologists to be awarded the National Medal of Science.

Harry Harlow (1905–1981), Ph.D., Stanford, 1930, psychology. Best known for his primate work at the University of Wisconsin, where he demonstrated that infant monkeys deprived of tactile stimulation became socially incompetent, showing behaviors similar to autism. Harlow's early studies of what has come to be called "mother love" led to later investigations of the importance of tactile stimulation for human infants.

Herman von Helmholtz (1821–1894), M.D., Medical Institute of Berlin, 1843. Helmholtz had many interests but focused on the role of the sense organs as mediators of experience in the synthesis of knowledge. He published articles on physiological optics and physiological acoustics. He invented the ophthalmoscope and was the first to measure the speed of conduction of nerve impulses. Helmholtz's theories of color vision and auditory frequency analysis turned out to be correct in many respects.

Heinrich Hertz (1857–1894), Ph.D., University of Berlin, 1880, physics, under Hermann von Helmholtz. Professor Hertz was the first person to demonstrate the existence of electromagnetic radiation and the first to produce and broadcast radio waves. The unit of measurement for cycles per second (CPS) was changed to Hertz (Hz) to honor the memory of Dr. Hertz, a physicist who was also an enthusiastic linguist, learning Arabic and Sanskrit.

Martha McClintock (1947–), Ph.D., University of Pennsylvania, 1974, psychology. Currently professor of psychology and director of the Institute for Mind and Biology at the University of Chicago. Best known for her study of menstrual synchronicity among college women living on the same dormitory floor. The existence of human pheromones was first confirmed in Dr. McClintock's laboratory in 1998. Prior to this, pheromones were thought to exist only in the animal world.

Ronald Melzack (1929–), Ph.D., McGill, 1954, psychology. Presently Professor Emeritus at McGill. While a faculty member at MIT in 1959, he began a collaboration with Dr. Patrick Wall that resulted in the gate-control theory of pain. This theory has had a great impact on the field of pain and has resulted in Dr. Melzack receiving numerous international awards for his scholarly contributions.

George Wald (1906–1987), Ph.D., Columbia, 1932, zoology. Nobel laureate in medicine (1967) for his work on physiological and chemical processes in the eye. A pioneer in the measurement of the spectral sensitivity of the cone visual pigments.

John B. Watson (1887–1958), Ph.D., University of Chicago, 1903, psychology. Founded the school of psychology known as behaviorism at Johns Hopkins University in 1913. Watson used the method of Pavlovian conditioning to gain insights into human behavior. He left Johns Hopkins in 1920 to go into advertising and retired in 1945 as vice president of the William Esty Agency.

Carl Wernicke (1848–1905), M.D., University of Breslau, Poland. Dr. Wernicke described the symptoms now referred to as receptive aphasia. These symptoms include loss of comprehension of spoken language, although hearing remains intact. The affected person may retain the ability to speak fluently, although his or her speech has no understandable meaning or syntax. Damage to the brain in the superior portion of the left temporal lobe is responsible for the condition. This part of the brain is now called Wernicke's area.

Max Wertheimer (1880–1943), Ph.D., University of Wurzburg, 1904, psychology. Worked on the fundamentals of Gestalt psychology from 1910 to 1914. A basic idea was that our perceptions have properties not predicted from the sensations comprising them. That is, perceptions do not have a one-to-one correspondence with sensory stimulation. Many known perceptual phenomena can be traced back to the studies of the Gestalt psychologists.

Bibliography

Readings:

Ackerman, D. *A Natural History of the Senses.* New York: Vintage, 1990. This is an absolutely fascinating piece of literature. I regularly recommend it to friends, colleagues, and students.

Backhaus, W. G. K., R. Kliegl, and J. S. Werner, eds. *Color Vision: Perspectives from Different Disciplines*. New York: Walter de Gruyter, 1998. An edited volume that treats the subject of color vision from the perspectives of art, psychology, physiology, genetics, and philosophy.

Bloom, F., A. Lazerson, and L. Hofstadter. *Brain, Mind, and Behavior.* New York: Freeman, 1985. This book takes the stance that the mind is explainable in terms of the interactions among the brain's component parts. Chapter 4 is especially relevant for our purposes.

Bregman, A. S. *Auditory Scene Analysis.* Cambridge: M.I.T. Press, 1990. A challenging but worthwhile experience for those seriously interested in music perception. This long and detailed book provides a summary of the research on the formation of auditory images.

Carlson, N. R. *Physiology of Behavior* (8^{th} ed.). Boston: Allyn and Bacon, 2004. Dr. Carlson does an excellent job of providing current information about sensory psychology.

Colavita, F. B. *Sensory Changes in the Elderly.* Springfield: Charles C. Thomas, 1978. Although published some time ago, this book still contains readable and relevant information.

Corey, D. P., and S. D. Roper, eds. *Sensory Transduction.* New York: Rockefeller University Press, 1992. The contributors to this volume describe original research on the transduction mechanisms used by sensory receptors. Highly technical.

Corso, J. F. *Aging Sensory Systems and Perception.* New York: Prager, 1981. Although out of print, used copies can still be found. Provides practical suggestions for coping with age-related sensory and perceptual changes.

Denes, P. B., and E. N. Pinson. *The Speech Chain* (2^{nd} ed.). New York: Freeman, 1991. This relatively short book will tell you all you want to know (and probably more) about speech production and language comprehension.

Elkins, J. *The Object Stares Back: On the Nature of Seeing.* New York: Harvest Books, 1996. This interesting book takes a nontechnical approach to "looking and seeing." Not only do we capture objects with our gaze, but our gaze is captured by objects.

Ephret, G., and R. Romand, eds. *The Central Auditory System.* New York: Oxford University Press, 1997. This edited book describes in detail the structure and function of the various divisions of the auditory system, from the cochlea to the auditory cortex. The contributors deal primarily with the auditory system of the cat.

Field, T. *Touch Therapy.* New York: Elsevier, 2000. Dr. Field, one of the most prominent researchers in the area of touch therapy, describes the many physical and mental health benefits of massage.

Filshie, Jacqueline, and Adrian White, eds. *Medical Acupuncture: A Western Approach.* Edinburgh, Scotland: Churchill Livingstone, 1998. This edited work includes contributions from Western scientists and from acupuncture practitioners. As might be expected from a Western perspective, the focus is on the analgesic rather than the purported curative properties of acupuncture.

Gazzaniga, M. *The Bisected Brain.* New York: Appleton-Century Crofts, 1970. This book is a classic in the "split brain" area, written by the foremost researcher in the field.

———, ed. *The New Cognitive Neurosciences.* Cambridge, MA: MIT Press, 2000. Although this edited volume contains many interesting chapters, your attention is especially directed to the excellent contribution by P. K. Kuhl.

Getchell, B. V., R. L. Doty, L. M. Bartoshuk, and J. B. Snow, eds. *Smell and Taste in Health and Disease.* New York: Raven Press, 1991. This massive work, 55 chapters from 70 contributors, deals exclusively with the senses of taste and smell! The chapters are more or less evenly divided between those dealing with normal functioning and those dealing with gustatory and olfactory disorders.

Gibson, J. J. *The Senses Considered as Perceptual Systems.* Boston: Houghton Mifflin, 1966. Dr. Gibson was an important theorist and a respected researcher in the area of human perception. His book is a classic.

Goldstein, E. B. *Sensation and Perception* (6^{th} ed.). Pacific Grove: Wadsworth, 2002. This is the most popular sensation and perception textbook on the market, read by thousands of college students each semester. If you are going to read a sensation and perception text, this is the one.

Gregory, R. L. *Eye and Brain.* New York: McGraw-Hill, 1966. Although it is more than 40 years old, this book is still an excellent source for the understanding of many visual illusions and other visual phenomena. There is a fifth edition out, but try the old one first.

Jerome, J. *The Elements of Effort.* New York: Simon and Schuster, 1997. If you are or have ever been a runner, you will find this book of interest. The author's description of the role of the Golgi tendon organ in confidence building is unique and creative.

Kruger, L., ed. *Pain and Touch.* San Diego: Academic Press, 1996. This is a rather technical edited volume, describing psychological, neurophysiological, and psychophysical studies of touch and pain.

Laing, D. D., R. L. Doty, and W. Breipohl, eds. *The Human Sense of Smell.* New York: Springer, 1991. This volume contains a wealth of clinical data on human anosmia and other olfactory phenomena. Definitely not light reading.

Leahey, T. H. *A History of Psychology: Main Currents in Psychological Thought* (6th ed.). Upper Saddle River, NJ: Prentice Hall, 2004. If you want to learn more about Gestalt psychology and/or the historical connection between the study of sensory processes and psychology, or about some of the important historical contributors to academic psychology, this book is a fine place to start.

Lippa, Richard A. *Introduction to Social Psychology* (4th ed.). Pacific Grove: Brooks/Cole, 1994. This is a textbook of social psychology. Chapter 4 provides a good overview of the dynamics of people perception.

Mack, A., and I. Rock. *Inattentional Blindness.* Cambridge, MA: MIT Press, 1998. The authors propose and test the hypothesis that attention is necessary for visual perception. Finding supporting results, they expand the hypothesis to include other sense modalities.

Melzack, R., and P. D. Wall. *The Challenge of Pain* (rev. ed.). New York: Penguin Books, 1988. The two best-known pain researchers explore the puzzle of pain, the physiology of pain, and the treatment of pain.

Moore, B. C. J., ed. *Hearing.* San Diego, CA: Academic Press, 1995. This edited volume summarizes virtually all the areas of hearing research. Although the chapters are well written, this work is suggested for highly motivated readers.

Sacks, O. *The Man Who Mistook His Wife for a Hat.* London: Duckworth, 1985. This is an entertaining and informative book by a noted neurologist and writer. The consequences of neurological damage for perceptual processes are skillfully and sensitively described.

Sekuler, R., and R. Blake. *Perception* (4th ed.). Boston: McGraw-Hill Humanities/Social Sciences/Languages, 2002. This book describes recent contributions to the field of perception from cognitive neuroscience.

Shepard, R. N. *Mind Sights.* New York: Freeman, 1990. Dr. Shepard has created original visual illusions and ambiguous figures that he presents and explains. This book is entertaining, interesting, and informative.

Thorne, B. M., and T. Henley. *Connections in the History and Systems of Psychology* (2nd ed.). Boston: Houghton Mifflin, 2001. The authors provide interesting biographical sketches of the important historical figures in psychology.

Wall, P. D., and R. Melzack, eds. *Textbook of Pain* (3rd ed.). London: Churchill Livingstone, 1994. This book, edited by the "fathers" of modern pain research, deals with every conceivable aspect of pain.

Wright, R. D., ed. *Visual Attention.* New York: Oxford University Press, 1998. An edited volume containing chapters contributed by cognitive scientists with an interest in various aspects of visual attention. Some chapters are of general interest, while others are less so, being highly theoretical. The chapter on "change blindness" by O'Regan is especially interesting.

Internet Resources:

"AgingEye Times." www.agingeye.net. This site explores problems facing the aging eye, such as glaucoma, cataract, macular degeneration, and diabetic eye disease.

Chandler, Daniel. "Visual Perception 4." www.aber.ac.uk/media/Modules/ MC10220/visper04.html. This site examines (among many other things) cultural differences in perception. Have fun!

"National Eye Institute." U.S. National Institutes of Health. www.nei.nih.gov/ index.asp. This Web site includes current information about eye health, including eye disease, vision care, research results, funding, and education programs. In addition to a clinical studies database, it provides photos, images, and videos on a number of eye-related topics.

"Relief of Pain and Suffering." UCLA Louise M. Darling Biomed Library—History and Special Collections. www.library.ucla.edu/libraries/biomed/his/ painexhibit/index.html. This exhibit covers many aspects of pain, including pain pathways, pain measurement, pain alleviation, phantom limb pain, and the gate-control theory of pain.

"Sensation and Perception Tutorials." Hanover College Psychology Department. psych.hanover.edu/krantz/sen_tut.html. Tutorials on visual phenomena are provided, including motion and depth perception and the Gestalt "laws" of perceptual organization.

"Serendip." Supported by Bryn Mawr College, the National Science Foundation, and the Howard Hughes Medical Institute. serendip.brynmawr.edu. This site provides access to virtually any aspect of sensation and perception, including an online demonstration of the blindsight phenomenon.

Sensation, Perception, and the Aging Process

Part II

Professor Francis B. Colavita

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Francis B. Colavita is an Emeritus Associate Professor of Psychology at the University of Pittsburgh, having recently retired after 39 years as a faculty member. Dr. Colavita served as Psychology Department Chairman from 1980 to 1988. He has received five awards for teaching excellence, including the Chancellor's Distinguished Teaching Award in 1997. This is the highest award for teaching excellence bestowed by the University of Pittsburgh. Dr. Colavita was selected to participate as a faculty member on the fall 2000 voyage of the Semester at Sea Program and was chosen to serve as academic dean on the summer 2003 Semester at Sea voyage.

Dr. Colavita attended the University of Maryland on an athletic scholarship, graduating with a B.A. in Experimental Psychology in 1961. He received his Ph.D. in Physiological Psychology from the University of Indiana in 1964. He then completed a two-year U.S. Public Health Service Postdoctoral Research Fellowship at the Center for Neural Sciences before accepting an assistant professorship at the University of Pittsburgh in 1966. In addition to his affiliation with the University of Pittsburgh, Dr. Colavita also holds an adjunct faculty position at Florida Atlantic University.

Dr. Colavita's 30 published scholarly articles are in the areas of sensory processes, perception, and recovery of function following brain damage. His book, *Sensory Changes in the Elderly*, was published in 1978. In addition to his academic pursuits, Dr. Colavita is a licensed psychologist who has maintained a small clinical practice in neuropsychology for the past 20 years, specializing in the assessment of perceptual and cognitive deficits in individuals with head injuries and/or learning disabilities.

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Part II

Sensation, Perception, and the Aging Process

Scope:

The 24 lectures in this course are taught from the perspective of academic psychology. Thus, a recurring concern throughout the course is the understanding of human behavior. Behavior does not occur randomly or haphazardly. Behavior has reasons. It happens in response to some detectable stimulus event that has taken place in our internal environment (for example, a thought or memory) or our external environment (for example, a sight or sound). A complete understanding of some behavior requires that we identify the stimulus that elicited that behavior. For instance, we cannot understand the behavior of a sleeping house cat that suddenly wakes up and runs to the back door unless we somehow discover that mice on the back porch are vocalizing in the ultrasonic range, which is well beyond the frequency range of the human ear but not that of the feline ear. Once we identify the stimulus, we understand the cat's behavior.

As alluded to above, one of the primary goals of psychology is understanding behavior. Accordingly, since its inception around 1910, behavioristic psychology has had a strong interest in the study of sensory processes. A major determinant of behavior is the information from the environment sent to our brain by our various sensory systems. Because the sensory systems of different animal species have different sensitivity characteristics, different species may live in the same physical space, but they live in very different "sensory worlds." We may define the sensory world as that part of the physical world accessible to our sensory receptors. The honeybee can see ultraviolet light; humans cannot. Humans can see the colors of the rainbow; cats cannot. Cats can hear ultrasonic frequencies; humans cannot. It is clear that some of the behavioral differences between different species can be better understood by having knowledge of the sensory capacities of these different species. You can fool your spouse with a good Halloween costume, but you cannot fool the family dog once it gets downwind of you. This is because the olfactory sensitivity of the dog is many times greater than that of the human.

It is true, as far as it goes, to say that behavior occurs in response to some detectable stimulus. However, it is more precise to say that behavior is the result, not just of one's sensations, but of one's perceptions. Simply put, a perception is a sensory event along with the meaning that the sensory event has acquired because of a particular organism's previous experience with that or a similar sensory event. As an example of the difference between a sensation, which may be relatively devoid of meaning, and a perception, which may be charged with meaning, consider the following: Two dogs hear a short, 1,000-cycle-per-second tone. One dog orients toward the tone briefly, then quickly loses interest. The second dog begins to wag its tail and salivate at the sound of the tone, showing obvious excitement. The behavioral differences between these dogs make more sense if we are told that the year is 1900 and that the latter animal has spent time as a subject in the classical conditioning laboratory of Dr. Ivan P. Pavlov. The meaning that the tone has acquired for this animal, namely, that dried meat powder is about to be blown into its mouth, is an example of a perception. To employ a human example of the difference between a sensation and a perception, imagine the following hypothetical situation: Two people are standing in a crowd in Vatican Square, one a devout Catholic who lives in Rome and the other an Asian tourist who knows nothing of Catholicism or its rituals. Suddenly a puff of white smoke is emitted from the upper level of the Sistine Chapel. The meaning that this visual stimulus will have for these two individuals is the difference between a sensation and a perception. We see that for different dogs or humans or what have you, the same sensory events can and do acquire different meanings, leading to different perceptions. Thus, it is not simply our sensory world that determines our behavior but our "perceptual world," which is determined by our unique life experiences.

This course describes how our sensory systems respond to the energy from our physical environment and how, based upon our past experience with a particular sensory event, the brain creates the perceptions that determine our behavior. Another important component of the course is a consideration of the way the aging process influences both our sensations and our perceptions. Unavoidable changes occur in the sensitivity and acuity of our sensory systems as we age, resulting in young people and older people actually living in different sensory worlds. It is also the case that young people and old people have generally had different life experiences, which is how stimuli acquire meaning and result in our perceptions. The aging process has implications for one's sensory world and one's perceptual world. The first 12 lectures in this course will expand on the difference between a sensation and a perception and elaborate on the concept of the perceptual world. The functioning of the visual, auditory, and cutaneous systems, and the changes in functioning associated with the aging process, will also be discussed in these 12 lectures. The last 12 lectures will deal with the senses of pain, taste, smell, vestibulation, and kinesthesis. Special categories of human perception, such as speech perception, face recognition, and person perception, will also be addressed. As in the initial 12 lectures, attention will be paid to the role of the aging process. All lectures are presented at a level that does not presume previous coursework in sensory processes.

Lecture Thirteen
Pain—Early History

Scope: Until the early 1900s, there was some question as to whether pain existed as a separate sense or whether it was simply the result of overstimulation of one of the other senses. The confusion arose because the receptors for pain, free nerve endings, are the most primitive receptors in the body. They are equally responsive to a wide array of energy forms, rather than having specialized in the detection of a single energy form, as have the receptors of all our other sensory systems. Pain is frequently thought of as simple, direct (that is, proportional to the amount of tissue damage), and necessary. It may be necessary (as a warning system), but it is neither simple nor proportional to tissue damage.

Although we learn more about pain year by year, many aspects remain a puzzle. For instance, what is the difference between "good pain" and "bad pain"? Also, pain perception can be influenced by cultural conditioning, attentional factors, expectation, and the meaning we attach to the stimulus. Questions remain regarding the phenomenon of the placebo effect, whereby an inert substance can significantly reduce pain magnitude if one believes that it can. Another pain-related issue suggesting that pain is not so simple is the phenomenon of acupuncture. Acupuncture has been used in China as a component of traditional Chinese medicine (TCM) for at least 5,000 years, yet Western science has acknowledged its existence only in the last 35 years. Does acupuncture alleviate pain, and if it does, what is the mechanism? These questions and others are raised in this lecture. The answers will be provided in Lecture Fourteen.

Outline

I. As recently as 100 years ago, some scientists questioned whether pain was actually a separate sense or whether it was simply overstimulation of one of the other senses.

- **A.** The confusion arose because free nerve endings, which serve as pain receptors, are the most primitive of the body's receptors.
  - **1.** Most receptors have evolved with a sensitivity to a single form of energy, such as light, sound, taste, or smell.
  - **2.** Free nerve endings have no "preferred" mode of stimulation, being equally responsive to chemicals, pressure, extremes of temperature, tissue damage, electricity, or radiant energy.
  - **3.** Free nerve endings also respond to the standard categories of cutaneous stimuli, although with less precision than the encapsulated end organs.
- **B.** Pain also differs from the other senses in that pain has both sensory and drive-like qualities.
  - **1.** It is not possible to concentrate on anything else when, for instance, you are experiencing a severe toothache, a migraine headache, or kidney stones.
  - **2.** Some pain medications and surgical procedures do not abolish pain but provide relief by reducing pain's drive-like properties.

II. Even after pain was identified as being more than overstimulation of some other sense, scientists continued to erroneously view pain as simple, direct, and necessary. This characterization turned out to be inaccurate.

- **A.** Pain is unquestionably necessary. People with no pain sensitivity exist, and they are at great risk of injury. Pain provides us with important warning signals that permit us to avoid injuries.
  - **1.** Such individuals tend to die young because they do not suffer the effects of pain and, therefore, are often risk-takers.
  - **2.** Such children have bitten off their tongues or one of their fingers with no feeling of pain.
  - **3.** Another such individual developed infected blisters on his feet from wearing improperly sized shoes with no discomfort.
  - **4.** Barefoot individuals with a congenital indifference to pain have inadvertently walked through broken glass or live campfire embers.
- **B.** Pain has a signaling function, but problems arise when the pain continues after we get the signal. That is considered "bad pain."
  - **1.** Endurance athletes make the distinction between "good pain" and "bad pain."

2. The "good pain" might provide them with information about their level of performance.

C. Although pain may be necessary, it is certainly not simple and direct.

1. The degree of attention we pay to a stimulus contributes significantly to whether or not we experience it as painful.
2. The meaning we attribute to a stimulus contributes significantly to how painful we perceive that stimulus to be.
3. If we expect something to be painful, it is more likely to be experienced as painful.

III. The existence of the *placebo effect* (the situation in which an inert substance can have analgesic properties if one believes it is a true analgesic) indicates that pain is far from simple.

A. A placebo treatment can be expected to be effective in approximately 35 percent of people treated with it. This is why clinical trials with new drugs include a placebo group.

B. Some physicians believe that the use of a placebo treatment is appropriate to help relieve the discomfort of a patient with hypochondriacal tendencies. Other physicians believe there is an ethical issue here, in that some deception of the patient is involved.

IV. Cultural factors influence pain.

A. An experience perceived as painful in one culture may have no such connotation in another.

B. Examples of such experiences include intentional decorative scarring of the face, childbirth, or boxing.

V. Another puzzle about pain involves the efficacy of acupuncture anesthesia.

A. Does acupuncture reduce or eliminate pain?

B. If acupuncture works, what is the mechanism by which it produces analgesia?

C. Acupuncture has existed for at least 5,000 years. Why has Western science paid attention to this phenomenon only for the past few decades?

Suggested Reading:

Goldstein, *Sensation and Perception* (6^{th} ed.), pp. 460–466.

Questions to Consider:

1. If a medical procedure existed to eliminate pain but left the other cutaneous sensations intact, would you opt for it? If so, why? If not, why not?
2. People frequently speak of "emotional pain." Do you feel that this is an appropriate use of the word *pain*?

Lecture Fourteen

Pain—Acupuncture, Endorphins, and Aging

Scope: Western medicine was unable to acknowledge the existence, let alone the effectiveness, of acupuncture anesthesia because the Chinese explanation for acupuncture involved the balance and flow of an invisible, unmeasurable life force, *Qi* (pronounced "chee"), and Western science was used to dealing with phenomena that are public and measurable. The gate-control theory of pain proposed by Canadian researchers Ronald Melzack and Patrick Wall in 1965 suggested a mechanism for the effectiveness of acupuncture that was visible and measurable, thereby permitting Western science to talk about and study acupuncture. This set the stage for Western medicine to eventually accept acupuncture as effective.

An interesting scientific event that relates to pain and to acupuncture was the discovery of the endorphins in the mid-1970s. Endorphins are morphine-like substances produced in the brain and released in response to pain. There is some evidence that at least some of the analgesic effects of acupuncture are due to the fact that stimulation of some acupuncture sites causes the release of endorphins. Further, the release of endorphins has been implicated in the effectiveness of the placebo effect. Pretreatment of human subjects with naloxone, an opiate antagonist, reduces or abolishes the placebo effect for pain.

The question of the aging process and pain perception turns out to be somewhat complicated. We must first differentiate between superficial (*bright*) pain and deep (*dull*) pain. Data suggest that as we age, we become less sensitive to superficial pain and more sensitive to deep pain.

Outline

I. Acupuncture has been a part of TCM for more than 5,000 years, yet most Westerners had never heard of it until the early 1970s.

- **A.** James Reston, an American journalist in China in connection with President Nixon's 1972 visit, was treated with acupuncture in a Chinese hospital. This event marked the beginning of interest in alternative medicine in the United States.
- **B.** Western science continued to ignore acupuncture because the Chinese explanation did not meet the criteria for Western science.
  - **1.** Acupuncture was thought by Chinese practitioners to unblock the flow of an invisible, unmeasurable life force known as *Qi*.
  - **2.** Qi was supposed to flow through 12 meridians in the human body, but those meridians could not be found by Western anatomists.

II. Shortly before this time, a theory of pain had been proposed by two Western scientists, Ronald Melzack and Patrick Wall. Although not directly addressing acupuncture, this theory, the *gate-control theory*, suggested a possible mechanism for the efficacy of acupuncture anesthesia that was compatible with known anatomical facts.

- **A.** Events on the surface of the skin reach the nervous system by way of *A-delta nerve fibers*, which come from encapsulated end organs, and *C fibers*, which come from free nerve endings. Both fibers go into the spine on the way up to the brain.
- **B.** On the way to the brain, these two types of nerve fibers send off branches to the *substantia gelatinosa*, which acts as a gate.
- **C.** More A-delta fibers are stimulated by touch, warm, and cold stimuli, while more free nerve endings are activated by stimuli that are typically thought of as painful.
- **D.** The gate-control theory of pain proposed that anything that increases excitation in the substantia gelatinosa causes the gate to close, thus closing the door to pain. Anything that inhibits electrical activity in the substantia gelatinosa causes the gate to open, thus opening the door to pain.
- **E.** C fibers, when they send collaterals to the substantia gelatinosa, produce an inhibitory effect in it, whereas A-delta fibers produce an excitatory effect in it.

F. The theory predicted that increasing activity in A-delta fibers should reduce pain. The ratio of A-delta to C fibers that a given stimulus activated would determine whether that stimulus would be perceived as warmth, cold, or touch as opposed to pain.

1. So-called counter-irritants, such as ice packs, heating pads, massages, whirlpool baths, and alcohol rubs, increase activity in A-delta fibers and reduce pain.
2. Insertion of acupuncture needles, as done by a trained practitioner, can also increase activity in A-delta fibers. Those needles may also be rotated, tapped, heated, or hooked up to a battery to increase effectiveness.
3. Acupuncture may also make use of what are called *trigger zones*, which are neurological links between parts of the body.

III. The discovery was made in the early 1970s that the body produces its own opiates, substances known as *endorphins*. The word *endorphin* is a composite of the words *endogenous* and *morphine*.

A. Endorphins have the capacity to reduce the severity of (not eliminate) pain.

B. Endorphins have been implicated in some of the analgesic effects of acupuncture.

C. There are two categories of endorphins:

1. *True endorphins* are pituitary hormones.
2. *Enkephalins* are peptide neurotransmitters that function in certain parts of the brain.
3. Pituitary hormones can enter the bloodstream, possibly explaining why a needle inserted at one site in the body can reduce pain sensitivity at some other site in the body.
4. Inserting needles in some standard acupuncture sites has been shown to cause the release of endorphins in the body.
5. Pretreatment with naloxone (an opiate antagonist) reduces the effectiveness of acupuncture anesthesia.

IV. Endorphins are released in the body when we experience pain. In addition to pain, there are some other experiences that can cause endorphin release.

A. Effort can result in endorphin release; some people feel that the so-called “runner’s high” may be due to endorphins.

B. Certain pleasant stimuli, such as music, cause endorphin release.

C. A pleasant event that results in a tingling in your spine is most likely releasing endorphins.

D. The discovery in the early 1980s of *Substance P,* a pain neuro-transmitter, has added to our understanding of pain and ways to alleviate it.

V. Normal aging (even in the absence of neuropathology) has been shown to influence pain sensitivity.

A. There are differences of opinion as to how pain sensitivity changes with age.

1. The elderly are sometimes portrayed as spending a good deal of time talking about their aches and pains. This suggests the possibility of greater pain sensitivity with age.
2. Some physicians feel that the elderly become less sensitive to pain in that they seem to experience less discomfort in receiving shots, can undergo minor surgical procedures without anesthetic, and may be unaware of accidental cuts and scratches until they see blood. This suggests less pain sensitivity with age.

B. The confusion may be the result of the fact that there are two broad categories of pain, superficial pain and deep pain.

1. Superficial pain, also called *bright pain*, involves the surface of the body and typically results from cuts or puncture wounds.
2. Deep pain, also called *dull pain*, is more associated with muscles, joints, ligaments, and tendons and yields a throbbing, aching sensation.

C. Pain sensitivity was studied in human subjects ranging in age from 18 to 80.

1. Superficial pain sensitivity appeared to decrease with age.
2. Deep pain sensitivity appeared to increase with age.

Suggested Reading:

Colavita, *Sensory Changes in the Elderly*, chapter 8.

Filshie and White, *Medical Acupuncture: A Western Approach*.

Questions to Consider:

1. Does the expression "no pain, no gain" sound philosophical or silly to you? Why?

2. Does your health insurance cover acupuncture? How do you feel about this?

Lecture Fifteen

Taste—Stimulus, Structures, and Receptors

Scope: When most people think of the taste of a favorite food, they unconsciously include its aroma, color, texture, and temperature. Hot, spicy foods also owe their characteristic taste to mild pain components. However, to a taste researcher, the sense of taste is composed of the four taste primaries, which are sweet, salty, sour, and bitter.

A misconception held by many people is that the raised spots visible on the tongue are taste buds or taste receptors. They are not. The visible spots are taste papillae, each spot marking the location of a tiny crater in the tongue. The taste buds are goblet shaped clusters of cells down in the craters, and the taste receptors are also located—one receptor per taste bud—in the craters. Neither taste buds nor taste receptors can be seen with the naked eye. The middle of the tongue has no taste buds or receptors and is, in fact, taste blind.

Humans, along with rats, dogs, horses, and monkeys to name a few other species, are born with a "sweet tooth" (an unlearned preference for the taste of sweet). Although it is not as strong, we also have an unlearned preference for salt, but bitter and sour are acquired tastes. We actually start life with an aversion to these two flavors.

Another interesting taste-related phenomenon is *wisdom of the body*, which refers to the ability of animals to actively seek out substances they need to maintain adequate nutrition. This is why deer travel long distances in the dead of winter to lick salt blocks put out for them by forest rangers. In the laboratory, rats have been deprived of different vitamins. When presented with a cafeteria-style feeding situation, the deprived animals select foods high in whichever vitamin they need. If the sense of taste is destroyed, the animals no longer choose the needed food. There is evidence that humans also seek out foods that compensate for a nutritional deficit.

Outline

I. To a scientist working in the area of sensory processes, the word *taste* refers only to the four taste primaries: sweet, salty, sour, and bitter.

- **A.** Japanese taste researchers have suggested a fifth taste primary, which they call *umami*. This translates approximately to "savory."
- **B.** Most people use the word *taste* when they really mean *flavor*. Whereas *taste* refers to sweet, sour, salty, and bitter, *flavor* includes the smell, temperature, texture, and color of a food.
- **C.** The exemplar for sweet is sugar; for salty, sodium chloride; for sour, dilute acetic acid; for bitter, quinine powder; and for umami, MSG.

II. The structures on the tongue that are involved in the sense of taste are the taste papillae, the taste buds, and the taste receptors. (Figure 15a)

- **A.** The visible bumps on the surface of the tongue are the taste papillae. The papillae mark the locations on the tongue of small moat-like depressions that surround the papilla (singular), much as a castle is surrounded by a moat.
- **B.** Molecules of the taste substance mix with saliva and flow into the moat, where they encounter taste buds that are located in the walls of the moat.
- **C.** A taste bud is composed of a goblet-cluster of 20–24 cells, the middle cell being the actual taste receptor.
- **D.** On the tip of the tongue, we have the *fungiform papillae*; on the edge of the tongue, we have the *foliate papillae*; and on the back of the tongue, we have the *circumvallate papillae*.
- **E.** The middle of the tongue has no taste buds or receptors and is, in fact, taste blind.
- **F.** Taste receptors die every 7–10 days and are replaced by another cell in the taste bud, which becomes the new receptor.

G. Taste receptors completely adapt to the taste of a substance in from 1½ to 3 minutes. If you were to hold a substance in your mouth for this length of time, it would lose its taste. Some very strong tastes might take slightly longer to adapt.

III. Most people have heard of the "sweet-tooth" phenomenon, an expression that refers to the preference most of us have for a sweet taste over a salty, sour, or bitter taste.

- **A.** The sweet-tooth phenomenon is almost universal in the mammalian species, although cats are an exception.
- **B.** Experiments indicate that the preference for a sweet taste is innate, rather than the result of learning and experience.
  - **1.** Neural connections have been identified between taste nerves and parts of the brain involved in feelings of pleasure.
  - **2.** In the wild, sweet-tasting substances are not usually poisonous and typically contain sugar, a good source of energy.
  - **3.** Animals born with an innate preference for sweet are more likely to survive.
  - **4.** Although less well developed than our preference for sweet, our preference for salty foods stems from our need for sodium chloride.

IV. There is evidence that animals somehow sense when they have a nutritional deficit and will actively seek out a diet that corrects this deficiency.

- **A.** This ability to detect and correct a dietary deficiency has been called *wisdom of the body*.
- **B.** Examples of wisdom of the body include deer traveling long distances in winter to lick blocks of salt put out by game wardens and cows seeking out salt blocks strategically placed by dairy farmers.
- **C.** Wisdom of the body also occurs in humans. Children or adults with adrenal insufficiency (a medical condition requiring increased salt intake) develop a craving for salt, although they are unaware of the increased need for salt.
- **D.** Laboratory experiments with animals indicate that such cravings can also be established for different vitamins.

V. Experiments with human subjects have revealed where on our tongues we experience various tastes.

- **A.** The tip of the tongue is maximally sensitive to sweet.
- **B.** The sides of the tongue are best at discriminating sour and bitter.
- **C.** The back of the tongue plays more of a role in foods for which hot, spicy, and mild pain components are an aspect.

Suggested Reading:

Carlson, *Physiology of Behavior* (8th ed.), pp. 233–238.

Goldstein, *Sensation and Perception* (6th ed.), pp. 487–499.

Questions to Consider:

1. What is flavor?

2. Why are most people unaware that the middle of the tongue is taste blind?

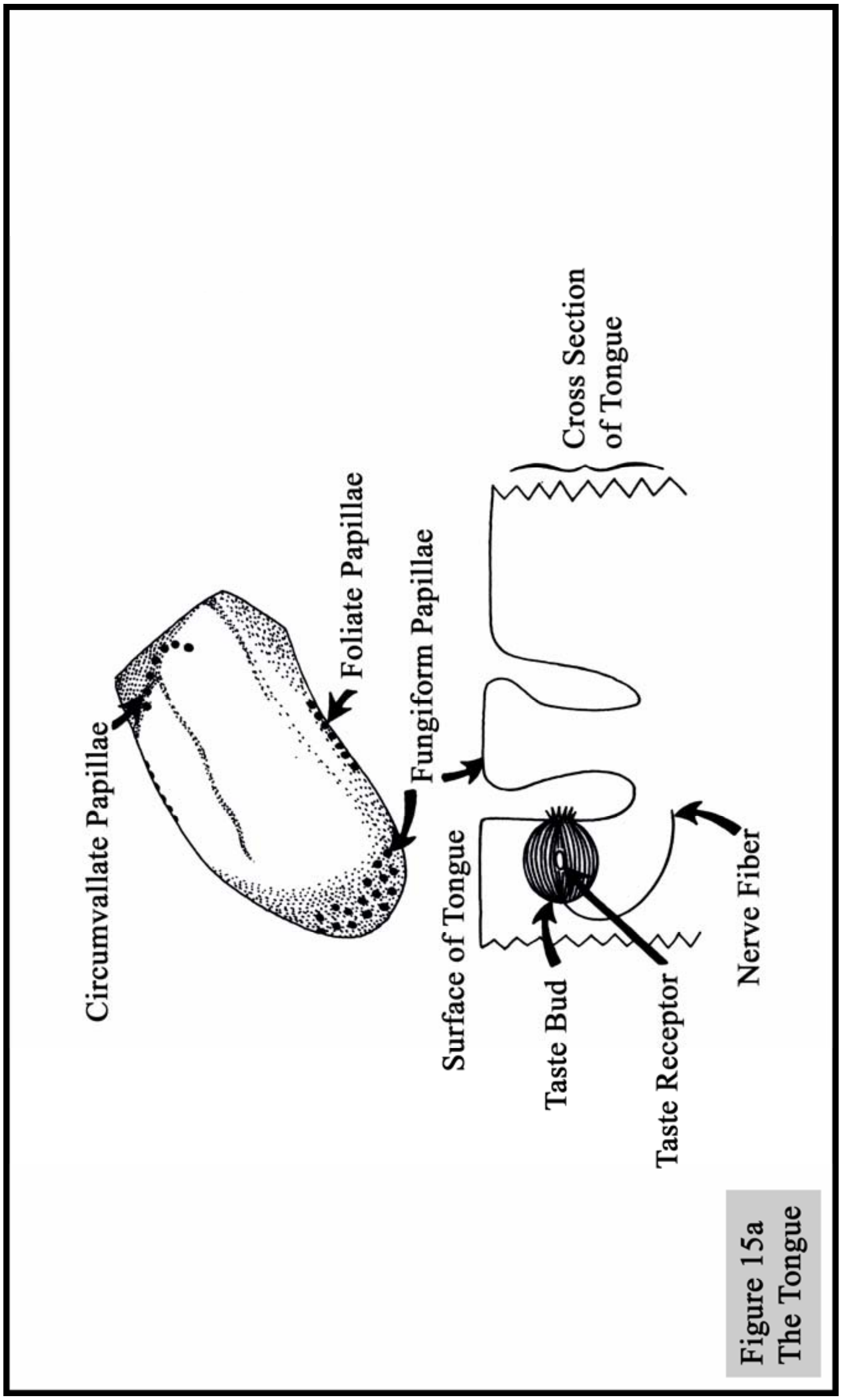

Figure 15a
The Tongue

Lecture Sixteen

Taste—Factors Influencing Preferences

Scope: All normal people are born with the same innate taste preferences. Yet by adulthood, people around the world have such different taste preferences that it is hard to believe that at one time they were similar. The following are some factors that contribute to individual differences in taste preference:

- **Age**: An 80-year-old may have fewer than half as many taste receptors as an 8-year-old. This is one reason why the young and the old have different taste preferences.
- **Learned taste aversion**: There is a special relationship between taste and illness programmed into the brain's circuits. Thus, if we experience a taste and become ill even hours later, we will develop an aversion to that taste, even though the taste may have had nothing to do with the illness. This is not only true for humans but also for many other animal species.
- **Cultural factors**: Different cultures teach their members to like certain tastes and to be repulsed by others. Learning and cultural programming can easily override the preferences we are born with.
- **Familial genetics**: Taste blindness for certain tastes runs in some families, as do extreme taste sensitivities. This has been well documented for the taste of bitter, and it may also be the case for other tastes.
- **Special foods**: Many people, mostly women, have strong cravings for chocolate. There is more at work here than just the sweet-tooth phenomenon. These cravings have been reported to be especially strong when a woman is sad, has been jilted, or is experiencing premenstrual syndrome (PMS). The chocolate craving appears to have an emotional component. Some researchers think the cravings are due to the phenylthylanine in chocolate. This substance is apparently produced in the brain when we are in love, resulting in a "heady" feeling.

Outline

I. A healthy, young adult human has approximately 10,000 taste receptors on the tongue. Children may have more than 10,000 taste receptors, and the elderly may have fewer than 10,000 taste receptors.

A. In addition to taste buds on the tip, sides, and back of the tongue, children have taste buds (and receptors) on the inside of the cheeks, the back of the throat, and the soft palate. These additional receptors are lost as young adulthood approaches.

B. People have fewer taste receptors on the tongue as they pass middle age and approach old age.

1. Taste receptors die off every 7–10 days and are replaced by new receptor cells.
2. As we age, the replacement process falls behind the dying-off process.
3. The resulting decrease in taste sensitivity alters taste preferences in the elderly.
4. Illness, excessive exposure to x-rays, smoking, and alcohol abuse can also adversely affect the sense of taste, no matter what one's age.

II. Another factor influencing taste preferences is *learned taste aversion*, the ease with which we develop a dislike for a taste that has been associated with illness.

A. The research literature on learned taste aversion indicates that in animals ranging from rats to human beings, there is a special relationship between taste and illness such that this category of learning occurs far more easily than most of our learned behaviors.

B. Even if illness occurs 90 minutes after a taste experience, rats still learn to avoid that taste in the future, although the taste experience had no part in causing the illness. This special category of learning has obvious survival value.

C. Peoples' unique experiences with tastes and illnesses contribute to the range of individual differences in taste preferences and aversions.

1. The taste does not have to cause the illness for the learned aversion to occur.
2. Foods ingested before feelings of nausea caused by morning sickness or chemotherapy become aversive to the affected individual.

III. Cultural factors play a large part in peoples' taste preferences. Different societies condition and program the behavior of their members in many ways, including taste preferences.

- **A.** The Masai have a fondness for the taste of cow's blood.
- **B.** Some cultures readily consume horsemeat, snakes, grasshoppers, rodents, bats, and other creatures. Other cultures find these tastes unacceptable and/or repulsive.
- **C.** In India, many people have a need for protein, yet several hundred million cattle roam the city streets because of the sacredness of such animals in Hinduism.
- **D.** In the United States, there is a cultural taboo against eating dog meat and horse meat.

IV. Familial genetics can also influence taste preferences.

- **A.** Phenylthiocarbamide (PTC), a synthetic substance, can be tasted by two-thirds of the population (called *tasters*) but not by the other third (called *nontasters*). Being a taster or nontaster runs in families, and tasters are highly sensitive to bitter.
- **B.** Some tasters find caffeine and saccharine unpleasantly bitter.
- **C.** Some taste researchers think that other taste sensitivities and preferences may also have a genetic component.

V. Some substances with unique tastes achieve popularity in some segments of the population because of their special properties. Three such tastes are chocolate, ginger, and puffer fish, or *fugu*.

- **A.** Many people (mostly women) experience cravings for chocolate.
  - **1.** Chocolate has been described as an "emotional" food, in that cravings increase during periods of sadness, relationship problems, or PMS.
  - **2.** Chocolate contains phenylthylamine (PEA), which is apparently produced when we are in love.
  - **3.** Some researchers believe that PEA mimics the good feelings of being in love.
- **B.** Some people develop an affinity for the taste of ginger through using it to clear the palate or for its presumed medicinal value.
  - **1.** Ginger in various forms has been used to manage seasickness, motion sickness, and stomach distress in general.
  - **2.** Ginger is used as a cough suppressant, a fever reducer, and as an enhancer of immune system functioning.
  - **3.** Ginger appears to have antioxidant properties.
- **C.** A third example of a food that is a culturally acquired taste is the Japanese puffer fish, or *fugu*.
  - **1.** Fugu is extraordinarily poisonous, containing a toxin hundreds of times more powerful than strychnine unless prepared by a licensed fugu chef.
  - **2.** In preparing the fish, a skilled fugu chef leaves just a trace of the poison to tingle the lips of the consumer. More than a trace, however, will kill the consumer.
  - **3.** Despite the fact that fugu is very expensive and can be poisonous, it continues to be popular in Japan.

Suggested Reading:

Ackerman, *A Natural History of the Senses*, pp. 125–172.

Colavita, *Sensory Changes in the Elderly*, chapter 6.

Questions to Consider:

1. Can you think of practical applications of the learned taste aversion phenomenon?

2. Why might the issue of seasoning the food at a family reunion be problematic?

Lecture Seventeen

Smell—The Unappreciated Sense

Scope: If people are asked which of their senses they would miss the least, many choose smell. As we will see, smell is actually more important for humans than most of us realize. If we became blind and deaf, most of us could learn to identify friends and family members by smell. We could also learn to identify people from different cultures by smell because our scent is, in part, determined by what we eat, and as we saw in Lecture Sixteen, different cultures have different dietary habits.

The stimuli for smell are airborne and gaseous. The receptors for smell are located in the olfactory crypt on the olfactory epithelium, a patch of tissue measuring 2.5 square centimeters. Because the olfactory epithelium is located out of the mainstream of inspired air, we must create eddy currents to carry molecules of odorous substances to the receptors by producing a sharp "sniff" to maximize smell sensitivity.

Smell can enhance our experience in a variety of situations. Incense is used in many formal religious ceremonies. Used-car dealers spray artificial "new-car scent" in their vehicles to make them more attractive to buyers. Realtors know that the odor of fresh oven-baked bread in the kitchen will make a prospective purchaser more likely to buy.

Neuroanatomically, the sense of smell is organized in a manner suggesting its participation in a variety of important areas in both humans and lower animals. Smell information goes directly from the receptors to the cerebral cortex, without first passing through subcortical relay stations, as does information from all the other sensory systems. Smell data are then sent to 20 different parts of the brain, including areas involved in memory, emotional reactivity, and motivation.

Outline

I. Smell (or *olfaction*), along with taste, represent the chemical senses in humans.

- **A.** Unlike the other senses, smell stimuli do not have unique names, as colors or tastes do, but are likened to other things (e.g., flowery, fruity) or other experiences (e.g., putrid, burnt). We can identify 10,000 different odors.
- **B.** We have 10 million smell receptors. They are located on a 2.5-square-centimeter patch of tissue called the *olfactory epithelium*, which is located out of the mainstream of inspired air. Smell sensitivity is enhanced by a sharp "sniff," thus creating eddy currents that bring odorous molecules into contact with the receptors.
- **C.** Smell stimuli are airborne and gaseous.
- **D.** Until fairly recently, research on the sense of smell has lagged behind research on the other senses. There are several reasons for this.
  1. Smell stimuli are hard to control—how do you turn a smell on or off?
  2. The receptors are relatively inaccessible.
  3. There is an inadequate technical vocabulary to describe smells.
  4. Historically, smell has been considered less important than the other senses.

II. Olfaction in humans is considerably more sensitive than we realize.

- **A.** We all have heard descriptions of the incredible smell sensitivity of dogs. There are also documented instances of incredible smell sensitivity in humans.
- **B.** An individual human smell receptor is as sensitive as an individual dog smell receptor. Dogs, however, have 1,000 times as many receptors as we do.
- **C.** If it becomes necessary, we can make far greater use of our sense of smell.
  1. Blind people become able to recognize family and friends by smell, not because they have a better sense of smell, but because they must depend more on this sense.

2. With practice, one can identify people from different cultures by smell because our diets influence our body odors and different cultures have different diets.
3. Human subjects can recognize their own worn T-shirts by smell.
4. Experiments suggest that women have a better sense of smell than men.

D. Smell may influence people without our conscious awareness.

1. A phenomenon known as the *McClintock effect,* named for Martha McClintock, the psychologist who discovered it, suggests that odor cues result in menstrual synchrony among female students living on the same dormitory floor.
2. Thus, McClintock is credited with being the first person to demonstrate the existence of a human *pheromone*.
3. Pheromones are odorous stimuli that can produce a physiological response in some other species member.

III. Cultural factors are a major determinant of the degree to which people make use of olfactory information.

A. Generally speaking, babies show a preference for pleasant and familiar odors at a very early age.

B. Our sense of smell peaks at age 8.

C. Many Western cultures mask olfactory stimuli with deodorants and room fresheners.

D. We teach our children not to use olfactory cues.

1. Children naturally use smell to investigate novel objects or foods.
2. Children are frequently told, "It's not polite to smell your food. Just eat it."

E. *Ayurvedic medicine* (the holistic health care system developed in India thousands of years ago and still in use) uses smell as an important part of examining patients and diagnosing diseases.

1. Around 250 years ago, Western physicians began to feel that using smell to help diagnose illness was unscientific and undignified.
2. Some medical conditions (such as phenylketonuria [PKU], diabetes, and kidney disorders) are associated with a particular odor that can help in diagnosis of the condition.

IV. Although Western cultures may downplay the primary importance of olfaction, smell stimuli are utilized nevertheless to enhance various significant experiences.

A. The aroma is an important component of a good meal.

B. Scented candles enhance romantic interludes.

C. Incense is used in many formal religious ceremonies.

D. Used-car dealers use aerosol "new-car scent" sprays to make their cars more attractive to customers.

E. Realtors claim that the odor of fresh baked bread in the kitchen is effective in turning lookers into buyers.

V. Neuroanatomical studies of the brain suggest that olfaction is far more critical for normal human functioning than previously realized.

A. Smell receptors have direct connections with the cerebral cortex without initially passing through various subcortical relay stations, as is found in all the other senses.

B. By means of the olfactory bulbs, which are the structures that receive input from smell receptors, odorous stimuli generate neural activity in 20 different parts of the brain.

1. The olfactory system projects to parts of the brain involved in memory.
2. Olfactory signals reach parts of the brain involved in emotional response.
3. Brain structures involved in motivated behavior also have connections to the olfactory system.

C. Examples exist wherein the sense of smell in animals overrides the strength of their other senses.

Suggested Reading:

Goldstein, *Sensation and Perception* (6th ed.), pp. 473–481.

Sekuler and Blake, *Perception* (4th ed.), pp. 542–572.

Questions to Consider:

1. It has been shown in the laboratory that people can tell the difference between around 10,000 different odors. Why do you suppose most people are surprised to learn this fact?
2. Data suggest that, in general, women are more sensitive to odors and are better at identifying odors than men. No physiological explanation for this sex difference has been identified as yet. Do you have any ideas or opinions about this difference?

Lecture Eighteen

Smell—Consequences of Anosmia

Scope: The sense of smell has neural connections with brain regions involved in motivation, emotion, and memory. Research with animals has revealed some of the significance of these connections. A relationship between sexual behavior and smell has been identified in animals ranging from insects to nonhuman primates. Chemical odorous sex attractants called *pheromones* are produced and released by females of many species to attract males during the breeding season. Evidence for the importance of pheromones in humans is scanty at best, but perfume manufacturers take advantage of the possibility in their advertising. Sexual behavior is abolished in rats and hamsters following removal of the olfactory bulbs. The control of sexual behavior of humans is far more complex than that of lower animals, but it appears that 25 percent of people who become anosmic lose their sex drive.

A relationship between smell and human memory has also been documented. Some individuals have powerful *olfactory imagery*, whereby a particular odor can recall in vivid detail some event from the past. In addition, recent evidence suggests that a decline in smell sensitivity correlates with the onset of memory impairment in people with Alzheimer's disease and other forms of senile dementia.

The aging process has been shown to diminish smell sensitivity. This diminishment has negative implications for the elderly in a number of areas, such as carelessness with personal hygiene due to a reduced ability to smell body odor; risk of inadequate nutrition due to loss of pleasure in eating; less joy in daily life because of decreased ability to smell flowers, fresh bread, and other pleasant odors; and greater risk of sickness or injury as a result of reduced sensitivity to the smell of smoke, gas, hazardous chemicals, or spoiled food.

Outline

I. In laboratory experiments, *anosmia* (loss of the ability to smell) has been shown to alter significantly the behavior of animals.

- **A.** Following removal of the olfactory bulbs, territorial animals neither mark their own territory nor respect the markings of other animals.
- **B.** Rats and hamsters made anosmic no longer engage in sexual behavior.
- **C.** The sexual behavior of many animal species, ranging from insects to nonhuman primates, is strongly influenced by pheromones, odorous chemical attractants.
  - **1.** There is no strong evidence that pheromones are a significant factor in human sexual behavior.
  - **2.** Perfume manufacturers would have you believe otherwise.
- **D.** Although the mechanism is not understood at this time, statistical evidence indicates that approximately 25 percent of humans who become anosmic as a result of injury or infection lose their sex drive.

II. Recent evidence points to a connection between smell and memory to the point of suggesting that declines in smell sensitivity sometimes correlate with declines in memory.

- **A.** Some individuals possess powerful olfactory imagery, such that encountering a particular smell will reinstate the clear memory of some event or experience that may have happened decades ago. This phenomenon is called the *Proust effect*, named for a similar incident described in *Swann's Way*, a work by French author Marcel Proust.
- **B.** There are now a number of reports indicating that declines in smell sensitivity occur at the same time that memory impairments begin to show up in people with some form of senile dementia, such as Alzheimer's disease.
  - **1.** Scientists acknowledge the possibility that tests of smell sensitivity may be able to predict the onset of memory impairment at an early stage of memory loss so that remediation techniques can be applied sooner.
  - **2.** To date, such smell tests have shown about an 80 percent accuracy rate, as good as any test currently available to predict memory loss.

C. Discoveries in the realm of neuroscience also suggest a relationship between smell and memory.
   1. For centuries, it has been believed that the adult human brain is incapable of producing new brain cells.
   2. Recently, it has been demonstrated that two regions of the adult human brain are, in fact, capable of producing new cells. These two parts of the brain are the olfactory bulbs and the hippocampus.
   3. The olfactory bulbs receive input from smell receptors.
   4. The hippocampus is a forebrain structure known to be critical for the consolidation of short-term memory into long-term memory.

III. There is a form of holistic therapy called *aromatherapy*, defined as the therapeutic use of the essential oils of plants to affect mood or health. Proponents of aromatherapy claim that certain odors can alleviate conditions ranging from personality disorders to digestive problems. Although most of the claims of aromatherapy remain untested, there is some laboratory evidence that motivation and emotion may be responsive to different odors.

A. Aromatherapy dates from the 1930s, when French chemist Rene-Maurice Gattefosse, who worked in a family perfume manufacturing company, discovered what he considered the curative properties of plant oils.

B. Not all scientists agree with the claims of the benefits of aromatherapy.

C. However, the odor of green apples has been shown to lower blood pressure and to promote relaxation.

D. The odor of lavender has been demonstrated to raise the basal metabolic rate, to facilitate concentration, and to increase alertness.

IV. Smell sensitivity has been shown to decline as a consequence of the aging process.

A. Olfactory sensitivity is quite variable among the elderly.
   1. After the age of 55, the sense of smell declines precipitously in men, whereas women retain their smell sensitivity for about 20 years longer.
   2. The decline in smell sensitivity varies considerably, however, and some individuals in their 70s and older perform as well as middle-aged subjects on tests of smell sensitivity.

B. In general, in the elderly, the olfactory epithelium gets thinner and individual receptors are lost.

C. At any age, some environmental experiences, including blows to the head, infections of the olfactory epithelium, exposure to x-rays, use of such drugs as steroids, and use of tobacco products can reduce smell sensitivity, although such harmful agents have a worse effect on older people.

D. Age-related olfactory deficiencies have potentially serious consequences.
   1. We lose the ability to smell our own body odor and risk causing people to avoid us.
   2. We lose much of the pleasure of eating and risk nutritional deficiencies.
   3. We lose the joy of smelling positive smells (such as babies, flowers, fresh bread, and so on).
   4. The reduced ability to smell smoke, gas leaks, spoiled food, and hazardous chemicals poses a safety risk.

Suggested Reading:

Ackerman, *A Natural History of the Senses*, pp. 3–64.

Colavita, *Sensory Changes in the Elderly*, chapter 5.

Questions to Consider:

1. Some people believe that pheromones have an effect in humans and some people doubt such an effect. Why do we know more about smell-related animal sexual behavior than we do about smell-related human sexual behavior?

2. Do you think that when aromatherapy appears to have positive consequences it is the result of the placebo effect or the therapeutic consequences of smell stimuli?

Lecture Nineteen

The Vestibular System—Body Orientation

Scope: The vestibular system responds to changes of the body's position in space. This system is made up of two components with two different functions. Both components are housed in the inner ear, which is why most medical problems involving the inner ear affect both auditory and vestibular functioning.

One component of the vestibular system is the *semicircular canals*. This system provides us with sensory information about the acceleration and deceleration of the body and about the direction in which the body is moving. The semicircular canals do not respond to constant rates of movement, only changes in the rate of movement.

The second component of the vestibular system is made up of two inner-ear structures known as the *utricle* and *saccule*. These structures tell us when we are not in an upright position with respect to the pull of gravity. The utricle and saccule cannot function in a gravity-free environment, nor do they provide information about body orientation when we are underwater. Seasickness, other forms of motion sickness, and the "bed spins" experienced by people who drink too much alcohol and lie down with their eyes open all involve the vestibular system.

The elderly generally dislike the vestibular stimulation from swings, roller coasters, and so on that young people are fond of. This preference change is due more to the loss of stomach muscle tone, fat accumulation, and changes in the ability of connective tissue to prevent greater motion of the internal organs than to vestibular sensitivity changes per se.

Outline

I. Several human sensory systems are concerned with the detection of movement.

- **A.** The auditory system responds to movement at a distance from the body.
- **B.** The cutaneous system responds to movement on the surface of the body.
- **C.** The vestibular system responds to movement of the whole body.

II. The two portions of the vestibular system are responsive to two different categories of movement. Both portions are housed in the inner ear, near the auditory receptors. (Figures 19a and 19b)

- **A.** The vestibular structures that respond to velocity changes are the *semicircular canals*.
  - **1.** There are three semicircular canals in each inner ear: the superior, the posterior, and the lateral.
  - **2.** Each canal is in a different orientation, making it more responsive to movement in a particular direction.
    - **a.** The superior canal goes from front to back.
    - **b.** The posterior canal goes from left to right.
    - **c.** The lateral canal goes from side to side.
  - **3.** At the base of each semicircular canal is a distinctive swollen region called the *ampulla*.
  - **4.** Each of these canals is attached to a reservoir and is filled with an incompressible fluid, *endolymph*.
  - **5.** Inside the ampulla is a gelatinous structure called the *cupula*, which can block the canal so that fluid cannot move through it.
  - **6.** The vestibular hair cells embedded in the cupula are bent by movement of the endolymph in the canal caused by body motion.
  - **7.** Because the hair cells and cupula are "spring loaded," the semicircular canals are sensitive to changes in velocity, not steady-state motion.
  - **8.** Research has shown that animals of all kinds, with the exception of frogs, have semicircular canals that signal movement in two opposite directions.
- **B.** The *utricle* and *saccule* are the portions of the vestibular system that respond to changes in bodily orientation with respect to the pull of gravity or the upright. They are sometimes labeled the *gravitational receptors*.
  - **1.** Hair cells in the base of the utricle and saccule have their tips imbedded in a flexible membrane.

2. The surface of the membrane is covered with tiny calcium carbonate particles called *otoliths*.
3. When we lean, gravity shifts the otoliths and bends the hair cells.
4. With our eyes closed, deviation from the upright cannot be detected in a zero-gravity environment.

III. Gravity is not the "curse of the elderly," as it is occasionally called.

A. The force of gravity is necessary for maintenance of normal muscle tone.

B. Astronauts are severely weakened by an extended stay in a gravity-free environment. On occasion, they are too weak to exit the space capsule without help.

IV. As we saw in Lecture Seven, there are several commonalities between the auditory system and the vestibular system.

A. The auditory and vestibular systems share the same cranial nerve.

B. Both sensory systems are located in the inner ear.

C. Both require physical stimulation of hair cells for transduction to occur.

D. Both the auditory and the vestibular system require the presence of endolymph.

E. Anything harmful to one of these two systems, such as ototoxic drugs, is usually harmful to the other.

V. Certain categories of vestibular stimulation are responsible for motion sickness, with its resultant feelings of headache, chills, nausea, and muscular weakness.

A. Motion sickness (including seasickness) is far more likely to occur from passive movements, rather than active movements.

1. Vertical movements produce a greater effect than lateral movements. Movement in several planes simultaneously produces the worst effect.
2. Slow, oscillating movements are more potent for sickness than short, rapid movements.
3. Animals show motion sickness as well.

B. "Bed spins," which can be experienced by lying on one's back with open eyes after a bout of heavy drinking, is also a vestibular phenomenon.

1. Alcohol is infused into the endolymph of the semicircular canals, changing its specific gravity.
2. The equilibrium of the system is disrupted, resulting in the hair cells bending over.
3. The discontinuity between the messages sent to the brain from the bent hair cells that movement is occurring and the messages from the eyes that no movement is occurring results in the experience of the room spinning.
4. The sensation of spinning in the opposite direction occurs as the alcohol leaves the endolymph, although the affected individual is usually asleep for this part of the experience.

VI. It is widely known that our preferences for sources of vestibular stimulation, such as riding on roller coasters or swinging on playground swings, changes as we age. There are several reasons for this.

A. There are degenerative changes in the vestibular portion of the eighth cranial nerve, just as there are in the auditory portion.

B. Vestibular receptors are lost as a function of age

C. Calcium deficiencies, which are more frequent in the elderly, change the properties of the otoliths in the utricle and saccule.

D. Loss of tone in stomach muscles, the accumulation of abdominal fat, and the reduced ability of connective tissue to hold the internal organs firmly in place add to the aversiveness of certain types of vestibular stimulation among older people.

Suggested Reading:

Carlson, *Physiology of Behavior* (8th ed.), pp. 219–222.

Colavita, *Sensory Changes in the Elderly*.

Questions to Consider:

1. There are documented instances of scuba divers in murky water becoming disoriented and swimming down when they mean to swim up. How is such a "malfunction" of the vestibular system possible?
2. Would it be possible to perform the tasks of daily life if an individual were to lose all functioning of the vestibular system? What adjustments would have to be made?

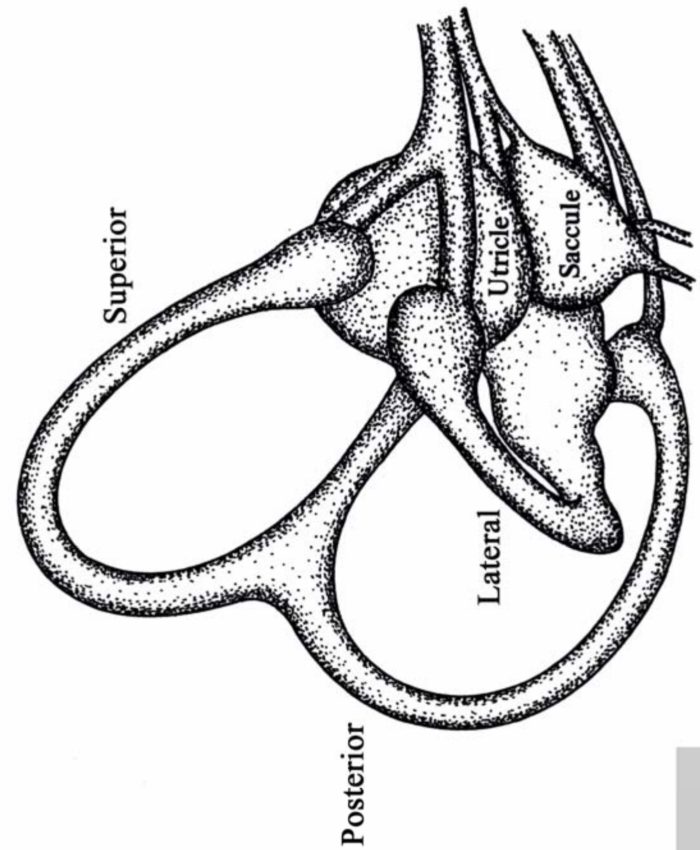

Figure 19a
The Vestibular Structures

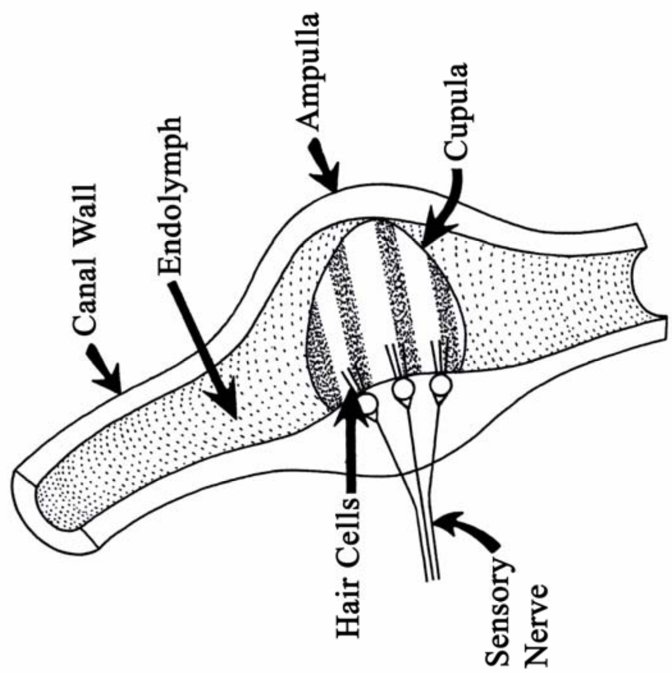

Figure 19b
The Ampulla

Lecture Twenty

The Kinesthetic Sense—Motor Memory

Scope: The kinesthetic sense is sometimes called the "muscle memory" sense, but it is far more than this. The kinesthetic sense sends to the brain continuous sensory feedback from receptors located not only in the muscles but also in the tendons, ligaments, and joints. This sense is crucial for the ability to perform daily activities, such as sitting, standing, walking, and climbing stairs, where coordination of antagonistic muscle groups is necessary and cooperation between body parts is required to maintain fluidity of motion. The kinesthetic sense also provides the information needed for Olympic-caliber gymnasts and divers to perform their amazing physical feats.

It is not possible to master a complex motor activity simply by reading a book. We must practice the requisite motor movements over and over until the brain learns from kinesthetic feedback what it feels like when we finally do it right. Even then, hundreds or even thousands of additional repetitions are required until the phenomenon of *automaticity* is established in the frontal lobes. When automaticity is established, we can use the cognitive and volitional capabilities of the brain for strategic planning, rather than for moment-to-moment monitoring and orchestration of individual limb movements. The establishment of automaticity represents a neurological distinction between a novice and an expert in such activities as tennis or golf, where both motor skill and strategy are essential.

Laboratory studies indicate that precision of input from the kinesthetic system reaches its peak in the middle to late teens and begins to show almost imperceptible declines by the late 20s. There are no top Olympic gymnasts and divers in their 30s. By the time we are in our 50s and beyond, we must substitute experience and strategy for youth in such activities as tennis and golf. We can no longer have complete confidence in the accuracy of kinesthetic feedback. This change translates into, among other things, shortening one's backswing in golf.

Outline

I. The kinesthetic system provides the brain with information about the position and movement of the limbs in space.

- **A.** The kinesthetic sense is sometimes called the "muscle feedback" sense, although it has other important functions.
- **B.** In addition to monitoring activity in the muscles, the kinesthetic system measures tension and force in the ligaments and tendons and the direction, speed, and angularity of movements involving the joints.

II. The kinesthetic sense depends upon receptors located in muscles, tendons, ligaments, and in the joint capsules.

- **A.** Receptors in the muscles, called *muscle spindles*, respond to the degree of contraction in a given muscle. Data from the muscle spindles permit cooperation between antagonistic muscle groups to permit fluidity of movement.
- **B.** Receptors known as *Golgi tendon organs* are located in the tendons.
  - **1.** Golgi organs monitor the moment-to-moment force exerted by muscles on tendons (tendons attach muscles to bones).
  - **2.** If a tendon experiences an unfamiliar or unusually heavy load, the Golgi tendon organs trigger a "clasp-knife" protective reflex that causes the muscle to collapse to prevent injury.
  - **3.** Part of athletic training is to teach the Golgi organs to accept higher and higher muscle loadings without firing the protective reflex.
  - **4.** Another goal of athletic training is to teach the Golgi tendon organs to accept the higher muscle loadings that accompany the "follow-through" motion.
- **C.** Ligaments attach bone to bone at the joints.
  - **1.** There are stretch receptors in the ligaments and joints that respond to changes in the angles at which a joint is bent.
  - **2.** These same receptors are sensitive to the velocity of movement and the degree of limb rotation.

III. Kinesthetic feedback to the brain permits us to improve the efficiency and effectiveness of motor activities through practice.

- **A.** It is not sufficient to read a book on how to perform skilled motor activities, such as playing golf or tennis.
- **B.** We must perform a skilled motor activity over and over again so that the brain develops an awareness of what the kinesthetic feedback feels like when we "do it right."
- **C.** The precision and sophistication of kinesthetic feedback required to perform different physical activities shows enormous variation.
    - **1.** Most of us have sufficient kinesthetic sensitivity to learn to operate a standard-shift transmission.
    - **2.** Very few of us have sufficient kinesthetic sensitivity to be an Olympic-caliber gymnast or diver.

IV. The human brain is also capable of a function called *automaticity*.

- **A.** Initially, a coordinated sequence of motor responses requires that each component of the sequence be planned and thought about separately.
- **B.** After sufficient repetitions, the kinesthetic feedback associated with the whole motor sequence has become familiar enough that the motor cortex can produce the motor sequence without the need for continuous monitoring by the cognitive portions of the brain.
- **C.** This function, automaticity, leaves our cognitive capacities free for strategic planning and represents a major difference between novices and experts in various sports, including gymnastics, diving, tennis, and golf.
    - **1.** Novice athletes work at the nuts and bolts of the sport.
    - **2.** Expert athletes work on the strategy of the sport because they have established automaticity.
    - **3.** Automaticity is a robust cognitive phenomenon. Once you have thoroughly memorized a poem or learned an activity, such as riding a bicycle or driving a standard-shift car, you do not forget or lose the ability to perform the activity.

V. The aging process plays a major role in kinesthetic sensitivity.

- **A.** Evidence suggests that maximum sensitivity of kinesthetic feedback is achieved in humans at around the age of 12, the age at which the myelin sheath is fully developed.
- **B.** Laboratory studies show that people in their mid to late 20s display very small decrements in the accuracy of kinesthetic feedback.
- **C.** By the 40s, amateur golfers and tennis players notice a difference in their games.
- **D.** Older athletes can still achieve success in their sports, but adjustments must be made.
    - **1.** Older athletes in such sports as golf and tennis must substitute accuracy and control for speed and power (e.g., shorten the backswing).
    - **2.** Older athletes must use more experience and strategy in place of pure athleticism.
    - **3.** Older athletes find satisfaction in competing in sporting events that have age categories.
    - **4.** In normal aging, the kinesthetic changes that we undergo pose little or no major impediment to everyday life in people up to and through their 80s.

Suggested Reading:

Colavita, *Sensory Changes in the Elderly*, chapter 9.

Jerome, *The Elements of Effort*, pp. 38–41.

Questions to Consider:

1. Kinesthetic feedback is responsible for the success of virtually every move we make, yet most people have never heard of the kinesthetic system. What does this say about human curiosity?

2. Can you think of examples of automaticity at work in your everyday life?

Lecture Twenty-One
Brain Mechanisms and Perception

Scope: The human brain represents the result of millions of years of evolutionary changes, but the older parts of the brain do not disappear when new parts develop. The newer parts simply grow over the older parts, which still retain their original functions. The newest part of the human brain, the cerebral cortex, regulates the higher mental processes, including perception.

The human brain exhibits bilateral anatomical symmetry up through the forebrain. The cerebral cortex, however, is slightly asymmetrical. Parts of the left hemisphere are larger in most people. The anatomical asymmetry in the cerebral cortex corresponds to a functional asymmetry that extends to the phenomenon of perception. Research suggests that the perception of language is the province of the left cerebral hemisphere.

Perceptual dysfunction is caused by focal loss of brain cells—loss of brain cells in a certain part of the brain. Therefore, the diffuse loss of cortical neurons inevitably brought about with age is not typically an issue in perceptual dysfunction. Similarly, studies have shown that memory storage is spread throughout the brain, thus making memory less vulnerable to diffuse brain damage.

Outline

I. The human brain represents the highest level of organizational complexity yet achieved on Earth. This complex organ has evolved over millions of years, and some parts of the human brain are far older than other parts.

- **A.** The oldest part of the human brain is the hindbrain, which controls the vital functions, such as blood pressure, respiration, and heart rate.
- **B.** The midbrain represents an intermediate level of brain development.
  - **1.** The midbrain also determines our levels of sleep, wakefulness, and arousal.
  - **2.** The midbrain is responsible for reflex orientation to sensory stimuli.
- **C.** The forebrain has three broad categories of important functions.
  - **1.** The forebrain regulates the physiological drives, such as hunger, thirst, sex, and temperature regulation.
  - **2.** The forebrain is involved in emotional reactivity.
  - **3.** The forebrain controls the automatic aspects of our motor behavior, such as balance, postural adjustment, and initiation and fluidity of movement.
- **D.** The cerebral cortex is the newest part of the human brain. It controls the higher mental processes and gives us important inhibitory capabilities.
  - **1.** The higher mental processes include thinking, willing, problem solving, concept formation, and perception.
  - **2.** The inhibitory capabilities of the cerebral cortex give us the option of dealing with life on a level more civilized than "fight or flight."

II. The cerebral cortex is divided into the frontal, parietal, occipital, and temporal lobes, each lobe being represented in both the left- and right-brain hemispheres. (Figure 21a)

- **A.** The frontal lobes are concerned with motor functions, broadly defined.
  - **1.** The planning of motor sequences is a frontal lobe function.
  - **2.** Interpreting a map or a blueprint involves the frontal lobes, because this is preparation for motor activity.
  - **3.** The frontal lobes also enable us to inhibit motor activity if the timing is not advantageous.
  - **4.** The problems with impulsivity seen in AD/HD are thought by many researchers to be the result of underfunctioning of frontal lobe inhibitory circuits.
- **B.** The anterior portions of the parietal lobes receive sensory messages from the cutaneous receptors in the skin. The posterior portions of the parietal lobes are actually visual association areas, meaning that these brain regions are important for certain categories of visual perception.

C. The occipital lobes are the primary visual cortical areas, the first areas to receive sensory messages from the visual receptors. From the occipital lobes, sensory data from the visual receptors are transmitted to the visual association areas for further analysis.

D. The upper (dorsal) portion of the temporal lobe is the primary receiving area for hearing (including speech). The lower (ventral) portion of the temporal lobe is another visual association area.

E. The four lobes of the brain have neural connections with each other and with subcortical brain regions. The complex interconnectedness of brain regions has important implications for perception.

1. The same perception can be evoked by different sensory inputs (for example, the concept of your significant other can be evoked by a picture, a smell, a tone of voice, and so on).

2. Memory can be used to imagine a sight, sound, or smell that evokes a perception.

III. In general, neurologists and neuropsychologists anticipate some type of motor dysfunction following significant frontal lobe damage and some type of sensory or perceptual dysfunction following significant damage to the parietal, occipital, or temporal lobes.

IV. The left and right hemispheres of the human brain appear to be bilaterally symmetrical.

A. True anatomical symmetry in the human brain occurs only at the levels of the hindbrain, midbrain, and forebrain.

B. There are measurable left brain-right brain asymmetries in most humans at the level of the cerebral cortex. These asymmetries have behavioral significance.

1. A neurologist named Juhn Wada discovered two areas where the left hemisphere is consistently bigger than the right.

a. The first area is along the sylvian sulcus or fissure, in the area where we perceive speech.

b. The second area consists of the pyramidal tracks, which are the nerve fiber bundles that carry information from the primary motor cortex out to the peripheral muscles.

2. Most people are right-handed (the left brain controls the right side of the body).

3. Most babies are born with asymmetries favoring the left cerebral hemisphere.

4. Because of plasticity, if a person suffers brain damage to the left hemisphere at a young age, he or she will switch to being right-hemisphere dominant and vice versa.

C. Speech appears to be a left-hemisphere phenomenon in all normal (non-brain-damaged) right-handed individuals and in 70 percent of normal left-handed individuals.

V. Significant brain cell loss in the cerebral cortex can have consequences for perceptual abilities.

A. Some diffuse loss of cortical neurons with age is inevitable.

1. However, such diffuse loss is not typically an issue in perceptual dysfunction.

2. Perceptual dysfunction is caused by focal loss of brain cells, that is, loss of brain cells in a certain part of the brain.

B. All categories of senile dementia involve significant cortical brain cell loss, and all categories of senile dementia result in both cognitive and perceptual impairments, including loss of memory.

C. Karl Lashley, an early physiological psychologist, studied the different parts of the brain as related to memory and concluded that memory storage is spread throughout the brain, thus making memory less vulnerable to diffuse brain damage.

Suggested Reading:

Carlson, *Physiology of Behavior* (8th ed.), pp. 84–85.
Gazzaniga, *The Bisected Brain.*

Questions to Consider:

1. Would it surprise you to learn that there is no strong evidence for hemispheric asymmetry in any animal below the level of humans? If so, why? If not, why not?

2. Children born with a tendency to be left-handed can be trained to become right-hand dominant. Some parents believe that such training will help a child experience less inconvenience in our “right-handed” society. Explain why you agree or disagree with this reasoning.

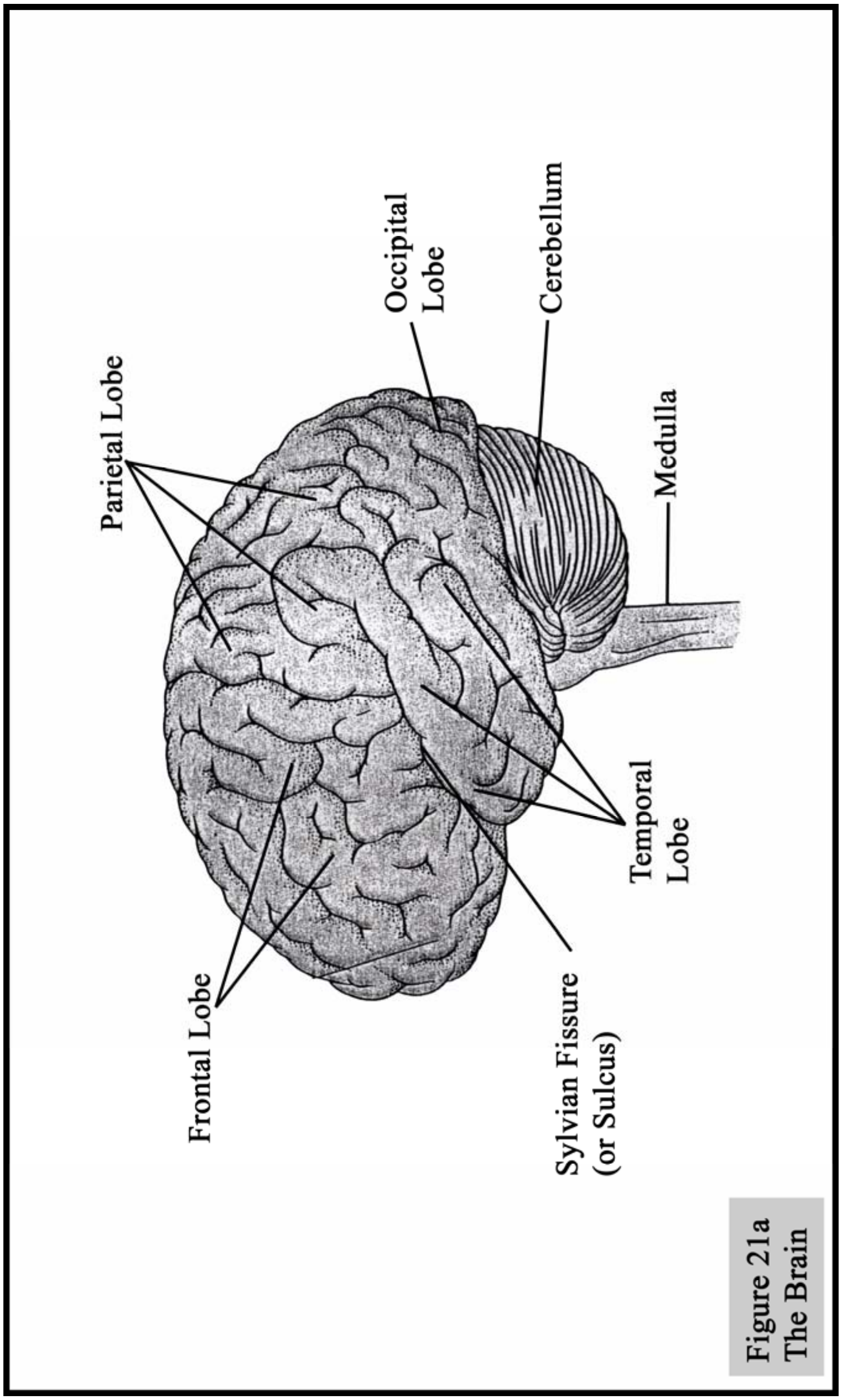

Figure 21a
The Brain

Lecture Twenty-Two
Perception of Language

Scope: Language is made up of verbal auditory stimuli that have become charged with meaning. The perception of speech is clearly an important perceptual capacity for humans. Language is so critical that it has two areas of the brain dedicated to it, one for speech production and one for speech comprehension. The cortical region critical for speech comprehension (*Wernicke's area*) is located in the left temporal lobe in the region known as the *auditory cortex*.

Words are made up of *phonemes*, the smallest distinguishable vocal utterances. Different languages can have different phonemes. The phonemes that a baby hears in the language of his or her caregivers during the first few months of life lead to the establishment of dedicated connections between auditory receptors and neurons in the auditory cortex. A phonemic "perceptual map" is formed, with each phoneme having a specific site in the auditory cortex.

In later life, the ease of acquisition of a second language will depend upon the degree of phonemic overlap between the first and second languages. Most individuals who begin to learn a second language after age 12 are unlikely to speak it like a native.

The aging process has some implications for speech perception. The phenomenon of presbycusis interferes with processing of the high-frequency components of speech sounds, while decreases in auditory nerve conduction speed result in intelligibility problems with rapid speech.

Outline

I. In the 1950s, it was generally believed that human sensory, motor, and cognitive capabilities were controlled by specific centers in the brain. A decade later, we saw that the brain is not divided into centers but that most human activities involve the intercommunication and cooperation of different motivational systems of the brain.

II. There are two exceptions to the finding that the human brain is not divided into task-specific centers.

- **A.** One involves language perception.
- **B.** The other involves human face perception.

III. There are actually two speech centers in the human brain, one center for the production of speech and one for the understanding of speech. (Figure 22a)

- **A.** The center for the expression or production of speech is known as *Broca's area*. It is located (in most people) in the posterior portion of the left frontal lobe.
- **B.** The center for the understanding or reception of speech is known as *Wernicke's area*. Wernicke's area is located along the upper boundary of the left temporal lobe (along the left sylvian fissure).
- **C.** Damage to either speech area produces a neurological condition known as *aphasia*.
  1. Damage to Broca's area produces *expressive aphasia*, in which the individual can understand speech but cannot express it.
  2. Damage to Wernicke's area produces *receptive aphasia*, in which the individual can express speech sounds but cannot understand speech.
  3. If brain damage involves both Broca's area and Wernicke's area, the affected individual can neither generate nor understand speech sounds. Such a condition is referred to as *global aphasia*.
- **D.** The conceptualization system in the brain appears to be separate from the spoken language system, in that people with global aphasia have been taught to communicate using sign language.

IV. Words are made up of *phonemes*, the smallest distinguishable utterances of speech.

- **A.** Different languages are made up of different phonemes and different numbers of phonemes. English contains 43 phonemes, while Hawaiian has only 15.
- **B.** Neonatal infants can produce any phoneme from any language in the course of their random babbling.

1. Over the first few months or so of life, babies hear only phonemes from the language spoken by their caregivers, and babies are rewarded for uttering noises that sound like the language of the caregiver.
2. During this time period, dedicated connections begin to form between auditory receptors in the inner ear and specific sites in the auditory cortex, creating a phonemic perceptual map. Each phoneme in the baby's native language is represented at a specific site in the auditory cortex.

V. Although it can be modified relatively easily for the next decade, the phonemic perceptual map is well established by six months and completed by the first year of life.

A. A child's babbling now includes only phonemes found in his or her language.

B. A child can easily learn two (or even three) languages simultaneously, because multiple perceptual maps can be formed simultaneously and do not interfere with one another.

C. Learning a second language after the first language has been mastered is more difficult.

1. The completed perceptual map of the first language makes formation of the second more problematic.
2. After the age of 12, an individual is unlikely to acquire a second language and speak it like a native.
3. The degree of difficulty depends upon the overlap of phonemes from the two languages.

D. After a phonemic perceptual map is formed, we become functionally deaf to sounds not found in our native language.

VI. After the age of 1, children whose caregivers speak to them a lot construct words from phonemes faster than the children of more taciturn caregivers.

VII. Advanced age contributes to some declines in speech comprehension and intelligibility.

A. Presbycusis results in the high-frequency components of speech sounds being missed by an older listener.

B. We also develop a general decrease in auditory sensitivity due to the thickening of the eardrum and atrophy in the stria vascularis.

C. Age-related degenerative changes in the auditory nerve result in slower conduction speed, causing problems in the comprehension of rapid speech.

D. The overall decline in hearing sensitivity with age creates problems with speech intelligibility and speech comprehension that are especially troublesome when listening to a soft-spoken person in a noisy environment.

Suggested Reading:

Sekuler and Blake, *Perception* (4th ed.), pp. 484–495.

Questions to Consider:

1. A 16-year-old girl came to the United States 80 years ago, speaking only Polish and a little German. She quickly learned English, became a U.S. citizen, and ran several small businesses. When she died at the age of 93, she still had a heavy Polish accent. Why was she unable to lose her foreign accent after almost 80 years of speaking English?
2. Are you aware of any data suggesting that any animal below the level of a human can acquire and use language (not simply as auditory signals but as symbolic stimuli)?

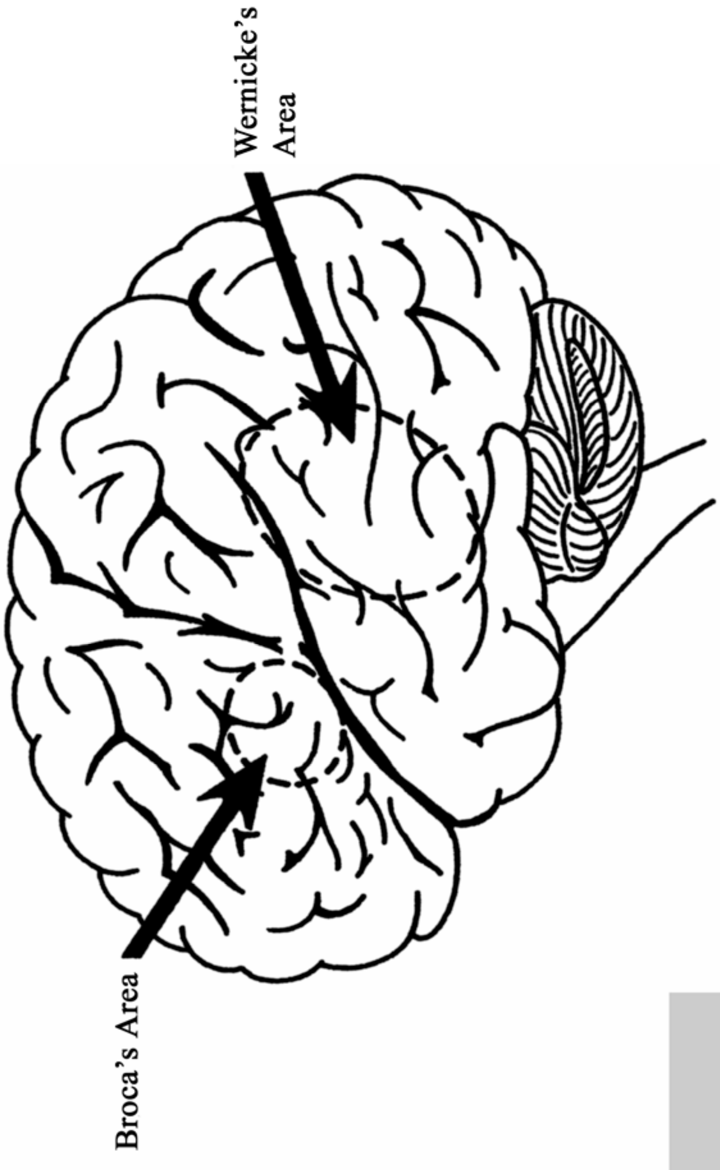

Figure 22a
The Centers for Speech

Lecture Twenty-Three
The Visual Agnosias

Scope: Our capacities to identify an object by its form, apprehend its color(s), determine its location in space, and estimate its rate of motion all seem to occur automatically as the result of a single act of perception. Actually, this is not the case. Each of these component parts—form, identity, color, location in space, and motion—is analyzed in a different visual association area and integrated with memories of our past experiences with the object in question to create an overall perception.

The contribution of different regions of the visual association cortex to overall visual perception is suggested from instances in the human clinical literature when focal brain damage alters or abolishes one component of a perception, such as color or identity, but leaves the remaining components intact. This literature deals with the *visual agnosias*. *Agnosia* means "failure to know." It does not refer to blindness but to an inability to apprehend a particular aspect of a visual perceptual experience. One category of visual agnosia, *prosopagnosia*, refers to a deficit in the ability to recognize human faces. People with this condition are not only unable to recognize the faces of family and friends but cannot even recognize their own faces in a mirror.

Because visual agnosias result from focal rather than diffuse brain damage, they are not an accompaniment of the diffuse brain cell loss associated with aging.

Outline

I. Our perception of events in the visual field is so automatic and natural that we fail to appreciate the complexity of what we are doing.

- **A.** A visual perception typically includes an awareness of the color, shape, identity, location in space, and direction and velocity of motion of some object or objects.
- **B.** Each of the components of the overall perception is analyzed in a different region of the brain; these regions are known as *visual association areas*, all part of the *visual association cortex*.
- **C.** Damage to a particular visual association area can eliminate a single element of a visual perception, leaving the other elements of the perception intact.

II. Focal (as opposed to diffuse) damage to a visual association area does not result in blindness but in a condition known as *visual agnosia*.

III. *Agnosia* means "a failure to know" something. There are six general categories of visual agnosia, each associated with damage to a different visual association area.

IV. Color agnosia (*achromatopsia*) has been seen in patients following damage to the medial (middle portion of the) occipital lobe.

- **A.** Patients with such damage experience no loss of visual acuity, but they see only in black and white. This is not traditional colorblindness, in that, when studied scientifically, the cones are still intact and functioning normally.
- **B.** Achromatopsia results in problems with daily activities, such as coordinating one's wardrobe or obeying traffic lights.

V. There are two categories of visual shape agnosia, both of which involve the inferior (bottom half of the) temporal cortex.

- **A.** In *apperceptive visual agnosia*, the patient can point to an object's location, identify its color, and determine whether or not the object is moving but cannot determine the object's shape. The patient can determine the object's shape if permitted to hold or touch the object. Likewise, the patient can identify people through smell or through voice recognition. Such individuals are functionally blind and cannot perform such everyday activities as driving.

B. In *associative visual agnosia*, the patient can perceive the object's shape, as evidenced by being able to draw the object, but cannot identify the object or tell what it is used for.

1. In associative visual agnosia, there seems to be a disconnect between the inferior temporal cortex and the language system used for naming objects.
2. If the object cannot be named, its use is not easily retrieved from memory.

VI. *Spatial location agnosia* has been seen in patients with damage in the posterior parietal lobe. Affected individuals can be shown a visual display with an object in it. The patient can name the object and describe its function but cannot say where it is located in the visual field.

VII. In the condition called *motion agnosia*, the affected individual cannot perceive motion. The experience is somewhat akin to time-lapse photography, in which objects are not seen to be moving but abruptly disappear from one location and instantly reappear at another location. This condition is associated with brain damage at the boundary of the lateral occipital cortex and the posterior temporal cortex.

A. One patient with such damage had great difficulty crossing streets because cars seemed far away, but as she started across the street, they were suddenly upon her. She learned to use sounds cues to cross safely.

B. Pouring coffee or tea into a cup was also problematic for this patient because initially, there was little liquid in the cup, and in what seemed like the next instant, the cup was overflowing. Again, she grew to depend on sound cues for help.

C. Following the speech of others was made more difficult for the patient by the fact that their mouth movements were not in sync with their words. She found it best not to look at peoples' lips as she spoke to them.

D. Being in a room with a group of people was quite disturbing, in that the people were perceived as disappearing from one spot and reappearing elsewhere whenever they moved. This patient tried to avoid such situations.

VIII. *Prosopagnosia* is a form of visual agnosia characterized by an inability to recognize human faces.

A. Our ability to recognize human faces is so important to us that a portion of our brain is dedicated to it. The critical brain region appears to be the ventral portion of the right temporal lobe.

B. Patients may see eyes, ears, a nose, and a mouth but may not be able to recognize an individual face.

C. Affected individuals may be unable to recognize their own faces in a mirror.

IX. Normal age-related diffuse brain cell death does not produce the visual agnosias; instead, they are the product of focal damage to a specific cortical location.

Suggested Reading:

Carlson, *Physiology of Behavior* (8th ed.), pp. 190–201.

Sekuler and Blake, *Perception* (4th ed.), pp. 233–243.

Questions to Consider:

1. How can laboratory experiments using animal subjects help us to understand the visual agnosias?
2. What (if anything) can we infer about the way the brain creates our perceptions from clinical cases of visual agnosia?

Lecture Twenty-Four
Perception of Other People/Course Summary

Scope: In our final lecture, we will first cover some of the dynamics at work in our perception of other people. We will then summarize the overall course content, with mention of some directions in which the field of sensation and perception seems to be going.

Our perception of other people is an active process in which we begin making assumptions about such variables as motives, personality, and intelligence shortly after meeting someone. We will discuss some common perceptual errors that we all have made in our personality assessment of others. The literature also indicates that our perception of other people and their behavior is strongly influenced by their physical attractiveness and by the cultural conditioning we were exposed to during our formative years.

In the remainder of our final lecture, we will revisit the threefold instructional goals for the course: to provide an overview of sensory physiology, to describe the role of the brain in creating perceptions, and to demonstrate how the aging process can affect both sensations and perceptions. The lecture concludes with a survey of current research projects, such as smell and memory, smell and mate selection in humans, aromatherapy, sensory prosthesis, and brain-imaging techniques used to understand perceptual phenomena.

Outline

I. We have two goals in our final lecture.

- **A.** The first goal is to describe some of the dynamics at work in our perception of other people.
- **B.** The second goal is to provide an overall course summary, along with some examples of current research directions in the field.

II. People perception is an active process.

- **A.** We make inferences about people, their motives, their personalities, their goals, and their intentions.
- **B.** These inferences can lead to the creation of self-fulfilling prophesies in our dealings with other people.
- **C.** These inferences can come from previous information or knowledge we have about people.
- **D.** These inferences also come from the first impressions we acquire when we meet someone.

III. First impressions are of great importance in our perception of other people.

- **A.** They can actually distort later perceptions of another person, because we become committed to our first impressions.
- **B.** First impressions once formed can be very difficult to overcome.
    - **1.** We need to avoid being "wedded" to our own first impressions.
    - **2.** If you find that you are the one about whom someone is going to make a first impression, whether during a first date, an initial job interview, or any such situation, you need to make an effort to make a positive first impression.

IV. Three errors in the perception of other people are so common that they have their own names. These are the *halo effect*, the *logical error*, and the *central tendency error*.

- **A.** The halo effect refers to our tendency to form an overall positive impression of someone based upon knowledge of a single positive trait.
- **B.** The logical error is the belief that certain traits go together. For instance, knowing someone is polite might predispose us to believe that he or she is also friendly, honest, and intelligent. Con men use this error to their advantage.
- **C.** The central tendency error causes us to ignore variability and to see people as more consistent than they really are.

V. Although we would prefer to deny it, evidence indicates that our overall perception of someone is influenced by his or her physical attractiveness.

A. Children react to one another on the basis of physical attractiveness as early as kindergarten.

B. Elementary school teachers evaluate the same disruptive behavior differently in physically attractive and physically unattractive children.

  1. The unattractive child is likely to perceived as a "problem child."

  2. The same behavior in an attractive child is more likely to be perceived as an aberration that is uncharacteristic of the child.

C. Physically attractive MBAs have higher salaries than their less attractive counterparts.

VI. Cultural factors also influence our perception of other people. Societies indoctrinate their members from an early age with beliefs, attitudes, preferences, and behaviors. This indoctrination influences the perception of people from other cultures.

A. People who make direct eye contact are perceived as honest, open, direct, and forthright in the United States. Such people are perceived as intrusive, aggressive, and rude in Japan.

B. Different cultures require different amounts of "personal space," that is, the usual and comfortable distance between strangers or casual acquaintances in a conversation.

  1. In the United States, such personal space is about three feet.

  2. In Sweden, the appropriate personal space distance is four feet.

  3. In Arab countries, the usual personal space is less than an arm's length.

  4. This difference affects the perception of people with other culturally determined personal space needs.

C. In "high-context" cultures, such as those of the Mediterranean and Middle Eastern regions, body language and nonverbal cues are critical for the accurate interpretation of verbal messages. In "low-context" cultures, such as those of the United States and Britain, the interpretation of spoken words is less dependent on nonverbal cues. Serious misperceptions of meaning can occur as a result of this cultural variable.

VII. The remainder of this lecture will be used to restate the instructional goals for the course and to note some current trends in sensation and perception research.

VIII. The initial instructional goals of the course were threefold.

A. The first goal was to provide an overview of sensory physiology sufficient to show how our sensory receptors serve as the interface between the physical world and the brain.

  1. Sensory receptors are specialized cells that change electromagnetic, mechanical, chemical, or thermal energy into a form to which the brain is responsive.

  2. Thus, our receptors define our sensory world.

B. The second goal of the course was to describe how perceptions are created in the brain by integrating basic sense data with our past experiences. Past experiences stored in the brain give meaning to our present sensory experiences.

C. The third goal was to point to examples of how the aging process can alter both our sensory world and our perceptual world. The aging process influences our perceptual world through changes in personality, life experiences, expectations, wisdom, brain functioning, and the nervous systems.

IX. Current research in the field of sensation and perception suggests that the emphasis has shifted from pure research to applied research. That is, the field is now more concerned with practical, useful applications of knowledge than in the past.

A. Current research on the sense of smell is a good example of this point.

  1. Investigations into the relationship between the sense of smell and human memory are ongoing.

  2. The relatively new field of evolutionary psychology reports evidence that odor may be involved in human interaction, attraction, and mate selection.

  3. Aromatherapy, long ignored by the scientific community as lacking in scientific merit, is now the subject of scholarly research.

B. Greater understanding of how our sensory systems operate is leading to improvements in the field of sensory prosthesis, including such devices as cochlear implants and retinal chips.

- **C.** Real-time, high-tech, brain-imaging techniques provide insights into how different parts of the brain cooperate and coordinate in the creation of perceptions.
- **D.** The study of cultural differences in perception takes on considerable practical significance in light of the move toward a global economy.

Suggested Reading:

Lippa, *Introduction to Social Psychology* (2nd ed.), chapter 4.

Questions to Consider:

1. Do you think the halo effect is a universal human trait, or is it more likely to be a cultural phenomenon?
2. Can you devise a standard formula for making a good first impression that would apply to all cultures?

Glossary

A-delta fibers: Rapidly conducting nerve fibers that carry information from encapsulated end organs in the skin to the central nervous system.

Accommodation: The ability of the lens of the eye to alter its focal properties by changing its shape.

Active touch: Exploration and identification of objects in the environment through actively touching them.

Air conductive hearing: Auditory experiences resulting from sound waves transmitted from the eardrum through the ossicles to the cochlea.

Alzheimer's disease: A form of senile dementia resulting in widespread neural degeneration in the brain, an early sign being memory loss.

Anosmia: Inability to perceive odors.

Aphasia: A disorder of the associative aspects of language.

Arcus senilis: An opaque ring just inside the border between the cornea and the sclerotic coat, usually apparent by the mid- to late 60s.

Automaticity: The process by which repetition and practice permits an individual to perform a coordinated sequence of motor movements without conscious thought.

Axon: The elongated portion of a neuron that transmits the action potential from the cell body to the terminal end branches.

Ayurvedic medicine: The holistic system of health care that was in use in India 10,000 years ago and is still in use today.

Basilar membrane: The flexible membrane located in the cochlea upon which the auditory hair cells are located.

Bed spins: A vestibular phenomenon experienced by individuals who drink too much alcohol and lie on their backs in bed.

Behaviorism: The school of psychology founded by John B. Watson around 1913 that stated that the subject matter of psychology should be behavior, not the mind.

Binocular depth cues: Depth cues that depend on the simultaneous use of both eyes.

Blindsight: The ability, following damage to the visual cortex, to point to an object in the visual field with no awareness of seeing it.

Blind spot: A small area on each retina where the receptors are pushed aside by the optic nerve leaving the eyeball on its way to the brain.

Bone conductive hearing: The perception of sound through vibrations in the temporal bone that are transmitted directly to the cochlea without the involvement of the eardrum and ossicles.

Broca's area: The brain region in the left (usually) frontal lobe necessary for the expression of speech.

C fibers: The small-diameter, slow-conducting nerve fibers that transmit pain information from the free nerve endings to the central nervous system.

Cataracts: Clouding of the lens of the eye, usually due to aging.

Central tendency error: The perceptual error of seeing people as more consistent than they actually are.

Cerebral cortex: The outer mantle of cell bodies that covers the subcortical parts of the brain.

Choroid coat: The retinal layer at the back of the eye that absorbs stray light.

Cochlea: The bony inner-ear structure that contains the auditory receptors.

Conductive hearing loss: Hearing loss caused by interruption or dampening of sound waves before they reach the receptors.

Cones: The centrally located visual receptors responsible for detailed color vision in normal levels of illumination.

Critical flicker frequency (CFF): The highest rate of visual flicker an individual can perceive before the flicker turns into a steady light.

Decibel (dB): A unit of pressure used to measure sound waves.

Deep pain: Dull, aching, throbbing pain.

Determinism: The basic assumption of science asserting our belief in a lawful universe where cause and effect are in operation.

Echolocation: The ability to locate objects in space by emitting high-frequency pulses and using the two ears to sense the location in space from which the object reflects back those pulses.

Encapsulated end organs: The general term used to refer to the various types of cutaneous receptors found in the skin.

Endorphins: Morphine-like substances produced in the brain that can have analgesic effects.

Forebrain: A subcortical brain region involved in emotional reactivity and the expression of the primary drives.

Fovea: The central portion of the retina that contains only cones and has the greatest visual acuity.

Free nerve endings: The primitive receptors in the skin (and other regions of the body) primarily responsible for pain sensations.

Gate-control theory: Melzack and Wall's theory that our perception of pain is determined by the ratio of A-delta to C fibers that a stimulus excites.

Gestalt psychology: An early school of psychology that is best remembered today for its phenomenological approach to perception and perceptual organization.

Glaucoma: A medical condition in which increased fluid pressure in the eyeball can damage the retinal elements and the optic nerve.

Golgi organs: Receptors in the tendons that respond to the amount of tension generated by a contracting muscle.

Halo effect: The tendency to form an overall positive impression of someone from a single positive trait.

Hertz (Hz): A unit of measurement for the number of cycles a sound wave (or any continuous wave) completes in one second.

Hindbrain: The primitive portion of the brain that controls vital functions, such as breathing and heart rate.

Hippocampus: A forebrain structure known to be involved in the consolidation of short-term memory into long-term memory.

Infrared: The portion of the electromagnetic energy spectrum just above the red end of the visible spectrum, invisible to the human eye.

Inner ear: The cochlea, semicircular canals, utricle, and saccule.

Intra-aural muscles: The two tiny muscles located in the middle ear, known as the stapedius and the tensor tympani muscles.

Kinesthetic sense: The sense that responds to the position and motion of our limbs.

Krause end bulbs: One of the encapsulated end organs in the skin, thought to respond to cold.

Learned taste aversion: The tendency for humans and other animals to develop an aversion to a taste that is temporally contiguous with feelings of illness, even if the taste is unrelated to the illness.

Ligaments: The tough connective tissue that attaches bones together at a joint.

Lobes of the brain: The human brain is composed of the frontal, parietal, occipital, and temporal lobes.

Logical error: A perceptual error resulting from the faulty belief that certain personality traits (such as politeness and honesty) always go together.

Long wavelengths of light: Colors located toward the red end of the visible spectrum.

Macular degeneration: Degeneration in the central 5 mm of the retina that surrounds and includes the fovea.

McClintock effect: The phenomenon whereby college coeds who live on the same dormitory floor frequently have menstrual periods that start around the same time.

Meissner corpuscle: An encapsulated end organ in the skin that responds to touch.

Midbrain: Subcortical brain region responsible for reflex orientation to sensory stimuli.

Middle ear: The air-filled space between the eardrum and cochlea, containing the ossicles and the intra-aural muscles.

Monocular depth cues: Depth cues, such as those used by artists in a painting, that can be perceived with one eye.

Muscle spindles: Receptors located in muscles that respond to the degree of contraction.

Myopia: Nearsightedness; an inability to see distant objects clearly due to a focal error in the eye.

Object identification: The higher-order aspect of visual perception requiring the integrity of the visual cortex.

Object location: The lower-order aspect of visual perception mediated by neural circuits in the midbrain.

Olfactory bulbs: Structures located under the frontal lobes that receive information from the smell receptors.

Olfactory epithelium: The area of tissue at the top of the nasal cavity, measuring 2.5 square centimeters, where the smell receptors are located.

Olivocochlear bundle: A bundle of nerve fibers going from the central nervous system back to the auditory receptors in the cochlea, thought to be involved in selective attention.

Optical instruments of the eye: The cornea and the lens are the optical instruments of the eye.

Optic tectum: The midbrain region responsible for reflex orientation to abrupt changes in the visual field.

Ossicles: The chain of three tiny bones in the middle ear known as the malleus, incus, and stapes.

Otitis media: A middle-ear infection.

Otoliths: The tiny calcium carbonate particles found in the utricle and saccule.

Otosclerosis: A hereditary condition resulting in partial or complete immobilization of the stapes.

Ototoxic drugs: Drugs that can be harmful to auditory and vestibular hair cells.

Outer ear: The portion of the auditory system from the ear to the eardrum.

Pacinian corpuscle: One of the encapsulated end organs in the skin, known to be sensitive to pressure and vibrations.

Passive touch: The situation in which a person remains passive while tactile stimulation is applied to the skin.

Perceptual world: The meaning that a sensory array has for a particular individual as a result of that individual's unique history with that or a similar stimulus array.

Perilymph: The liquid having the consistency of blood that fills the cochlea and the semicircular canals.

Personal space: In public situations, the distance maintained from another person or persons with which one feels most comfortable.

Phenylketonuria: An inherited metabolic disorder that can cause retardation; PKU produces a characteristic odor in those who have it.

Phenylthiocarbamide (PTC): A synthetic substance that some people (called *tasters*) can taste and others (called *nontasters*) cannot.

Phenylthylamine (PEA): A substance found in chocolate and thought to contribute to chocolate cravings.

Pheromones: Odorous chemicals released by some species that produce physiological responses in conspecifics.

Phonemes: The smallest distinguishable utterances in a language.

Phonemic perceptual maps: Dedicated connections between auditory receptors and cells in the auditory cortex are created in children who repeatedly hear phonemes spoken by caregivers, with each phoneme having a different spatial location in the auditory cortex.

Pigment epithelium: The retinal layer containing the blood supply that provides nutrients for the receptors.

Placebo effect: The ability of an inert substance to reduce symptoms if the recipient believes in its efficacy.

Plasticity: The ability of the brain to compensate for damage.

Presbycusis: A progressive loss of hearing for high frequencies as a function of age.

Presbyopia: A deficit in near vision resulting from age-related loss of elasticity and accommodation.

Prosopagnosia: A form of visual agnosia characterized by an inability to recognize human faces.

Pyramidal tracts: The nerve fiber bundles that carry instructions from the motor cortex to the peripheral muscles.

Rods: The visual receptors mediating noncolor vision in dim light.

Ruffini cylinders: One of the encapsulated end organs in the skin thought to be sensitive to warm stimuli.

Saccule: Part of the vestibular system found under the semicircular canals; a protuberance, slightly smaller than the utricle, that responds to changes in the head’s orientation.

Semicircular canals: The portion of the vestibular system that responds to angular acceleration and deceleration.

Sensorineural hearing loss: Hearing loss due to damage or degeneration of receptors and/or auditory nerve fibers.

Sensory supporting structures: Structures such as the ossicles or the hairs on the skin that make a stimulus more accessible to the sensory receptors.

Sensory suppression: The inability to perceive both of two touch stimuli delivered simultaneously to different body areas.

Sensory world: Those portions of the physical environment to which an organism’s sensory receptors are responsive.

Short wavelengths of light: The blue-violet end of the visible spectrum.

Specific gravity: The weight of an object in air divided by the weight of an equal volume of water.

Speed of light: The speed of light is 186,000 miles per second.

Speed of sound: The speed of sound is approximately 1,110 feet per second in air at normal atmospheric pressures.

Stria vascularis: The highly vascularized tissue layer inside the cochlea that appears to act as a DC battery, amplifying the electrical output of the hair cells.

Substantia gelatinosa: A nucleus in the dorsal horn of the spinal cord, proposed as the “gate” in the gate-control theory of pain.

Superficial pain: “Bright,” sharp, surface pain.

“Sweet-tooth” phenomenon: Refers to the unlearned preference for the taste of sweet seen in humans and many other species.

Sylvian sulcus (or sylvian fissure): The upper boundary of the temporal lobe.

Taste bud: A goblet-shaped cluster of cells below the surface of the tongue.

Taste papilla: One of the visible bumps on the surface of the tongue, surrounded by moat-like trenches containing the taste buds.

Taste receptor: Each of the 10,000 taste buds on the tongue contains a taste receptor.

Tectorial membrane: A stiff membrane in the cochlea against which the auditory hair cells rub when vibrations from sound waves are initiated in the basilar membrane.

Tendons: Strong bands of connective tissue that attach muscles to bones.

Traditional Chinese medicine (TCM): A holistic health care system used in China for more than 5,000 years, which includes acupuncture as a component.

Tympanic membrane: The technical term for the eardrum.

Ultraviolet: The frequency of electromagnetic energy just below the blue-violet end of the visible spectrum, invisible to the human eye.

Utricle: Part of the vestibular system found under the semicircular canals; a protuberance, somewhat larger than the saccule, that responds to changes in the head's orientation.

Visible spectrum: That portion of the electromagnetic energy spectrum visible to the human eye, ranging from approximately 400 nm to 700 nm.

Visual agnosia: A condition usually caused by brain injury in which different aspects of the visual field are unrecognizable to the individual.

Wernicke's area: A brain region in the upper portion of the left temporal lobe important for speech comprehension.

Biographical Notes

Tiffany Field, Ph.D., University of Massachusetts, 1976, developmental psychology. Founded the Touch Research Institute (TRI) at the University of Miami School of Medicine in 1992, where she remains as director. Dr. Field studies the relationship between touch and health (both physical and psychological health). She is well known for her studies of high-risk infants.

Eleanor Gibson (1910–2002), Ph.D., Yale, 1938, psychology. Studied perceptual development in children and is best known for her work with the *visual cliff*, demonstrating that babies can perceive depth. In 1992, Dr. Gibson became one of only 10 psychologists to be awarded the National Medal of Science.

Harry Harlow (1905–1981), Ph.D., Stanford, 1930, psychology. Best known for his primate work at the University of Wisconsin, where he demonstrated that infant monkeys deprived of tactile stimulation became socially incompetent, showing behaviors similar to autism. Harlow's early studies of what has come to be called "mother love" led to later investigations of the importance of tactile stimulation for human infants.

Herman von Helmholtz (1821–1894), M.D., Medical Institute of Berlin, 1843. Helmholtz had many interests but focused on the role of the sense organs as mediators of experience in the synthesis of knowledge. He published articles on physiological optics and physiological acoustics. He invented the ophthalmoscope and was the first to measure the speed of conduction of nerve impulses. Helmholtz's theories of color vision and auditory frequency analysis turned out to be correct in many respects.

Heinrich Hertz (1857–1894), Ph.D., University of Berlin, 1880, physics, under Hermann von Helmholtz. Professor Hertz was the first person to demonstrate the existence of electromagnetic radiation and the first to produce and broadcast radio waves. The unit of measurement for cycles per second (CPS) was changed to Hertz (Hz) to honor the memory of Dr. Hertz, a physicist who was also an enthusiastic linguist, learning Arabic and Sanskrit.

Martha McClintock (1947–), Ph.D., University of Pennsylvania, 1974, psychology. Currently professor of psychology and director of the Institute for Mind and Biology at the University of Chicago. Best known for her study of menstrual synchronicity among college women living on the same dormitory floor. The existence of human pheromones was first confirmed in Dr. McClintock's laboratory in 1998. Prior to this, pheromones were thought to exist only in the animal world.

Ronald Melzack (1929–), Ph.D., McGill, 1954, psychology. Presently Professor Emeritus at McGill. While a faculty member at MIT in 1959, he began a collaboration with Dr. Patrick Wall that resulted in the gate-control theory of pain. This theory has had a great impact on the field of pain and has resulted in Dr. Melzack receiving numerous international awards for his scholarly contributions.

George Wald (1906–1987), Ph.D., Columbia, 1932, zoology. Nobel laureate in medicine (1967) for his work on physiological and chemical processes in the eye. A pioneer in the measurement of the spectral sensitivity of the cone visual pigments.

John B. Watson (1887–1958), Ph.D., University of Chicago, 1903, psychology. Founded the school of psychology known as behaviorism at Johns Hopkins University in 1913. Watson used the method of Pavlovian conditioning to gain insights into human behavior. He left Johns Hopkins in 1920 to go into advertising and retired in 1945 as vice president of the William Esty Agency.

Carl Wernicke (1848−1905), M.D., University of Breslau, Poland. Dr. Wernicke described the symptoms now referred to as receptive aphasia. These symptoms include loss of comprehension of spoken language, although hearing remains intact. The affected person may retain the ability to speak fluently, although his or her speech has no understandable meaning or syntax. Damage to the brain in the superior portion of the left temporal lobe is responsible for the condition. This part of the brain is now called Wernicke's area.

Max Wertheimer (1880−1943), Ph.D., University of Wurzburg, 1904, psychology. Worked on the fundamentals of Gestalt psychology from 1910 to 1914. A basic idea was that our perceptions have properties not predicted from the sensations comprising them. That is, perceptions do not have a one-to-one correspondence with sensory stimulation. Many known perceptual phenomena can be traced back to the studies of the Gestalt psychologists.

Bibliography

Readings:

Ackerman, D. *A Natural History of the Senses.* New York: Vintage, 1990. This is an absolutely fascinating piece of literature. I regularly recommend it to friends, colleagues, and students.

Backhaus, W. G. K., R. Kliegl, and J. S. Werner, eds. *Color Vision: Perspectives from Different Disciplines*. New York: Walter de Gruyter, 1998. An edited volume that treats the subject of color vision from the perspectives of art, psychology, physiology, genetics, and philosophy.

Bloom, F., A. Lazerson, and L. Hofstadter. *Brain, Mind, and Behavior.* New York: Freeman, 1985. This book takes the stance that the mind is explainable in terms of the interactions among the brain's component parts. Chapter 4 is especially relevant for our purposes.

Bregman, A. S. *Auditory Scene Analysis.* Cambridge: M.I.T. Press, 1990. A challenging but worthwhile experience for those seriously interested in music perception. This long and detailed book provides a summary of the research on the formation of auditory images.

Carlson, N. R. *Physiology of Behavior* (8^{th} ed.). Boston: Allyn and Bacon, 2004. Dr. Carlson does an excellent job of providing current information about sensory psychology.

Colavita, F. B. *Sensory Changes in the Elderly.* Springfield: Charles C. Thomas, 1978. Although published some time ago, this book still contains readable and relevant information.

Corey, D. P., and S. D. Roper, eds. *Sensory Transduction.* New York: Rockefeller University Press, 1992. The contributors to this volume describe original research on the transduction mechanisms used by sensory receptors. Highly technical.

Corso, J. F. *Aging Sensory Systems and Perception.* New York: Prager, 1981. Although out of print, used copies can still be found. Provides practical suggestions for coping with age-related sensory and perceptual changes.

Denes, P. B., and E. N. Pinson. *The Speech Chain* (2^{nd} ed.). New York: Freeman, 1991. This relatively short book will tell you all you want to know (and probably more) about speech production and language comprehension.

Elkins, J. *The Object Stares Back: On the Nature of Seeing.* New York: Harvest Books, 1996. This interesting book takes a nontechnical approach to "looking and seeing." Not only do we capture objects with our gaze, but our gaze is captured by objects.

Ephret, G., and R. Romand, eds. *The Central Auditory System.* New York: Oxford University Press, 1997. This edited book describes in detail the structure and function of the various divisions of the auditory system, from the cochlea to the auditory cortex. The contributors deal primarily with the auditory system of the cat.

Field, T. *Touch Therapy.* New York: Elsevier, 2000. Dr. Field, one of the most prominent researchers in the area of touch therapy, describes the many physical and mental health benefits of massage.

Filshie, Jacqueline, and Adrian White, eds. *Medical Acupuncture: A Western Approach.* Edinburgh, Scotland: Churchill Livingstone, 1998. This edited work includes contributions from Western scientists and from acupuncture practitioners. As might be expected from a Western perspective, the focus is on the analgesic rather than the purported curative properties of acupuncture.

Gazzaniga, M. *The Bisected Brain.* New York: Appleton-Century Crofts, 1970. This book is a classic in the "split brain" area, written by the foremost researcher in the field.

———, ed. *The New Cognitive Neurosciences.* Cambridge, MA: MIT Press, 2000. Although this edited volume contains many interesting chapters, your attention is especially directed to the excellent contribution by P. K. Kuhl.

Getchell, B. V., R. L. Doty, L. M. Bartoshuk, and J. B. Snow, eds. *Smell and Taste in Health and Disease.* New York: Raven Press, 1991. This massive work, 55 chapters from 70 contributors, deals exclusively with the senses of taste and smell! The chapters are more or less evenly divided between those dealing with normal functioning and those dealing with gustatory and olfactory disorders.

Gibson, J. J. *The Senses Considered as Perceptual Systems.* Boston: Houghton Mifflin, 1966. Dr. Gibson was an important theorist and a respected researcher in the area of human perception. His book is a classic.

Goldstein, E. B. *Sensation and Perception* (6^{th} ed.). Pacific Grove: Wadsworth, 2002. This is the most popular sensation and perception textbook on the market, read by thousands of college students each semester. If you are going to read a sensation and perception text, this is the one.

Gregory, R. L. *Eye and Brain.* New York: McGraw-Hill, 1966. Although it is more than 40 years old, this book is still an excellent source for the understanding of many visual illusions and other visual phenomena. There is a fifth edition out, but try the old one first.

Jerome, J. *The Elements of Effort.* New York: Simon and Schuster, 1997. If you are or have ever been a runner, you will find this book of interest. The author's description of the role of the Golgi tendon organ in confidence building is unique and creative.

Kruger, L., ed. *Pain and Touch.* San Diego: Academic Press, 1996. This is a rather technical edited volume, describing psychological, neurophysiological, and psychophysical studies of touch and pain.

Laing, D. D., R. L. Doty, and W. Breipohl, eds. *The Human Sense of Smell.* New York: Springer, 1991. This volume contains a wealth of clinical data on human anosmia and other olfactory phenomena. Definitely not light reading.

Leahey, T. H. *A History of Psychology: Main Currents in Psychological Thought* (6th ed.). Upper Saddle River, NJ: Prentice Hall, 2004. If you want to learn more about Gestalt psychology and/or the historical connection between the study of sensory processes and psychology, or about some of the important historical contributors to academic psychology, this book is a fine place to start.

Lippa, Richard A. *Introduction to Social Psychology* (4th ed.). Pacific Grove: Brooks/Cole, 1994. This is a textbook of social psychology. Chapter 4 provides a good overview of the dynamics of people perception.

Mack, A., and I. Rock. *Inattentional Blindness.* Cambridge, MA: MIT Press, 1998. The authors propose and test the hypothesis that attention is necessary for visual perception. Finding supporting results, they expand the hypothesis to include other sense modalities.

Melzack, R., and P. D. Wall. *The Challenge of Pain* (rev. ed.). New York: Penguin Books, 1988. The two best-known pain researchers explore the puzzle of pain, the physiology of pain, and the treatment of pain.

Moore, B. C. J., ed. *Hearing.* San Diego, CA: Academic Press, 1995. This edited volume summarizes virtually all the areas of hearing research. Although the chapters are well written, this work is suggested for highly motivated readers.

Sacks, O. *The Man Who Mistook His Wife for a Hat.* London: Duckworth, 1985. This is an entertaining and informative book by a noted neurologist and writer. The consequences of neurological damage for perceptual processes are skillfully and sensitively described.

Sekuler, R., and R. Blake. *Perception* (4th ed.). Boston: McGraw-Hill Humanities/Social Sciences/Languages, 2002. This book describes recent contributions to the field of perception from cognitive neuroscience.

Shepard, R. N. *Mind Sights.* New York: Freeman, 1990. Dr. Shepard has created original visual illusions and ambiguous figures that he presents and explains. This book is entertaining, interesting, and informative.

Thorne, B. M., and T. Henley. *Connections in the History and Systems of Psychology* (2nd ed.). Boston: Houghton Mifflin, 2001. The authors provide interesting biographical sketches of the important historical figures in psychology.

Wall, P. D., and R. Melzack, eds. *Textbook of Pain* (3rd ed.). London: Churchill Livingstone, 1994. This book, edited by the "fathers" of modern pain research, deals with every conceivable aspect of pain.

Wright, R. D., ed. *Visual Attention.* New York: Oxford University Press, 1998. An edited volume containing chapters contributed by cognitive scientists with an interest in various aspects of visual attention. Some chapters are of general interest, while others are less so, being highly theoretical. The chapter on "change blindness" by O'Regan is especially interesting.

Internet Resources:

"AgingEye Times." www.agingeye.net. This site explores problems facing the aging eye, such as glaucoma, cataract, macular degeneration, and diabetic eye disease.

Chandler, Daniel. "Visual Perception 4." www.aber.ac.uk/media/Modules/ MC10220/visper04.html. This site examines (among many other things) cultural differences in perception. Have fun!

"National Eye Institute." U.S. National Institutes of Health. www.nei.nih.gov/ index.asp. This Web site includes current information about eye health, including eye disease, vision care, research results, funding, and education programs. In addition to a clinical studies database, it provides photos, images, and videos on a number of eye-related topics.

"Relief of Pain and Suffering." UCLA Louise M. Darling Biomed Library—History and Special Collections. www.library.ucla.edu/libraries/biomed/his/ painexhibit/index.html. This exhibit covers many aspects of pain, including pain pathways, pain measurement, pain alleviation, phantom limb pain, and the gate-control theory of pain.

"Sensation and Perception Tutorials." Hanover College Psychology Department. psych.hanover.edu/krantz/sen_tut.html. Tutorials on visual phenomena are provided, including motion and depth perception and the Gestalt "laws" of perceptual organization.

"Serendip." Supported by Bryn Mawr College, the National Science Foundation, and the Howard Hughes Medical Institute. serendip.brynmawr.edu. This site provides access to virtually any aspect of sensation and perception, including an online demonstration of the blindsight phenomenon.