Chapter 14

**TOUCH AND PAIN**

Properly speaking, there is not a single sense of touch, but several somatosensory senses with different kinds of receptors. Mechanoreceptors are myelinated sensory receptors in the skin that quickly transduce physical movement on the skin into neural signals. Mechanoreceptors are divided into four types: SAI, SAII, FAI, and FAII. *SA* refers to slow-adapting; *FA* refers to fast-adapting. “I” mechanoreceptors have small receptive fields; “II” mechanoreceptors have larger receptive fields. Proprioception is the perception of the movements and position of our limbs. An illusion of proprioception, known as phantom limb syndrome, may occur in amputees. Thermoreception is the ability to sense changes in temperature on the skin. Cold fibers are thermoreceptors that fire in response to colder temperatures (30oC and below), whereas warm fibers are thermoreceptors that fire in response to warmer temperatures (above 36oC). Nociception is the perception of pain. Nociceptors can be either A-delta fibers or C-fibers. A-delta fibers are myelinated and conduct signals rapidly to alert us of the stinging, initial feeling of pain. Associated with the more chronic experience of throbbing pain, C-fibers are unmyelinated and conduct signals more slowly. The dorsal column-medial lemniscal pathway is the pathway for mechanoreceptors and proprioceptors. The spinothalamic pathway is the pathway for nociceptors and thermoreceptors. Both pathways project to the somatosensory cortex, an area in the anterior parietal lobe devoted to processing the information coming from the skin’s senses. The primary somatosensory cortex (S1) contains a somatotopic map of the body, in which the skin of the body maps onto the surface of S1 in a systematic way. The map is distorted in that areas of the body for which we need greater sensitivity (e.g., hands, mouth) have greater representation than for areas of the body for which we do not need as high sensitivity (e.g., back, legs). The gate control theory is a model that allows for top-down control of the pain signal coming up the spinal cord. Pain may be inhibited by endogenous opioids, which act as analgesics to reduce pain. Itch perception is regulated by pruriceptors, which respond to mild irritants by producing scratch sensations. Finally, haptic perception is the active use of touch to identify objects. Tactile agnosia, an inability to identify objects by touch, can result from damage to the somatosensory cortex. An important application of haptic perception is reading Braille.

Another important sense is the vestibular system, the sensory system responsible for the perception of balance and acceleration. It is housed in the semicircular canals and otolith organs, both located next to the inner ear. The semicircular canals are three tubes responsible for the signaling of head rotation. When the head moves in a particular direction, a fluid called endolymph shifts with it, causing hair cells in the semicircular canals to bend, transducing a neural signal. Similarly, hair cells in the otolith organs bend during acceleration of the head and head tilt, transducing a neural signal. Both project to the parietal insular vestibular cortex. Finally, many species of fish have their own special sensory ability, electroreception, which allow them to detect the presence of other animals.

Introduction

* The touch senses are different from audition, vision, and olfactory systems in an important way—it requires bodily contact and preferably contact and bodily motion.
* Properly speaking, there is not a single sense of touch, but several somatosensory senses.
  + There are different kinds of receptors in our skin to detect light pressure, deep pressure, pain, coldness, and heat.
  + There are receptors in our muscles that help regulate the position of our body.
* The vestibular system is also included in this chapter to ensure all sensory systems are covered in this book.

The Skin and Its Receptors

* The skin is the sense organ of touch.
* Touch receptors exist everywhere on the surface of the skin, inside the mouth, and on the tongue.
* Many touch receptors are located just below the outer layer of skin, called the **epidermis.**
  + The epidermis is avascular and gets its oxygen from the air.
  + In addition to its sensory functions, the epidermis functions to keep out pathogens and keep in fluids.
* Below the epidermis is the **dermis**, which houses most touch receptors.
  + The dermis holds the connective tissue and has a blood supply.
* Skin can also be divided into hairy skin (has hair growing on it) and glabrous skin (hairless). Glabrous skin is found on the palms, fingertips, soles of the feet, and bottom of the toes.
* Touch perception occurs when the skin is moved or touched, including indentation and stretching.
  + This mechanical stimulation activates one or more of the four types of mechanoreceptors in the skin.
  + **Mechanoreceptors** are sensory receptors in the skin that transduce physical movement on the skin into neural signals.
  + Mechanoreceptors are myelinated, allowing fast transmission of the neural signal.
  + The four types of mechanoreceptors are called **SAI mechanoreceptors, SAII mechanoreceptors, FAI mechanoreceptors,** and **FAII mechanoreceptors.**
  + *SA* stands for “slow-adapting” and *FA* stands for “fast-adapting.”
    - SA mechanoreceptors tell us about continued pressure on the skin.
    - FA mechanoreceptors tell us about temporary stimulation of the skin.
  + Roman numeral I means they have small receptive fields and Roman numeral II means they have larger receptive fields.
    - SAI and FAI receptors have high spatial resolution due to densely packed receptive fields, meaning they help us detect small objects and pinpoint objects in space.
    - SAII and FAII receptors have lower spatial resolution due to a more dispersed receptive fields. They have higher sensitivity to light touch, but are not as precise in determining where on the skin the touch occurs.

SAI Mechanoreceptors

* SAI mechanoreceptors are responsible for touch perceptions of pattern and texture.
* They are responsible for two-point thresholds, i.e., the minimum distance at which a person can detect two touches instead of just one.
  + Two-point thresholds vary across the skins surface.
  + Where it is most sensitive (fingers and lips), there is the highest density; where it is least sensitive (back and legs), there is the lowest density.

SAII Mechanoreceptors

* In addition to having maximum response to steady pressure, SAII mechanoreceptors are good at stretching from side to side, making them crucial for object grasping.

FAI Mechanoreceptors

* FAI mechanoreceptors respond to the onset and offset of a stimulus.
* They respond well to low-frequency vibrations.
* They are especially good at detecting “slip,” i.e., when an object is sliding across the surface of the skin. Thus, they are useful in avoiding dropping objects and maintaining grip.

FAII Mechanoreceptors

* FAII also respond to the onset and offset of a stimulus.
* They are more sensitive to higher frequency vibrations.
* Because of their high sensitivity to touch, they are helpful in feeling small pressure on the skin, such as when an insect lands on the skin.
* They are also used for fine motor control.

Proprioception: Perceiving Limb Position

* **Proprioception** is defined as the perception of the movements and position of our limbs.
* Three kinds of sensory receptors in our bodies provide us information about limb movement and position.
  + **Muscle spindles** are muscle cells that have receptors embedded in them that sense information about muscle length and therefore muscle action.
  + **Joint receptors** are found in each joint that sense information about the angle of the joint.
  + **Golgi tendon organs** are receptors in the tendons that measure the force of a muscle’s contraction.
* Proprioception is seldom consciously attended to.
* Alcohol consumption affects proprioception, making it more difficult for proprioceptors to give feedback on limb position.
* Those who have lost limbs may have false proprioception in a condition known as **phantom limb syndrome**, which refers to the illusory sensory reception in a missing appendage.

Thermoreception

* **Thermoreception** is the ability to sense changes in temperature on the skin.
* **Thermoreceptors** are the sensory receptors in the skin that signal information about the temperature as measured on the skin.
  + They respond to a range of skin temperatures, from 17oC to 43oC.
  + This is the range of temperatures experienced by our skin, not the actual ambient temperature.
  + Skin temperature above 43oC or below 17oC is experienced as pain.
* **Cold fibers** are thermoreceptors that fire in response to colder temperatures (30oC and below) as measured on the skin.
* **Warm fibers** are thermoreceptors that fire in response to warmer temperatures (above 36oC) as measured on the skin.
* At intermediate temperatures (between 30oC and 36oC), cold and warm fibers fire at a steady rate.
* Cold and warm fibers also fire when you touch objects that are colder or warmer than the skin temperature.
* Warm fibers also have a secondary peak in sensitivity when exposed to very low temperatures, known as a paradoxical heat experience.

Nociception and the Perception of Pain

* **Pain** is the perception and the unpleasant experience of actual or threatened tissue damage.
* Occurring from direct trauma to the skin, **nociceptive pain** is the pain that develops from tissue damage that causes nociceptors in the skin to fire.
* Found both in the epidermis and dermis, **nociceptors** are sensory receptors in the skin that, when activated, cause us to feel pain.
* Nociceptors are often called free nerve endings because of their anatomical structure.
* Nociceptors are divided into two main types.
  + **A-delta fibers** are myelinated nociceptors that conduct signals rapidly and respond to heat and pressure.
    - They are associated with the stinging, initial feeling of pain.
  + **C-fibers** are unmyelinated nociceptors that conduct signals more slowly and respond to pressure, extreme temperatures, and toxic chemicals.
    - They are associated with the more chronic experience of throbbing pain and may be delayed.
* Pain serves an important evolutionary function. By alerting you to tissue damage, it allows you to take steps to minimize or repair the tissue damage. Those who get away from the source of pain are more likely to survive than those who do not.

Neural Pathways

* A nerve ending in the skin sends its axon into a nerve bundle, where it is joined by many other axons from adjacent nerve fibers.
* The nerve bundles then enter the spinal column and form synapses with bipolar cells at a **dorsal root ganglion.**
* Once in the spinal column, information is divided into two parallel tracts.
  + One tract is called the **dorsal column-medial lemniscal pathway,** which carries information from the mechanoreceptors and proprioceptors.
    - It travels on the dorsal side of the spinal cord and on the ipsilateral side of input from the skin.
    - It synapses in the medulla, where it crosses over to the contralateral side.
    - Then, it travels to the **ventral posterior nucleus of the thalamus.**
    - Finally, it goes to the somatosensory cortex.
  + The other tract is called the **spinothalamic pathway**, which carries information from the nociceptors and thermoreceptors
    - Its fibers cross over to the contralateral side in the spinal cord
    - Then, it goes directly to ventral posterior nucleus of the thalamus.
    - Finally, it goes to the somatosensory cortex.
  + There are also reflex circuits in the spinal cord that take information and send it right back to the muscles to allow fast reaction to dangerous situations.

Somatosensory Cortex

* The **somatosensory cortex** is an area in the anterior parietal lobe devoted to processing the information coming from the skin’s senses.
* The primary somatosensory cortex (S1) receives input from both the dorsal column-medial lemniscal pathway and the spinothalamic pathway.
* S1 contains a **somatotopic map** of the body, in which the skin of the body maps onto the surface of S1 in a systematic way.
  + The map is distorted in that areas of the body for which we need greater sensitivity (e.g., hands, mouth) have greater representation than for areas of the body for which we do not need as high sensitivity (e.g., back, legs).

Suborganization of the Somatosensory Cortex

* S1 is divided into three distinct neuroanatomical regions: Area 1, Area 2, and Area 3 (which is subdivided into Area 3a and Area 3b).
* Each area has its own distinct map of the body’s surface.
* Area 1 receives input from mechanoreceptors.
* Area 2 receives input from proprioceptors.
* Area 3a receives input from proprioceptors and nociceptors.
* Area 3b receives input from nociceptors and mechanoreceptors.
* These areas then send information to the secondary somatosensory cortex (S2), which is the somatosensory system’s “what” channel or ventral system for identifying objects.
* There is also a “where” channel or dorsal system which allows us to control movements on the basis of input from the somatosensory system.
  + The “where” channel continues to the posterior parietal cortex and the premotor cortex in the frontal lobe.
* In contrast to other systems, temperature information goes from S1 to the insular cortex and anterior cingulate cortex in the frontal lobe, areas involved in cognition. Their function in perceiving temperature is still unknown.

Pathways for Pain

* Pain can be modified by emotion and cognition.
* To account for this, the **gate control theory** is a model that allows for top-down control of the pain signal coming up the spinal cord.
* Nociceptors first synapse in the **substantia gelatinosa** of the **dorsal horn** in the spinal cord. At this point, a neural signal from the brain can inhibit the upward flow of pain information.
* The **anterior cingulate cortex** has a role in emotional pain.

The Neurochemistry of Pain: Endogenous Opioids

* The brain can release **endogenous opioids** into the blood, which act as analgesics to reduce pain.
* Because artificial opiates (e.g., codeine) mimic the effects of endogenous opioids, they can be effective at reducing pain.

The Perception of Itch

* Itch is different from pain, though both may be considered negative sensory experiences.
* Itchiness causes us to want to scratch the affected skin (an approach behavior), whereas pain induces a withdrawal response.
* Itch perception is caused by **pruriceptors**, which respond mostly to mild chemical irritants.
* The function of scratching may be to remove the possible irritant or it may be to induce actual tissue damage which acts to initiate an autoimmune response.

Haptic Perception

* The dynamic process of object identification by touch is called **haptic perception**.
* Wearing gloves can interfere with haptic perception, possibly by preventing the receptors from picking up vital information from the objects.
* **Exploratory procedures** are hand movements made in order to identify an object.

Tactile Agnosia

* **Tactile agnosia** is an inability to identify objects by touch, though there are no deficits in perception of texture, temperature, and pain. That is, the problem is one of identification rather than perception.
* Usually, only one hand is affected. If damage is to the left somatosensory cortex, then tactile agnosia would be observed in the right hand, but not the left hand.

The Vestibular System: The Perception of Balance

* The **vestibular system** is the sensory system responsible for the perception of balance.
* It is housed in the **semicircular canals** and **otolith organs**, both located next to the inner ear.
* The semicircular canals are three tubes responsible for the signaling of head rotation.
  + Each semicircular canal is filled with a liquid called **endolymph**.
  + When the head moves in any particular direction, the endolymph shifts with it.
  + When the endolymph shifts, hair cells in the semicircular canals bend, transducing a neural signal.
  + Because the semicircular canals are perpendicular to each other, each relays information about head movement on a different axis.
* The otolith organs are responsible for detecting acceleration of the head and identifying when the head is being tilted.
  + During acceleration or head tilt, hair cells in the otolith bend, giving information about motion or head tilt.
* Nerve fibers from the semicircular canals and otolith come together in the vestibular that then synapses in the **vestibular complex** in the brainstem.
  + The vestibular complex projects to several areas, including the **parietal insular vestibular cortex,** which is believed to maintain a representation of head angle, crucial for maintaining balance.

Application: Reading Braille

* Braille is an alphabet system using tactile letter instead of visual letters.
* Braille is usually read using the index figure, which feels the dots raised on the surface of the page. The index is used because it has the most mechanoreceptors of all the fingers.
* Braille is dependent on fine touch and the “what” system in the somatosensory cortex.
* Braille reading (100 words per minute) tends to be slower than visual reading (250 words per minute).
* Neuroimaging studies show reorganization of the brain in congenitally blind individuals compared to those who became blind later in life.
  + More white-matter fibers in the somatosensory cortex are observed in congenitally blind individuals, which may allow them to devote more of the somatosensory cortex to spatial processing.
  + Braille readers show activity in the occipital lobe when reading.
  + This research suggests that there is neural reorganization when a sensory system is disrupted.

***In Depth: Electroreception in Fish***

* Many species of fish have sensory organs that allow them to detect the electric fields of other fish.
* **Electroreception** is the ability to detect electric fields.
  + **Passive electroreception** means that the fish can detect electric fields by other animals.
    - Passive electroreceptors, known as **ampullae of Lorenzini**, are located inside the scales along the surface of most fish.
  + **Active electroreception** means that the fish generates its own electric field and then senses disturbances to it, analogous to the biosonar of bats and dolphins.
    - Active electroreceptors are known as **tuberous receptors.**
* The ampullae of Lorenzini and the tuberous receptors are tuned to electric fields of different frequencies (variations in voltage across time).
  + Ampullae of Lorenzini are tuned to detect the weak voltage produced by the movements of nearby fish.
  + Tuberous receptors are tuned to detect the fields generated by specific electric discharges by that fish, which means they can detect differences between smaller fish (prey) and larger fish (predators).