October 10:

- **Sensation** is the process that allows our brains to take in information via our five senses, which can then be experienced and interpreted by the brain.
- **Perception** is defined as our recognition and interpretation of sensory information.
- Human's best sense is vision.
- **Iris:** The colored part of your eye. It is actually a muscle that controls the size of the pupil.
- **Pupil:** The black part in the middle of the eye. It is the opening that allows light into the eyeball. The larger the pupil, the more light that comes in.
- **Sclera:** The white part of the eye. It is a tough membrane that serves as protection.
- **Cornea:** The fluid filled outer coating of the eye. It provides moisture and nutrients.
- **Lens:** Focuses the incoming light onto the retina. This lens is flexible and slight alterations in it can alter the focus of it, a process called **accommodation**.
  Aqueous Humor: This fluid nourishes the front of the eye.
- **Vitreous Humor:** This fluid nourishes and supports the inner part of the eye.
- **Retina:** The surface that the image lands on. The inner coating of the retina is the part that transmits the light signal into a neural signal.
- The retina **transduces** light from one form of energy to another form. Sensory neurons play the critical role of translating the physical properties of the outside world into neural signals, a process termed **transduction**. The sensory neurons are stimulated by light. When light hits them, it triggers a process that produces a neural signal, which is what our nerves use.
- **Photoreceptors:** Rods and Cones (Transduction proper – Red, Green, Blue) Light strikes the back of the eye stimulating photoreceptor cells which can be either rods or cones. Rods are not responsive to colour, but they are very responsive to dim light, which makes them great for low light situations. They are sensitive to the presence of light. Cones are sensitive to colour (red, green and blue) and provide a much more detailed image, which makes them great for high light, detailed imaging. The transduction is done via a bleaching process in which the photo-pigments are split, causing an action potential.
- **Bipolar Cells:** Image sharpening, edges and contours made crisper. The signal from the photoreceptors is then passed on to the bipolar cells which reprocess the signal in a way that tends to emphasize edges and contours. Essentially, when the photoreceptors associated with spatially close parts of the retina are sending very different signals, the bipolar cells accentuate these spots aiding us in our ability to perceive edges.
- **Ganglion Cells:** Colour sharpening, and introduction of yellow colour. The third and final step in the retina pre-processing of visual information is the ganglion cells. Ganglion cells come in two types, red/green and blue/yellow. Each cell represents an opponent process system. For example in red/green cells, the resting behaviour of the cell is to produce some mid-level rate of responding. This rate increases when red is present, and decreases when green is present.

The yellow/blue increases when both red and green are present but decreases when blue is present. Yellow stimulates both red and green photoreceptors.

October 7:

- **Confirmation bias** is the tendency to interpret new evidence as confirmation of one's existing beliefs or theories. Confirmation bias is especially strong these days because it's very easy to find other people who share your beliefs.
- The brain is excellent with dealing with confusion and uncertainty. It assumes information or ignores information in ways that allow it to make sense. It also relies heavily on past experiences to decide what makes sense.
- Once the sensation hits the brain, almost immediately, the brain starts to analyze it, and if necessary, change it.
- The raw sensory input that's coming in from the world through our eyes is called the **bottom-up influences**.
- As soon as the sensation enters the brain, the brain starts to analyze it, and if necessary, change it. This is called **top-down influences**.
- According to a group of German Psychologists called **Gestalt Psychologists**, the primary purpose of the visual system is the recognition of objects from basic visual elements. The objects are seen as more than a sum of the parts, and the critical problem facing the visual system is how to group the elements to form objects. Several principles, or laws, are used by the visual system to do this grouping. These laws are:
    1. **Proximity:** If things are close together in space, we tend to group them together.
    2. **Similar colour**
    3. **Similar size**
    4. **Common fate:** If a few elements within a complex display do something together, then they become grouped.
    5. **Good continuation:** Figures with edges that are smooth are more likely to be seen as continuous than edges that have abrupt or sharp angles.
    6. **Closure:** The brain tends to perceive forms and figures in their complete appearance despite the absence of one or more of their parts, either hidden or totally absent.
    7. **Common region**
    8. **Element Connectedness**
- Gestalt Psychologists looked at perception. Was one of European scientists' reactions to Freud.
- Gestalt in English means "The whole is more than the sum of the parts."
- The brain likes seeing things in one way.
- According to Piaget there are two processes at work in cognitive development: assimilation and accommodation. Cognitive growth is the result of the constant interweaving of assimilation and accommodation. **Assimilation** occurs when we modify or change new information to fit into our schemas. It keeps the new information or experience and adds to what already exists in our minds. **Accomodation** is when we restructure of modify what we already know so that

new information can fit in better. This results from problems posed by the environment and when our perceptions do not fit in with what we know or think.

October 9:

- To infer depth with one eye **(Monocular)**, we use the following:
    1. **Shading:** Depending on where light hits an object, you may perceive the depth as convex or concave.
       Convex: Coming out towards you.
       Concave: Going away from you.
       If the light hits the object from the top, then we perceive the depth as convex.
       If the light hits the object from the bottom, then we perceive the depth as concave.
- To infer depth with two eyes **(Binocular)**, we use the following:
    1. **Convergence:** Because the two eyes converge on an object when we are viewing it, the brain can use the angle of convergence as a cue to how far away that object is. The larger the angle, the nearer the object.
    2. **Retinal Disparity:** Whenever we are not focusing on an object, the image of that object falls on different points of the two retinas. The amount of disparity (difference) between the two retinal images can be used as a cue for distance.
- In order for people to recognize faces, the brain developed an area called the **fusiform gyrus/Brodmann area 37**, which is responsible for storing the unique features of everyone's face. If people have that area damaged, then it can be hard for them to recognize people by their faces. This is called **prosopagnosia/face blindness**. Prosopagnosia is a cognitive disorder of face perception in which the ability to recognize familiar faces, including one's own face, is impaired.
- **Capgras Syndrome/Imposter Syndrome** is a psychological condition in which people will have an irrational belief that someone they know or recognize has been replaced by an imposter.
  I.e. People with capgras syndrome can recognize faces but lose the sense of familiarity.

Textbook:

- **Section 4.1:**
- **Sensing the World Around Us:**
- The process of detecting and then translating the complexity of the world into meaningful experiences occurs in two stages.
- The first step is **sensation**, the process of detecting external events with sense organs and turning those stimuli into neural signals. All of this raw sensory information is then relayed to the brain, where perception occurs.
- **Perception** involves attending to, organizing, and interpreting stimuli that we sense.
- The raw sensations detected by the sensory organs are turned into information that the brain can process through **transduction**, when specialized receptors transform the physical energy of the outside world into neural impulses. These

neural impulses travel into the brain and influence the activity of different brain structures, which ultimately gives rise to our internal representation of the world.
- The sensory receptors involved in transduction are different for the different senses.
- All of our senses use the same mechanism for transmitting information in the brain, the action potential. As a result, the brain is continually bombarded by waves of neural impulses representing the world in all its complexity. Yet, it must be able to separate different sensory signals from one another so that we can experience distinct sensations. It accomplishes this feat by sending signals from different sensory organs to different parts of the brain. Therefore, it is not the original sensory input that is most important for generating our perceptions, but the brain area that processes this information. The idea that different senses are separated in the brain, was first proposed in 1826 by the German physiologist Johannes Müller and is known as the **doctrine of specific nerve energies**.
- Experience also influences how we adapt to sensory stimuli in our everyday lives. Generally speaking, our sensory receptors are most responsive upon initial exposure to a stimulus. The **orienting response** describes how we quickly shift our attention to stimuli that signal a change in our sensory world. In contrast, **sensory adaptation** is the reduction of activity in sensory receptors with repeated exposure to a stimulus.
- **Stimulus Thresholds:**
- An **absolute threshold** is the minimum amount of energy or quantity of a stimulus required for it to be reliably detected at least 50% of the time it is presented.
- A **difference threshold** is the smallest difference between stimuli that can be reliably detected at least 50% of the time.
- When you add salt to your food, you are attempting to cross a difference threshold that your taste receptors can register. Whether you actually detect a difference, known as a just noticeable difference, depends primarily on the intensity of the original stimulus. The more intense the original stimulus, the larger the amount of it that must be added for the difference threshold to be reached.
- This effect was formalized into an equation by Ernst Weber. **Weber's law** states that the just noticeable difference between two stimuli changes as a proportion of those stimuli.
- The study of stimulus thresholds has its limitations. Whether someone perceives a stimulus is determined by self-report. However, not all people are equally willing to say they sensed a weak stimulus.
- **Signal Detection:**
- If you are certain that a stimulus exists, then there is no reason to worry about whether you did or did not perceive something. However, there are many instances in which we must make decisions about sensory input that is uncertain. It is in these ambiguous situations that signal detection theory can be a powerful tool for the study of our sensory systems. **Signal detection theory** states that whether a stimulus is perceived depends on both the sensory experience and the

judgment made by the subject. Thus, the theory requires us to examine two processes: a sensory process and a decision process. In a typical signal detection experiment conducted in the laboratory, the experimenter presents either a faint stimulus or no stimulus at all; this is the sensory process. The subject is then asked to report whether or not a stimulus was actually presented; this is the decision process.

- In developing signal detection theory, psychologists realized that there are four possible outcomes:
    1. Hit
    2. Correct rejection
    3. False alarm
    4. Miss
- For example, you may be correct that you heard a sound (**hit**), or correct that you did not hear a sound (**correct rejection**). Of course, you will not always be correct in your judgments. Sometimes you will think you heard something that is not there (**false alarm**). On other occasions you may fail to detect that a stimulus was presented (**miss**). By analyzing how often a person's responses fall into each of these four categories, psychologists can accurately measure the sensitivity of that person's sensory systems.
- Studies using signal detection theory have shown that whether a person can accurately detect a weak stimulus appears to depend on a number of factors:
    1. The sensitivity of a person's sensory organs.
    2. A number of cognitive and emotional factors that influence how sensitive a person is to various sensory stimuli. These include expectations, level of psychological and autonomic-nervous-system arousal, and how motivated a person is to pay attention to nuances in the stimuli.
- Signal detection theory improves on simple thresholds by including the influence of psychological factors, such as a willingness to guess if uncertain.
- We can perceive **subliminal stimuli**, sensory stimulation that is below a person's threshold for perception, under strict laboratory conditions. Most laboratory-based studies use a technique known as **priming**, in which previous exposure to a stimulus can influence that individual's later responses, either to the same stimulus or to one that is related to it. In this type of study, experimenters often present a word or an image for a fraction of a second. This presentation is then immediately followed by another image, a **mask**, which is displayed for a longer period of time. The mask interferes with the conscious perception of the subliminal stimulus. The perceivers are often unaware that any stimulus appeared before the mask. Yet, a number of brain imaging studies have shown that these rapidly presented stimuli do in fact influence patterns of brain activity. Thus, it appears that subliminal perception can occur, and it can produce small effects in the nervous system.
- Subliminal messages have a mild effect on behaviour.
- **Gestalt Principles of Perception:**
- **Gestalt psychology** is an approach to perception that emphasizes that "the whole is greater than the sum of its parts." In other words, the individual parts of

an image may have little meaning on their own, but when combined, the whole takes on a significant perceived form. Gestalt psychologists identified several key principles to describe how we organize features that we perceive.

- One basic Gestalt principle is the **figure–ground principle**, which states that objects or figures in our environment tend to stand out against a background.
- **Proximity** and **similarity** are two additional Gestalt principles that influence perception. We tend to treat two or more objects that are in close proximity to each other as a group. As well, we tend to group individuals wearing the same uniform based on their visual similarity.
- **Continuity** refers to the perceptual rule that lines and other objects tend to be continuous, rather than abruptly changing direction.
- **Closure** refers to the tendency to fill in gaps to complete a whole object.
- **Working the Scientific Literacy Model:**
- **Top-down processing** occurs when our perceptions are influenced by our expectations or by our prior knowledge.
- **Bottom-up processing** occurs when we perceive individual bits of sensory information (e.g. sounds) and use them to construct a more complex perception (e.g. a message).
- **Attention and Perception:**
- **Divided attention** is when we are paying attention to more than one stimulus or task at the same time.
- **Selective attention** involves focusing on one particular event or task.
- **Inattentional blindness** is the failure to notice clearly visible events or objects because attention is directed elsewhere.
- **Section 4.2 The Visual System:**
- **How the Eye Gathers Light:**
- The primary function of the eye is to gather light and change it into an action potential.
- For the purposes of human perception, light is the radiation that occupies a relatively narrow band of the electromagnetic spectrum.
- Light travels in waves that vary in terms of two different properties: length and amplitude.
- The term **wavelength** refers to the distance between peaks of a wave.
- Long wavelengths correspond to our perception of reddish colours and short wavelengths correspond to our perception of bluish colours. Different shades of green would represent wavelengths of light in between the wavelengths of red and blue.
- **Amplitude** refers to the height of a wave.
- Low-amplitude waves are seen as dim colours, whereas high-amplitude waves are seen as bright colours.
- Light waves can also differ in terms of how many different wavelengths are being viewed at once. When you look at a clear blue sky, you are viewing many different wavelengths of light at the same time, but the blue wavelengths are more prevalent and therefore dominate your impression.

- If a large proportion of the light waves are clustered around one wavelength, you will see an intense, vivid colour. If there are a large variety of wavelengths being viewed at the same time, the colour will appear to be "washed out."
- We experience wavelength, amplitude, and purity as **hue** (colour of the spectrum), **intensity** (brightness), and **saturation** (colourfulness or purity). It is in the eye that this transformation from sensation to perception takes place.
- **The Structure of the Eye:**
- The eye consists of specialized structures that regulate the amount of light that enters the eye and organizes it into a pattern that the brain can interpret.
- The **sclera** is the white, outer surface of the eye.
- The **cornea** is the clear layer that covers the front portion of the eye and also contributes to the eye's ability to focus.
- Light enters the eye through the cornea and passes through the pupil. The **pupil** regulates the amount of light that enters by changing its size. It dilates to allow more light to enter and constricts to allow less light into the eye.
- The changes in the pupil's size are performed by the **iris**, a round muscle that adjusts the size of the pupil; it also gives the eyes their characteristic colour.
- The lens can change its shape to ensure that the light entering the eye is refracted in such a way that it is focused when it reaches the back of the eye. This process is known as **accommodation**.
- When the light reaches the back of the eye, it will stimulate a layer of specialized receptors that convert light into a message that the brain can then interpret, a process known as transduction. These receptors are part of a complex structure known as the retina.
- The **retina** lines the inner surface of the back of the eye and consists of specialized receptors that absorb light and send signals related to the properties of light to the brain.
- The retina contains a number of different layers, each performing a slightly different function.
- At the back of the retina are specialized receptors called **photoreceptors**. These receptors are where light will be transformed into a neural signal that the brain can understand.
- Having the photoreceptors wedged into the back of the eye protects them and provides them with a constant blood supply, both of which are useful to your ability to see.
- Information from the photoreceptors at the back of the retina is transmitted to the ganglion cells closer to the front of the retina. The ganglion cells gather up information from the photoreceptors; this information will then alter the rate at which the ganglion cells fire. The activity of all of the ganglion cells is then sent out of the eye through the **optic nerve**, a dense bundle of fibres that connect to the brain. This nerve presents a challenge to the brain. Because it travels through the back of the eye, it creates an area on the retina with no photoreceptors, called the **optic disc**. The result is a **blind spot**, a space in the retina that lacks photoreceptors.

- **The Retina: From Light to Nerve Impulse:**
- There are two general types of photoreceptors, **rods** and **cones**, each of which responds to different characteristics of light.
- **Rods** are photoreceptors that occupy peripheral regions of the retina; they are highly sensitive under low light levels. This type of sensitivity makes rods particularly responsive to black and grey.
- **Cones** are photoreceptors that are sensitive to the different wavelengths of light that we perceive as colour. Cones tend to be clustered around the **fovea**, the central region of the retina.
- When the rods and cones are stimulated by light, their physical structure briefly changes. This change decreases the amount of the neurotransmitter glutamate being released, which alters the activity of neurons in the different layers of the retina. The final layer to receive this changed input consists of ganglion cells, which will eventually output to the optic nerve. The ratio of ganglion cells to cones in the fovea is approximately one to one. In contrast, there are roughly 10 rods for every ganglion cell.
- Cones are clustered in the fovea and have a one-to-one ratio with ganglion cells, while rods are limited to the periphery of the retina and have a ten-to-one ratio with ganglion cells.
- In daylight or under artificial light, the cones in the retina are more active than rods. They help us to detect differences in the colour of objects and to discriminate the objects' fine details. In contrast, if the lights suddenly go out or if you enter a dark room, at first you see next to nothing, but over time, you gradually begin to see your surroundings more clearly. **Dark adaptation** is the process by which the rods and cones become increasingly sensitive to light under low levels of illumination. What is actually happening during dark adaptation is that the photoreceptors are slowly becoming regenerated after having been exposed to light. Cones regenerate more quickly than do rods, often within about ten minutes. However, after this time, the rods become more sensitive than the cones.
- **The Retina and the Perception of Colours:**
- The cones of the retina are specialized for responding to different wavelengths of light that correspond to different colours. However, the subjective experience of colour occurs in the brain. Currently, two theories exist to explain how neurons in the eye can produce these colourful experiences.
- One theory suggests that three different types of cones exist, each of which is sensitive to a different range of wavelengths on the electromagnetic spectrum. These three types of cones were initially identified in the 18th century by physicist Thomas Young and then independently rediscovered in the 19th century by Hermann von Helmholtz. The resulting **trichromatic theory or Young-Helmholtz theory** maintains that colour vision is determined by three different cone types that are sensitive to short, medium, and long wavelengths of light. These cones respond to wavelengths associated with the colours blue, green, and red. The relative responses of the three types of cones allow us to perceive many different colours on the spectrum. Yellow is perceived by

combining the stimulation of red and green sensitive cones, whereas light that stimulates all cones equally is perceived as white.

- The second theory is the **opponent-process theory**. In the 19th century, Ewald Hering proposed the **opponent-process theory** of colour perception, which states that we perceive colour in terms of opposing pairs: red to green, yellow to blue, and white to black. This type of perception is consistent with the activity patterns of retinal ganglion cells. A cell that is stimulated by red is inhibited by green; when red is no longer perceived such as when you suddenly look at a white wall, a “rebound” effect occurs. Suddenly, the previously inhibited cells that fire during the perception of green are free to fire, whereas the previously active cells related to red no longer do so. The same relationship occurs for yellow and blue as well as for white and black.
- The trichromatic and opponent-process theories are said to be complementary because both are required to explain how we see colour. The trichromatic theory explains colour vision in terms of the activity of cones. The opponent-process theory of colour vision explains what happens when ganglion cells process signals from a number of different cones at the same time. Together, they allow us to see the intense world of colours that we experience every day.
- **Common Visual Disorders:**
- Most forms of **colour blindness** affect the ability to distinguish between red and green. In people who have normal colour vision, some cones contain proteins that are sensitive to red and some contain proteins that are sensitive to green. However, in most forms of colour blindness, one of these types of cones does not contain the correct protein. Most forms of colour blindness are genetic in origin.
- **Nearsightedness**, or **myopia**, occurs when the eyeball is slightly elongated, causing the image that the cornea and lens focus on to fall short of the retina. People who are nearsighted can see objects that are relatively close up but have difficulty focusing on distant objects.
- Alternatively, if the length of the eye is shorter than normal, the result is **farsightedness** or **hyperopia**. In this case, the image is focused behind the retina. Farsighted people can see distant objects clearly but not those that are close by.
- Both types of impairments can be corrected with contact lenses or glasses, thus allowing a focused visual image to stimulate the retina at the back of the eye, where light energy is converted into neural impulses.
- In the last 20 years, an increasing number of people have undergone laser eye surgery in order to correct near- or farsightedness. In this type of surgery, surgeons use a laser to reshape the cornea so that incoming light focuses on the retina, which produces close to perfect vision. In nearsighted patients, the doctors attempt to flatten the cornea, whereas in farsighted patients the doctors attempt to make the cornea steeper.
- **Visual Perception and the Brain:**
- Information from the optic nerve travels to numerous areas of the brain. The first major destination is the **optic chiasm**, the point at which the optic nerves cross

at the midline of the brain. For each optic nerve, about half of the nerve fibres travel to the same side of the brain (**ipsilateral**), and half of them travel to the opposite side of the brain (**contralateral**). The outside half of the retina, closest to your temples, sends its optic nerve projections ipsilaterally. In contrast, the inside half of the retina, closest to your nose, sends its optic nerve projections contralaterally. The result of this distribution is that the left half of your visual field is initially processed by the right hemisphere of your brain, whereas the right half of your visual field is initially processed by the left hemisphere of your brain. This serves important functions, particularly if a person's brain is damaged. In this case, having both eyes send some information to both hemispheres increases the likelihood that some visual abilities will be preserved.

- Fibres from the optic nerve first connect with the **thalamus**, the brain's "sensory relay station." The thalamus is made up of over 20 different nuclei with specialized functions. The **lateral geniculate nucleus (LGN)** is specialized for processing visual information. Fibres from this nucleus send messages to the visual cortex, located in the occipital lobe, where the complex processes of visual perception begin. The lateral geniculate nucleus in the thalamus is where the information from the left and right optic nerves converge.
- The visual cortex make sense of all this incoming information starting with a division of labour among specialized cells. One set of cells in the visual cortex, first discovered by Canadian David Hubel and his colleague Torsten Wiesel in 1959, are referred to as **feature detection cells**. These cells respond selectively to simple and specific aspects of a stimulus, such as angles and edges. Feature detection cells of the visual cortex are thought to be where visual input is organized for perception; however, additional processing is required for us to accurately perceive our visual world. From the primary visual cortex, information about different features is sent for further processing in the surrounding secondary visual cortex. This area consists of a number of specialized regions that perform specific functions, such as the perception of colour and movement. These regions begin the process of putting together primitive visual information into a bigger picture. These specialized areas are the beginning of two streams of vision, each of which performs different visual functions. The **ventral stream** extends from the visual cortex to the lower part of the temporal lobe. The **dorsal stream**, on the other hand, extends from the visual cortex to the parietal lobe.
- **The Ventral Stream:**
- The ventral stream of vision extends from the visual cortex in the occipital lobe to the front portions of the temporal lobe. This division of our visual system performs a critical function: object recognition. Groups of neurons in the temporal lobe gather shape and colour information from different regions of the secondary visual cortex and combine it into a neural representation of an object.
- We can identify objects even when they are viewed in different lighting conditions or at different angles. This observation is an example of what is called **perceptual constancy**, the ability to perceive objects as having constant shape, size, and colour despite changes in perspective. What makes perceptual

constancy possible is our ability to make relative judgments about shape, size, and lightness.

- Specific genetic problems or brain damage can lead to an inability to recognize faces, a condition known as **prosopagnosia** or face blindness. People with face blindness are able to recognize voices and other defining features of individuals, but not faces. Importantly, these patients tend to have damage or dysfunction in the same general area of the brain: the bottom of the right temporal lobe.
- Brain imaging studies have corroborated the location of the "face area" of the brain. Using fMRI, researchers have consistently detected activity in this region, now known as the **fusiform face area (FFA)**. The FFA responds more strongly to the entire face than to individual features. Unlike other types of stimuli, faces are processed holistically rather than as a nose, eyes, ears, chin, and so on. However, the FFA shows a much smaller response when we perceive inverted faces. In this case, people tend to perceive the individual components of the face rather than perceiving the faces as a holistic unit. Interestingly, the FFA is also active when we perceive images of faces in everyday objects. The fact that these illusory perceptions of faces, known as **face pareidolia**, also activate the FFA suggests that this structure is influenced by top-down processing that treats any face-like pattern as a face.
- Although no one doubts that faces are processed by the FFA, there are alternative explanations for these effects. One possibility is that the FFA is being activated by one of the cognitive or perceptual processes that help us perceive faces rather than by the perception of faces themselves.
- The fact that a specific brain region is linked with the perception of faces is very useful information for neurologists and emergency room physicians. If a patient has trouble recognizing people, it could be a sign that he has damage to the bottom of the right temporal lobe.
- **The Dorsal Stream:**
- The dorsal stream of vision extends from the visual cortex in our occipital lobe upwards to the parietal lobe. The ventral stream identifies the object, and the dorsal stream locates it in space and allows you to interact with it.
- **Depth Perception:**
- **Binocular depth cues** are distance cues that are based on the differing perspectives of both eyes.
- **Convergence** occurs when the eye muscles contract so that both eyes focus on a single object. Convergence typically occurs for objects that are relatively close to you.
- **Retinal disparity/binocular disparity** is the difference in relative position of an object as seen by both eyes, which provides information to the brain about depth.
- **Monocular cues** are depth cues that we can perceive with only one eye.
- During **accommodation**, a monocular depth cue, the lens of your eye curves to allow you to focus on nearby objects.
- **Motion parallax** is a monocular depth cue in which we view objects that are closer to us as moving faster than objects that are further away from us.

- **Section 4.3 The Auditory and Vestibular Systems:**
- **Sound:**
- The function of the human ear is to detect sound waves and to transform them into neural signals. Sound waves are simply changes in mechanical pressure transmitted through solids, liquids, or gases.
- Sound waves have two important characteristics: frequency and amplitude.
- **Frequency** refers to wavelength and is measured in **hertz (Hz)**, the number of cycles a sound wave travels per second. Frequency is the quality of sound waves that is associated with changes in pitch.
- **Pitch** is the perceptual experience of sound wave frequencies.
  I.e. Pitch is the degree of highness or lowness of a sound.
- High-frequency sounds have short wavelengths and a high pitch.
- Low-frequency sounds have long wavelengths and a low pitch.
- The **amplitude** of a sound wave determines its loudness. High-amplitude sound waves are louder than low-amplitude waves.
- Humans are able to detect sounds in the frequency range from 20 Hz to 20 000 Hz.
- **Loudness**, a function of sound wave amplitude, is typically expressed in units called **decibels (dB)**.
- **The Human Ear:**
- The human ear is divided into outer, middle, and inner regions.
- The most noticeable part of your ear is the **pinna**, the outer region that helps channel sound waves to the ear and allows you to determine the source or location of a sound.
- The **auditory canal** extends from the pinna to the eardrum. Sound waves reaching the eardrum cause it to vibrate. Even very soft sounds, such as a faint whisper, produce vibrations of the eardrum.
- The middle ear consists of three tiny movable bones called **ossicles**, known individually as the **malleus** (hammer), **incus** (anvil), and **stapes** (stirrup).
- The eardrum is attached to these bones, so any movement of the eardrum due to sound vibrations results in movement of the ossicles.
- The ossicles attach to an inner ear structure called the **cochlea**, a fluid-filled membrane that is coiled in a snail-like shape and contains the structures that convert sound into neural impulses.
- Converting sound vibrations to neural impulses is possible because of hair-like projections that line the basilar membrane of the cochlea. The pressing and pulling action of the ossicles causes parts of the basilar membrane to flex. This causes the fluid within the cochlea to move, displacing these tiny hair cells. When hair cells move, they stimulate the cells that comprise the auditory nerves. The auditory nerves are composed of bundles of neurons that fire as a result of hair cell movements. These auditory nerves send signals to the thalamus, the sensory relay station of the brain, and then to the auditory cortex, located within the temporal lobes.

- As you might expect, damage to any part of the auditory system will result in hearing impairments. However, recent technological advances, such as cochlear implants, are allowing individuals to compensate for this hearing loss.
- **Sound Localization Finding the Source:**
- **Sound localization**, the process of identifying where sound comes from, is handled by parts of the brainstem as well as by a midbrain structure called the **inferior colliculus**.
- There are two ways that we localize sound:
    1. We take advantage of the slight time difference between a sound hitting both ears to estimate the direction of the source.
    2. We localize sound by using differences in the intensity in which sound is heard by both ears. This is known as a **sound shadow**.
- **Theories of Pitch Perception:**
- How we perceive pitch is based on the location along the basilar membrane that sound stimulates, a tendency known as the **place theory of hearing**.
- High-frequency sounds stimulate hair cells closest to the ossicles, whereas lower-frequency sounds stimulate hair cells toward the end of the cochlea.
- Another determinant of how and what we hear is the rate at which the ossicles press into the cochlea, sending a wave of activity down the basilar membrane.
- According to **frequency theory**, the perception of pitch is related to the frequency at which the basilar membrane vibrates.
  E.g. A 70-Hz sound stimulates the hair cells 70 times per second. Thus, 70 nerve impulses per second travel from the auditory nerves to the brain, which interprets the sound frequency in terms of pitch.
- However, we quickly reach an upper limit on the capacity of the auditory nerves to send signals to the brain: Neurons cannot fire more than 1000 times per second.
- However, we hear sounds exceeding 1000 Hz because of the **volley principle**. According to the volley principle, groups of neurons fire in alternating fashion.
- **Auditory Perception and the Brain:**
- The **primary auditory cortex** is a major perceptual centre of the brain involved in perceiving what we hear.
- The auditory cortex is organized in a very similar fashion to the cochlea. Cells within different areas across the auditory cortex respond to specific frequencies.
- The primary auditory cortex is surrounded by brain regions that provide additional sensory processing. This secondary auditory cortex helps us to interpret complex sounds, including those found in speech and music.
- The auditory cortices in the two hemispheres of the brain are not equally sensitive. In most individuals the right hemisphere is able to detect smaller changes in pitch than the left hemisphere and thus, the right hemisphere is also superior at detecting sarcasm, as this type of humour is linked to the tone of voice used.
- We are not born with a fully developed auditory cortex. In order to perceive our complex auditory world, the auditory cortices must learn to analyze different patterns of sounds.

- Brain imaging studies have shown that infants as young as three months of age are able to detect simple changes in pitch.
- Infants can detect silent gaps in a tone between the ages of 4 to 6 months, and develop the ability to localize sound at approximately 8 months of age. By 12 months of age, the auditory system starts to become specialized for the culture in which the infant is living. However, infants who are 10–12 months of age do not recognize sound patterns that are not meaningful in their native language or culture. Thus, children in this age group show different patterns of brain activity when hearing culturally familiar and unfamiliar sounds. This brain plasticity explains why many of us have difficulty hearing fine distinctions in the sounds of languages we are exposed to later in life. Interestingly, this fine-tuning of the auditory cortex also influences how we perceive music.
- **The Perception of Music:**
- Our ability to compare different pitches uses both the primary and secondary auditory cortex.
- Music perception also uses the human brain's ability to organize information into a coherent structure or pattern.
- The body's ability to adjust its position leads us to a discussion of another role played by the structures found within our ears: balance.
- When we listen to music, most people are able to detect the fact that certain patterns tend to repeat; as a result, our brains begin to expect beats to occur at specific times. This is the basis of our ability to detect musical beats or rhythms. This ability to detect rhythms or beats appears to be innate as even babies can do it.
- A number of brain imaging studies have shown that perceiving musical beats leads to activity in brain areas that are involved with coordinating movements.
- Researchers have shown that individual differences in the ability to detect musical beats are linked to differences in activity in the basal ganglia, a group of brain structures in the centre of the brain that are related to the coordination of movement.
- However, the basal ganglia does not work alone. When we perceive beats, there is an increase in connectivity between the basal ganglia and areas of the frontal lobe related to the planning of movements.
- Recently, researchers found that individuals with Parkinson's disease, who have damage to structures that input to the basal ganglia, have difficulty picking out subtle musical beats.
- **Sensation and the Vestibular System:**
- Our sense of balance is controlled, at least in part, by our **vestibular system**, a sensory system in the ear that provides information about spatial orientation of the head as well as head motion.
- This system consists of two groups of structures:
    1. The **vestibular sacs** are structures that influence your ability to detect when your head is no longer in an upright position. This section of your vestibular system is made up of two parts, the **utricle** ("little pouch") and the **saccule** ("little sac"). The bottom of both of these sacs is lined with

cilia (small hair cells) embedded in a gelatinous substance. When you tilt your head, the gelatin moves and causes the cilia to bend. This bending of the cilia opens up ion channels, leading to an action potential.

2. The **semicircular canals** are three fluid-filled canals found in the inner ear that respond when your head moves in different directions (up-down, left-right, forward-backward). The semicircular canals are responsible for your ability to perceive when your head is in motion. Receptors in each of these canals respond to movement along one of these planes. At the base of each of these canals is an enlarged area called the **ampulla**. The neural activity within the ampulla is similar to that of the vestibular sacs. Cilia are embedded within a gelatinous mass. When you move your head in different directions, the gelatin moves and causes the cilia to bend. This bending makes an action potential more likely to occur.

- **The Vestibular System and the Brain:**
- The two parts of the vestibular system send information along the vestibular ganglion to nuclei in the brainstem. Vestibular nuclei can then influence activity in a number of brain areas.
- The vestibular nuclei also project to part of the **insula**, an area of cortex that is folded in the interior of the brain. The insula helps us link together visual, somatosensory, and vestibular information.
- One reason for motion sickness is because of an inconsistency in the input from your visual and vestibular systems. The visual input is not moving, yet your vestibular system is sending signals to your brain saying that your body is in a moving car.
- **Module 4.4 Touch and the Chemical Senses:**
- **The Sense of Touch:**
- Sensual experiences are dependent on the actions of several types of receptors located just beneath the surface of the skin and also in the muscles, joints, and tendons. These receptors send information to the **somatosensory cortex** in the parietal lobes of the brain, the neural region associated with your sense of touch.
- Sensitivity to touch varies across different regions of the body. One simple method of testing **acuity** is to use the two-point threshold test. Regions with high acuity, such as the fingertips, can detect the two separate, but closely spaced, pressure points of the device, whereas less sensitive regions such as the lower back will perceive the same stimuli as only one pressure point. Body parts such as the fingertips, palms, and lips are highly sensitive to touch compared to regions such as the calves and forearms.
- Research has shown that women have a slightly more refined sense of touch than men, precisely because their fingers and therefore their receptors are smaller.
- The sensitivity of different parts of the body also influences how much space in the somatosensory cortex is dedicated to analyzing each body part’s sensations. Regions of the body that send a lot of sensory input to the brain such as the lips have taken over large portions of the somatosensory cortex while less sensitive regions like the thigh use much less neural space

- Like vision and hearing, touch is very sensitive to change. Merely laying your hand on the surface of an object does little to help identify it. What we need is an active exploration that stimulates receptors in the hand. **Haptics** is the active, exploratory aspect of touch sensation and perception.
- Active touch involves feedback. Haptics allows us not only to identify objects, but also to avoid damaging or dropping them. Fingers and hands coordinate their movements using **kinesthesis**, the sense of bodily motion and position.
- **Feeling Pain:**
- **Nociception** is the activity of nerve pathways that respond to uncomfortable stimulation.
- Our skin, teeth, corneas, and internal organs contain nerve endings called **nociceptors**, which are receptors that initiate pain messages that travel to the central nervous system.
- Two types of nerve fibres transmit pain messages:
    1. Fast fibres register sharp, immediate pain, such as the pain felt when your skin is scraped or cut.
    2. Slow fibres register chronic, dull pain, such as the lingering feelings of bumping your knee into the coffee table.
- The **gate-control theory** states that cells in the spinal cord regulate how much pain signalling reaches the brain. The spinal cord serves as a “neural gate” that pain messages must pass through. The spinal cord contains small nerve fibres that conduct pain messages and larger nerve fibres that conduct other sensory signals such as those associated with rubbing, pinching, and tickling sensations. Stimulation of the small pain fibres results in the experience of pain, whereas the larger fibres inhibit pain signals so that other sensory information can be sent to the brain. Thus, the large fibres close the gate that is opened by the smaller fibres.
- **Phantom Limb Pain:**
- **Phantom limb sensations** are frequently experienced by amputees, who report pain and other sensations coming from the absent limb.
- One explanation for phantom pain suggests that rewiring occurs in the brain following the loss of the limb. After limb amputation, the area of the somatosensory cortex formerly associated with that body part is no longer stimulated by the lost limb. Thus, if someone has her left arm amputated, the right somatosensory cortex that registers sensations from the left arm no longer has any input from this limb. Healthy nerve cells become hypersensitive when they lose connections. The phantom sensations, including pain, may occur because the nerve cells in the cortex continue to be active, despite the absence of any input from the body.
- One ingenious treatment for phantom pain involves the mirror box. This apparatus uses the reflection of the amputee’s existing limb, such as an arm and hand, to create the visual appearance of having both limbs. Amputees often find that watching themselves move and stretch the phantom hand, which is actually the mirror image of the real hand, results in a significant decrease in phantom pain and in both physical and emotional discomfort.

- **The Gustatory System Taste:**
- The **gustatory system** functions in the sensation and perception of taste.
- There are approximately 2500 identifiable chemical compounds in the food we eat. When combined, these compounds give us an enormous diversity of taste sensations. The **primary tastes** include salty, sweet, bitter, and sour. In addition, a fifth taste, **umami**, has been identified. **Umami**, sometimes referred to as “savouriness,” is a Japanese word that refers to tastes associated with seaweed, the seasoning monosodium glutamate (MSG), and protein-rich foods such as milk and aged cheese.
- Taste is registered primarily on the tongue, where roughly 9000 taste buds reside. In addition, on average, approximately 1000 taste buds are also found throughout the sides and roof of the mouth.
- The middle of the tongue has very few taste receptors, giving it a similar character to the blind spot on the retina.
- Taste receptors replenish themselves every 10 days throughout the life span—the only type of sensory receptor to do so.
- Receptors for taste are located in the visible, small bumps (papillae) that are distributed over the surface of the tongue. The papillae are lined with taste buds. The bundles of nerves that register taste at the taste buds send the signal through the thalamus and on to higher-level regions of the brain, including the gustatory cortex. Another region, the **secondary gustatory cortex**, processes the pleasurable experiences associated with food.
- One reason that some people experience tastes vividly while other people do not is because the number of taste buds present on the tongue influences the psychological experience of taste. Although approximately 9000 taste buds is the average number found on the human tongue, there is wide variation among individuals. Some people may have many times this number. Supertasters, who account for approximately 25% of the population, are especially sensitive to bitter tastes such as those of broccoli and black coffee. They typically have lower rates of obesity and cardiovascular disease, possibly because they tend not to prefer fatty and sweet foods.
- **The Olfactory System Smell:**
- The **olfactory system** is involved in the detection of airborne particles with specialized receptors located in the nose.
- Our sensation of smell begins with nasal airflow bringing in molecules that bind with receptors at the top of the nasal cavity.
- Within the nasal cavity is the **olfactory epithelium**, a thin layer of cells that are lined by sensory receptors called **cilia**—tiny hair-like projections that contain specialized proteins that bind with the airborne molecules that enter the nasal cavity.
- Humans have roughly 1000 different types of odour receptors in their olfactory system, but can identify approximately 10,000 different smells. This is possible because it is the pattern of the stimulation which gives rise to the experience of a particular smell. Different combinations of cilia are stimulated in response to different odours.

- These groups of cilia then transmit messages directly to neurons that converge on the **olfactory bulb** on the bottom surface of the frontal lobes, which serves as the brain's central region for processing smells. Unlike our other senses, olfaction does not involve the thalamus.
- The olfactory bulb connects with several regions of the brain through the olfactory tract, including the limbic system as well as regions of the cortex where the subjective experience of pleasure or disgust occurs.
- **Multimodal Integration:**
- **Multimodal integration** is the ability to combine sensation from different modalities such as vision and hearing into a single integrated perception.
- **Synesthesia:**
- **Synesthesia** is a condition in which one sense (e.g. hearing) is simultaneously perceived as if by one or more additional senses such as sight.
- More recent studies suggest that the brains of people with synesthesia may contain networks that link different sensory areas in ways not found in other people.
- **Autonomous sensory meridian response (ASMR)** is a condition in which specific auditory or visual stimuli trigger tingling sensations in the scalp and neck, sometimes extending across the back and shoulders. Like synesthesia, ASMR appears to be caused by unusual patterns of connections between different brain areas.

Definitions:

- **Absolute threshold:** The minimum amount of energy or quantity of a stimulus required for it to be reliably detected at least 50% of the time it is presented.
- **Autonomous sensory meridian response (ASMR):** A condition in which specific auditory or visual stimuli trigger tingling sensations in the scalp and neck, sometimes extending across the back and shoulders.
- **Binocular depth cues:** Distance cues that are based on the differing perspectives of both eyes.
- **Bottom-up processing:** Occurs when we perceive individual bits of sensory information (e.g. sounds) and use them to construct a more complex perception (e.g. a message).
- **Cochlea:** A fluid-filled membrane that is coiled in a snail-like shape and contains the structures that convert sound into neural impulses.
- **Conduction hearing loss:** Hearing loss resulting from damage to any of the physical structures that conduct sound waves to the cochlea.
- **Cones:** Photoreceptors that are sensitive to the different wavelengths of light that we perceive as colour.
- **Convergence:** Occurs when the eye muscles contract so that both eyes focus on a single object.
- **Cornea:** The clear layer that covers the front portion of the eye and also contributes to the eye's ability to focus.
- **Dark adaptation:** The process by which the rods and cones become increasingly sensitive to light under low levels of illumination.

- **Difference threshold:** The smallest difference between stimuli that can be reliably detected at least 50% of the time.
- **Divided attention:** Paying attention to more than one stimulus or task at the same time.
- **Doctrine of specific nerve energies:** First proposed in 1826 by the German physiologist Johannes Muller, the doctrine states that the different senses are separated in the brain.
- **Fovea:** The central region of the retina.
- **Frequency theory:** The perception of pitch is related to the frequency at which the basilar membrane vibrates.
- **Gate-control theory:** Explains our experience of pain as an interaction between nerves that transmit pain messages and those that inhibit these messages.
- **Gustatory system:** Functions in the sensation and perception of taste.
- **Haptics:** The active, exploratory aspect of touch sensation and perception.
- **Inattentional blindness:** A failure to notice clearly visible events or objects because attention is directed elsewhere.
- **Iris:** A round muscle that adjusts the size of the pupil; it also gives the eyes their characteristic colour.
- **Kinesthesis:** The sense of bodily motion and position.
- **Lens:** A clear structure that focuses light onto the back of the eye.
- **Monocular cues:** Depth cues that we can perceive with only one eye.
- **Multimodal integration:** The ability to combine sensation from different modalities such as vision and hearing into a single integrated perception.
- **Nociception:** The activity of nerve pathways that respond to uncomfortable stimulation.
- **Olfactory bulb:** A structure on the bottom surface of the frontal lobes that serves as the brain's central region for processing smells.
- **Olfactory epithelium:** A thin layer of cells that are lined by sensory receptors called cilia.
- **Olfactory system:** Involved in smell—the detection of airborne particles with specialized receptors located in the nose.
- **Opponent-process theory:** A theory of colour perception stating that we perceive colour in terms of opposing pairs: red to green, yellow to blue, and white to black.
- **Optic nerve:** A dense bundle of fibres that connect to the brain.
- **Perception:** Involves attending to, organizing, and interpreting stimuli that we sense. Is the study of how physical events relate to psychological perceptions of those events.
- **Perceptual constancy:** The ability to perceive objects as having constant shape, size, and colour despite changes in perspective.
- **Phantom limb sensations:** Frequently experienced by amputees, who report pain and other sensations coming from the absent limb.
- **Pitch:** The perceptual experience of sound wave frequencies.
- **Place theory of hearing:** How we perceive pitch is based on the location along the basilar membrane that sound stimulates.

- **Primary auditory cortex:** A major perceptual centre of the brain involved in perceiving what we hear.
- **Psychophysics:** The study of the relationship between the physical world and the mental representation of that world.
- **Pupil:** Regulates the amount of light that enters the eye by changing its size. It dilates to allow more light to enter and constricts to allow less light into the eye.
- **Retina:** Lines the inner surface of the eye and consists of specialized receptors that absorb light and send signals related to the properties of light to the brain.
- **Retinal disparity/binocular disparity:** The difference in relative position of an object as seen by both eyes, which provides information to the brain about depth.
- **Rods:** Photoreceptors that occupy peripheral regions of the retina. They are highly sensitive under low light levels.
- **Sclera:** Is the white, outer surface of the eye.
- **Selective attention:** Involves focusing on one particular event or task.
- **Semicircular canals:** Three fluid-filled canals found in the inner ear that respond when the head moves in different directions (up-down, left-right, forward-backward).
- **Sensation:** The process of detecting external events with sense organs and turning those stimuli into neural signals.
- **Sensorineural hearing loss:** Hearing loss that results from damage to the cochlear hair cells and the neurons comprising the auditory nerve.
- **Sensory adaptation:** The reduction of activity in sensory receptors with repeated exposure to a stimulus.
- **Signal detection theory:** Whether a stimulus is perceived depends on both sensory experience and judgment made by the subject.
- **Sound localization:** The process of identifying where sound comes from.
- **Top-down processing:** When our perceptions are influenced by our expectations or by our prior knowledge.
- **Transduction:** Takes place when specialized receptors transform the physical energy of the outside world into neural impulses.
- **Trichromatic theory/Young-Helmholtz theory:** Maintains that colour vision is determined by three different cone types that are sensitive to short, medium, and long wavelengths of light.
- **Vestibular sacs:** Structures that influence your ability to detect when your head is no longer in an upright position.
- **Vestibular system:** A sensory system in the ear that provides information about spatial orientation of the head as well as head motion.
- **Weber's law:** States that the just noticeable difference between two stimuli changes as a proportion of those stimuli.