

Educator's Guide and Script For
Human Body: The Sensory System

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INTRODUCTION

The goal of this program is to present an upper level high school or introductory pre-med or pre-nursing school overview of the anatomy and physiology of the sensory system. Using latest in 3-D graphics, medical imaging and for the first time detailed cadaver dissection, this program is designed to maximize student learning. *Human Body: The Sensory System* begins with an overview of how the exquisite system of human sensory organs evolved as a means of gaining information about our environment. Then the program examines each of the five senses: touch, smell, taste, hearing and sight in separate chapters. Each chapter provides an in depth look at how each sense functions not only to allow humans to enjoy life but to provide valuable information to make our lives safer and more robust.

ADVANCED VOCABULARY DEFINITIONS

- **Anvil:** Also known as the incus, it is the anvil shaped small bone in the middle ear that connects the malleus to the stapes
- **Aromatherapy:** Aromatherapy is a form of alternative medicine that uses volatile plant materials, known as essential oils, and similar aromatic compounds from plants, for the purpose of improving a person's mood, cognitive function or health
- **Auditory canal:** The ear canal, a tube running from the outer ear to the middle ear
- **Auditory cortex:** The primary region of the brain that is responsible for processing of sound information
- **Auricle:** The outer ear or pinna
- **Cochlea:** The snail-shaped structure in the inner ear where sound vibrations are converted into nerve impulses
- **Cornea:** The clear, dome-shaped front portion of the eye through which light passes to the lens
- **Dermis:** The deep vascular inner layer of the skin
- **Eardrum:** The membrane in the ear that vibrates to sound
- **Epidermis:** The outer layer of the skin covering the exterior body surface

- **Hammer:** Also known as the malleus, it is a hammer-shaped small bone of the middle ear which connects with the anvil and is attached to the inner surface of the eardrum
- **Homunculus:** A small construct of a human being
- **Inner ear:** The portion of the ear located within the temporal bone which includes the semicircular canals, vestibule, and cochlea and is responsible for hearing and balance
- **Iris:** Situated between the cornea and the lens, it is a thin diaphragm composed mostly of connective tissue and smooth muscle fibers
- **Lacrimal gland:** An almond-shaped gland of the eye that secretes tears
- **Limbic System:** A set of brain structures including the hippocampus, amygdala, anterior thalamic nuclei, and limbic cortex, which support a variety of functions including emotion, behavior, and long term memory
- **Middle ear:** The main cavity of the ear; between the eardrum and the inner ear
- **Nasal Chamber:** The chamber of the nose lying behind the vestibule of the external nose
- **Olfactory bulb:** A bulb shaped brain structure that receives input from the nerves of the nose
- **Optic nerve:** The nerve that transmits visual information from the retina to the brain
- **Photoreceptors:** A specialized neuron able to detect, and react to light
- **Retina:** The inner, light-sensitive layer of the eye; includes the rods and cones
- **Rods and cones:** These are cells inside the eye used by the retina to process light. Rods are used for low light levels and cones are used much higher light intensities
- **Sclera:** The whitish fibrous membrane that with the cornea forms the outer covering and protection of the eyeball
- **Sense receptors:** A sensory nerve ending that recognizes a stimulus in the internal or external environment of an organism
- **Sensory cortex:** The region of the brain associated with the parietal lobe
- **Stirrup:** Also known as the stapes, it is the stirrup-shaped bone that transmits sound from the anvil to the cochlea
- **Taste buds:** The cluster of receptors located on the tongue and soft palate that determine different tastes, such as sweet and sour
- **Temporal bone:** a thick bone forming the side of the human cranium and encasing the inner ear
- **Tear ducts:** Carry tears from the lacrimal sac into the nasal cavity
- **Vitreous humor:** The gel-like fluid in the main cavity of the eye behind lens and pupil that accounts for 80% of the eye's volume

SCRIPT

HUMAN BODY: THE SENSORY SYSTEM

The miracle of all miracles on this planet is the human body. Now see it in a way never revealed before.

The body has an exquisite system of sensory organs: eyes, ears, nose, tongue, the skin covering our body, all poised to keep us safe and provide us with pleasurable experiences throughout our lifetime. I am Dr. Mark Reisman. Let's explore the remarkable world of the human senses.

Evolution of the Senses

Augustina is in the kitchen making soup. Her keen sense of smell detects the rich aromas of the spices she's added to her brew. The timer goes off. Her hearing tells her it's time to taste the soup. Sensors on her lips, one of the most sensitive parts of her body, tell her that the soup is too hot for tasting. Using the refined sense of taste on her tongue, she detects a general lack of salt in the flavoring. Using her eyes, she scans the kitchen. She scans for where she last placed the salt container. Using the sense of touch in her fingertips, she is able to grab a pinch of salt. The soup is now ready, ready for a savory dining experience.

Senses have evolved over time as a way for animals to get information about their environment. Being alive means having some sensitivity to the surrounding world. Even single cell microbes have environmental awareness able to detect nearby chemical reactions.

Plants are sensitive to light, move their leaves and flower heads to track the sun as it moves through the sky. But it is members of the animal kingdom that require an even greater sensitivity to the environment. Even relatively simple animals, such as worms, have a keen sense of touch. They also have the ability to detect chemicals in the environment and have a simple sense of sight.

But it is early vertebrates, such as fish, that developed sight to a very high level through the evolution of eyes. And they can hear too. Interestingly, almost all fish have an inner ear very similar to our own. But they have no outer ear or eardrums. Instead sounds are carried to the inner ear by the body's tissue. Not surprisingly, fish have a sense we don't. They are able to detect subtle changes in water flow, sometimes as far away as 100 yards.

We all know that dogs have a keener sense of hearing than we do, and a much more developed sense of smell, almost 40 times more sensitive. This combination is probably why they have become such a great complement to us humans, sensing danger long before our own senses will come into play.

And birds of prey, like a bald eagle, have vision that is about eight times more powerful than our own. In short, there is nothing more important for an animal's survival than its senses, senses that inform it about the environment, telling it about danger and where food is.

Touch and Skin

Like the worm, our oldest, most primitive and pervasive sense is touch. Erin is blind. Nevertheless, she can still read using Braille - a system of raised dots which can be read by touch. Erin is able to differentiate stimuli that are only 1/10 of an inch apart. Unlike our other four senses, senses that have particular locations, touch sensors are located in the skin. They are everywhere.

Our skin is a most remarkable material. It is elastic. It protects us from solar radiation. It keeps stuff out like water. On average, it makes up about 10 pounds of the typical adult's body weight. Spread out it covers 20 square feet. Indeed, skin is the largest of the body's organs, an organ that helps regulate internal body temperature. And it's what we show to the world, particularly what we show to other people.

The most sensitive areas of the body are hands, face, neck, tongue, our feet, and the most sensitive of all: fingertips, and of course, lips. Go beneath the skin and you'll find a multiplicity of sense receptors.

Known as the homunculus, this 'little man' is a visualization of how the sensory cortex senses your body.

Anatomically, the skin is divided into two layers. The outer layer is the epidermis, the part of the skin we see. And the second, lower layer called the dermis. Here is where a multiplicity of your touch receptors are located. An area the size of your fingernail contains hundreds of these receptors. Your body has about twenty different types of nerve endings that all send messages to your brain. But the three most common receptors are - heat and cold, pain, and finally, pressure or touch receptors. The result is our skin receptors give us an important picture of the world, and tell us what is happening in our environment in an immediate way that helps ensure our survival.

Touch is keenly developed in children. Before sight and sound, children use touch to explore their world and develop their ability to control their muscles, control them by tracking and following the movements of their loving parents. And as we parents know, soon children are eager to learn about the world through their senses of taste and smell.

Smell

Tyler and Kira are about to have a fine meal. As they wait for their server, chemical changes are taking place inside their mouths. And already the smells of the restaurant are stimulating a visceral anticipation of the savory food that will soon arrive. Also, the familiar smell of the restaurant vividly recalls memories of an earlier time when Tyler

proposed to Kira. It creates a warm emotional glow for each. Smells are profound memory triggers for humans. The wine is brought out. Kira, who is a wine connoisseur, first smells the wine. Then swishes it around in her mouth, stimulating the taste buds on her tongue, and releasing more odors that find their way to the roof of her nasal chamber. As an adult, Kira can distinguish over 10,000 odors, odors that are commonly mistaken for tastes.

Remember all those single celled life forms and those worms? ... Creatures with the ability to distinguish chemicals in their environment? That's what our smell and taste senses are about, the detection of chemical substances in our environment.

For our diners, the sense of taste and smell are two of their most primitive senses. But senses with direct and immediate pathways to the brain. Here is how smell works.

Every time we inhale, currents of air swirl up through the nostrils to a "sheet" about the size of a small postage stamp on the roof of each nasal cavity, nasal cavities containing millions of olfactory receptor neurons. This section of the body is generally referred to as the olfactory bulb. Located here, it is actually an outgrowth of brain tissue. And because the olfactory bulb is part of the brain's limbic system, an area closely associated with memory and feeling, the olfactory bulb is sometimes called the "emotional brain." And of course, the world of smells is big business. Perfumes and fragrances gross over \$30 billion annually. And then there is the rapid development of an aromatherapy industry, an industry that employs scents to manage emotions.

Taste

The tongue is a really intriguing organ. It is a fleshy, movable, muscle attached to the floor of your mouth. I use it to move the food around as I chew. As I do this, taste arises, as with this apple. With the tip of my tongue, I detect sweetness. On the side of my tongue I determine that this apple has a sour tang to it. I take a sip of this coffee, and at the back of my tongue I taste its bitterness. Again on the side of my tongue, I can experience the salty nature of this chip. Sweet, sour, bitter and salty are the four basic tastes the tongue is able to detect, tastes that can be mapped across the surface of your tongue.

Here is a map of the taste buds on your tongue. For our two diners, only chemicals that dissolve in water determine the taste of the food they are eating. In other words, dissolved by their saliva. They will sense salty food almost immediately as it is instantly soluble in water, while other complex food molecules dissolve more slowly.

And of course, they have learned that each other's tastes are different. Everybody's tastes are a little different. In fact, your tastes will change as you get older. When you were a baby, you had taste buds not only on your tongue, but also on the sides and roof of your mouth. You started out very sensitive to different foods. But as you grew older, the nearly 10,000 taste buds began to disappear from the sides and roof of your mouth, leaving taste buds mostly on your tongue. In fact, as you age, your taste buds will decline

to about 5,000 and become less sensitive. This is why you will begin to eat foods that you hated as a child.

Hearing

If the body ultimately converts chemicals in the environment to neural electrical impulses through our senses of taste and smell, hearing converts mechanical movement into electrical impulses sent to the brain by a most ingenious biomechanical mechanism, a mechanism that also gives us our sense of balance.

The last of our five major senses to evolve was hearing. Hearing allows animals to sense danger at a distance, as well as communicate over vast distances, like when birds sing their songs.

Dancers, such as these, use their ear mechanism to not only move in relation to the music but also to help keep their balance. These skills all come from one of the body's most remarkable pieces of bioengineering - the ear.

Sounds are produced when an object like this bell vibrates, or the vocal cords in here vibrate and you can hear me speak. The vibrations produced by my vocal chords and the bell compress the air surrounding them, compress the air like the ripples on a pond. Like the ripples, sound waves move out from the source, such as the vibrating bell, in all directions. When the sound waves reach the ear, the ear mechanism through an incredible sequence of steps turns the sound into an electrical impulse that is sent to the brain where it is interpreted as a particular kind of sound. The ear mechanism is typically divided into three sections: the inner ear, the middle ear, and the outer ear.

When sound waves are produced from a source like my bell, they first encounter the outer ear which includes the irregularly shaped pieces of cartilage covered by skin called the auricle, and the ear lobe - the flap of skin that hangs down from the auricle, and of course, the opening and short auditory canal that transmits sound waves to the middle ear. The middle ear lies entirely within the skull. Separating the auditory canal from the middle ear cavity is the eardrum. Much like the skin on an actual drum vibrates when struck by drumsticks, the eardrum, a thin membrane, vibrates when struck by sound waves, in fact acting as an amplifier, thus beginning the remarkable conversion of sound waves into electrical impulses. Inside the middle ear are three tiny bones called the hammer, anvil and stirrup, named because of their resemblance to their real-life counterparts. When the eardrum vibrates, it causes the hammer to rock back and forth. This then causes the anvil to vibrate, which in turn causes the stirrup to move in and out. Now we come to the inner ear. Here the stirrup attaches to a membrane on what is called the organ of hearing. The inner ear occupies a large cavity in the temporal bone of the skull and contains a tiny structure shaped like a snail shell. Called the cochlea, it is filled with fluid. Fluid that produces pressure waves from the incoming vibrations. These pressure waves stimulate hair cells located on the inside of the cochlea, hair cells or nerve fibers that send nerve impulses to the auditory cortex of the brain. And at last,

miraculously, you interpret that as the sound of a bell. At least 10 steps, completed in microseconds. Further, because you have two ears you can also interpret the direction and distance of the original sounds.

In a movie chase scene the victim is able to determine the direction and distance of his pursuer by sound alone. He can do this because he has two ears.

Sight

Like hearing's two ears, we also have two eyes, two eyes that let us see color in three-dimensional space. Of all our senses, our eyes and sight have made us a vision-oriented species. Our vision is so refined that by the time we are nine years old, we can instantly interpret the objects in our environment and flawlessly focus on what is most important, most important to whatever task we are doing, such as when I am performing heart surgery.

Eyes have been around a long time. Some of the earliest complex creatures, such as these half a million-year-old trilobites, already had well-developed eyes. For us humans, eyesight provides our brain with more data about the outside environment than all the other senses combined. It is believed that half of the information in the conscious mind enters through the eyes. We can see color. In fact, the human eye can distinguish over 16 million shades of color. Our contrast range is greater than any modern camera, exceeding a contrast ratio of around 100:1 or about six and one-half f-stops. Most of us have a field of vision that encompasses 180° of the possible 360. And of course because we have binocular vision - two eyes - the world is revealed to us in three dimensions. So let's look at the anatomy of the human eyeball, and then trace the visual pathway, which conducts outside stimuli to the brain.

The human eye is an organ, an exquisite sensory organ, a spherical organ located in the skull's eye sockets. Connecting the sockets to the eyes are six small muscles. Considering their small size, they are some of the most powerful muscles of the body. Each moves the eye to one of the six "cardinal positions" of gaze: up/right, up/left, right, left, down/right and down/left. As we watch the eyeball roll around, we can see its external structures. Most obvious is the sclera, commonly known as "the white of the eye," a tough, opaque tissue that serves as the eye's protective outer coat. Inside is the colored iris, a membrane that is responsible for controlling the diameter and size of the dark pupil. The pupil is the doorway for light to enter the eye. And, of course, we all know eye color can range from green to blue to brown. Lastly, in the corner of each eye are the tear ducts that drain your tears, which are produced by the lacrimal gland. Interestingly, humans are the only known species to cry.

Next we come to the cornea, the transparent dome-like window at the front of the eye. Behind that is the lens, a transparent disc of tissue that changes shape, depending upon near or far vision. Behind the lens is the main bulk of the eye, a clear, jellylike fluid known as the vitreous humor. And at the back of the eye is the retina, a thin layer of light-sensitive rods and cones. These two kinds of photoreceptors are named for their

shapes. Rods function in low light and produce somewhat indistinct black-and-white images, whereas cones operate only in brighter light, and are responsible for clear, sharp, colorful images. The last piece of eyeball anatomy is the optic nerve, which connects the eye along a pathway to the brain.

Now let's look at the eye from the perspective of the sequence of vision. Light enters the eye at the cornea. The cornea bends the incoming light rays, light rays that are finely focused by the lens. The rays continue through the vitreous humor, finally projecting an upside down image on the retina lining. The retina converts the light rays into electrical impulses that proceed to the visual cortex of the brain.

It is the miracle of all miracles that somehow the brain puts it all together and when we look out on the world it all falls into place. We see what is important to us on a personal and cultural level.

Conclusion

We have just looked at the miraculous functioning of our five senses, especially as they relate to alerting us to danger and providing us with pleasure. But for us humans what's even more important about our sensory system is that it forms the foundation for language, language that has turned us into the only thinking species in the known universe. Thanks for joining me on our journey exploring our five senses. I'm Dr. Mark Reisman.

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