Miraculous Our Sensory World: How Do Four Anatomical Structures of Skeletal, Muscular, Nervous and Sensory Systems Work Together to see, smell, smile and taste?

Module 2 – The Nervous System

The town of Brainington is the capital city of Humanus Anatomeus and serves as it's control center. We are conducting a survey of the functions of this city focusing on the hardware and procedures used to protect its citizens. In the last two modules of Brainington, we learned of the openings of the skull and the muscles that are attached the skull.

Within the skull resides the brain, or the control center of Brainington. The brain is made up of four major regions. Each major region is described below:

1. **Cerebral Hemispheres**: These regions allow the city of Brainington to localize and interpret sensory inputs, control voluntary and involuntary muscle activity, process intellectual and emotional stimuli. These regions contain **gyri**, or elevated regions of tissue, and **sulci**, or shallow grooves that separate the gyri. Deeper grooves are known as **fissures**. The cerebral hemispheres contain both **cerebral cortex**, or **gray matter**, and **white matter**. The cerebral cortex is the superficial-most region of the cerebral hemispheres and functions as Brainington's "executive suite." That is, it is involved in processing sensations, making decisions, forming memories, etc. The white matter allows for communication between regions of the cerebral hemispheres and between the cerebral hemispheres and other brain regions. The cerebral Hemispheres contain several important anatomical landmarks, including:
   A. **Frontal lobe**: The anterior-most lobe of the brain. This lobe is separated from the more posterior parietal lobe by the **central sulcus** and from the more posterior and inferior temporal lobe by the **lateral sulcus**. The most posterior gyrus of this lobe is the **precentral gyrus** (just anterior to the central sulcus). The frontal lobe contains motor nerve centers that control motor function to the body, produce speech, and control eye movements.
   B. **Parietal lobe**: This lobe is separated from the more anterior frontal lobe by the **central sulcus**, the more inferior temporal lobe by the **lateral sulcus**, and the more posterior occipital lobe by the **parieto-occipital sulcus**. The anterior-most gyrus of this lobe is the **postcentral gyrus** (just posterior to the central sulcus). The parietal lobe contains the area that allows the perception and interpretation of sensory input from the body.
   C. **Temporal lobe**: This lobe is separated by the more superior frontal and parietal lobes by the **lateral sulcus** and by the more inferior cerebellum by the **transverse cerebral fissure**. The temporal lobe contains sensory areas that allow the perception and interpretation of auditory and olfactory input.
   D. **Occipital lobe**: The posterior-most lobe of the brain. This lobe is separated from the more anterior parietal lobe by the **parieto-occipital sulcus** and the more inferior cerebellum by the **transverse cerebral fissure**. The occipital

lobe contains sensory areas that allow the perception and interpretation of visual input.

E. **Insular lobe**: This is the fifth lobe of the brain and is buried deep to the **lateral sulcus**. The insular lobe is covered by parts of the frontal, parietal, and temporal lobes. The insula contains sensory areas that allow for the perception and interpretation of taste and the conscious perception of sensory input from the visceral organs.

2. **Diencephalon**: This region is located deep to the cerebral hemispheres and is involved in relaying information between parts of the cerebral hemispheres and between the cerebral hemispheres and other brain regions, such as the brain stem and cerebellum. The diencephalon is also involved in memory processing and controlling involuntary activities of the city of Brainington, such as overall city temperature, water balance, and hormonal output. The diencephalon is composed of several smaller centers including:
   - **A. Hypothalamus:** The anterior-most center of the diencephalon. This center is also just inferior to the thalamus. This center controls Brainington's water, temperature and hormonal output.
   - **B. Thalamus:** This center is just superior and posterior to the hypothalamus. This center relays information from the more inferior brain stem to specific lobes of the cerebral hemisphere for processing.
   - **C. Epithalamus:** This region is just inferior to the posterior side of the thalamus. This center controls Brainington's day/night cycle and lets its inhabitants know when the evening curfew starts.
3. **Cerebellum**: This region is separated by the more superior occipital lobe of the cerebral hemisphere by the **transverse cerebral fissure**. It is also located inferior and posterior to the diencephalon and posterior to the brain stem. The cerebellum functions to process information from the cerebral hemispheres to allow for smooth, coordinated movements and communication for the people of Brainington.
4. **Brain stem**: This region is located inferior to the diencephalon and anterior to the cerebellum. The brain stem also connects the rest of the brain of Brainington to the spinal cord, or the main highway leading into Brainington. The Brain stem functions to relay information between the cerebral hemispheres and the cerebellum and information between the spinal cord and the rest of the brain. The brain stem also relays information between the cerebral hemispheres and outer regions of the Brainington, such as the muscles. Several cranial nerves originate from the brain stem. The brain stem is composed of several smaller centers, including:
   - **A. Midbrain:** This region is located just inferior to the diencephalon and superior to the pons. Cranial nerves III and IV project from this center.
   - **B. Pons:** This region is located just inferior to the midbrain and superior to the medulla oblongata. Cranial nerves V, VI, VII, and VIII project from this center.
   - **C. Medulla oblongata:** This region is located just inferior to the pons and superior to the spinal cord. Cranial nerves IX, X, and XII project from this center.

Brainington has a complex and unique infrastructure with which it serves its inhabitants. The main connecting highway into and out of the city is called the **spinal cord.** Through the spinal cord Brainington receives vital input concerning conditions outside the city and sends out signals to takes actions that protect the city. There are other smaller highways that connect to specific parts of the surrounding countryside; these connections are termed **cranial nerves**. These cranial nerves can have sensory function (they sense things), motor function (they direct things to move), or both. There are 12 cranial nerves; the specific cranial nerves that serve the city are:

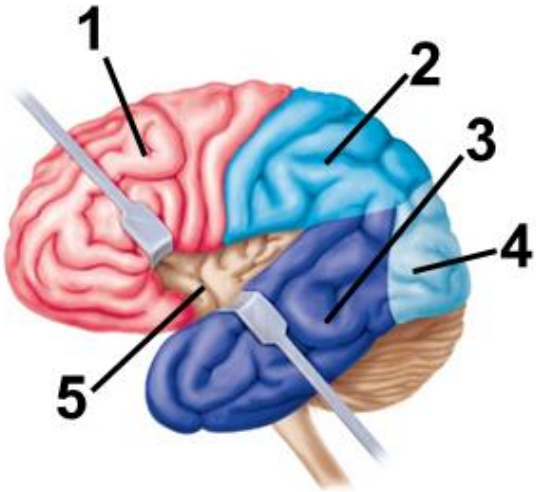
1. **CN I – the olfactory nerve** is a sensory nerve that extends to the anterior region of the brain, just inferior to the frontal lobe. At its distal end is a large bulb-like structure known as the **olfactory bulb**, while the thinner nerve leading to this bulb is the **olfactory tract**. The olfactory nerve carries information from the chemical "sniffers" deployed to detect polluted air. For us, this nerve has sensory function for smell.
   Sensory pathway: Nose -> Olfactory Nerve -> Temporal lobe -> Information processing.
2. **CN II – the optic nerve** is a sensory nerve that carries information from the optic sensors deployed on the periphery of the city (in us, these are known as eyes). To allow for three-dimensional vision, the optic nerves cross over each other in an “X” like pattern that is medial to the parietal lobes and inferior to the frontal lobe. This “X” like pattern is known as the **optic chiasma**.
   Sensory pathway: Eye -> Optic Nerve -> Thalamus (in diencephalon) -> Occipital lobe -> Information processing
3. **CN III – the oculomotor nerve** is a motor nerve that sends directions from the brain to the optic handles to "steer" them so they can focus in different directions. For us this nerve stimulates the muscles that control eye movement. The oculomotor nerve exits the midbrain and is just posterior and inferior to the optic chiasma of the optic nerve (II).
   Motor pathway: Frontal lobe -> Midbrain -> Oculomotor Nerve -> Eye muscles -> Movement
4. **CN IV – the trochlear nerve** is a motor nerve that also sends directions from the brain to the optic handles for “steering”. The trochlear nerve extends from the midbrain and is just lateral to the oculomotor nerve (III).
   Motor pathway: Frontal lobe -> Midbrain -> Oculomotor Nerve -> Eye muscles -> Movement
5. **CN V – the trigeminal nerve** has both sensory and motor functions. For sensory, it carries input from a variety of sensors located around the city (like the skin surrounding your skull when you feel something hot or cold). For motor, it sends output that controls the food processing machinery of the city (for us this is the muscles that move the mandible when chewing). The trigeminal nerve is a large nerve that extends from the pons and is just posterior and inferior to the trochlear nerve (IV).
   Sensory pathway: Skin, muscles, etc. -> Trigeminal Nerve -> Pons -> Thalamus -> Parietal lobe -> Information processing

Motor pathway: Frontal lobe -> Pons -> Trigeminal Nerve -> Chewing muscles -> Movement

6. **CN VI – the abducens nerve** is a motor nerve that, like the oculomotor and trochlear nerves, sends directions from the brain to the optic handles for "steering". The abducens nerve is the medial-most nerve extending from the junction of the pons and medulla oblongata of the brain stem.
   Motor pathway: Frontal lobe -> Pons -> Abducens Nerve -> Eye muscles -> Movement
7. **CN VII – the facial nerve** has both sensory and motor functions. For sensory, it carries input from chemical "tasters" (for us, our tongue) that ensure quality food for citizens. For motor, the facial nerve sends output that controls various city services (such as movement of the skeletal muscles attached to the skull that are involved in communication). The facial nerve extends from the junction of the pons and medulla oblongata and is just lateral to the abducens nerve (VI).
   Sensory pathway: Tongue -> Facial Nerve -> Pons -> Thalamus -> Insular lobe -> Information processing
   Motor pathway: Frontal lobe -> Pons -> Facial Nerve -> Facial muscles -> Movement
8. **CN VIII –the vestibulocochlear nerve** is a sensory nerve that carries input from the seismographs that monitor the stability of the city as well as sound transducers that monitor noise levels in the city. For us, this nerve senses sound and balance. The vestibulocochlear nerve extends from the junction of the pons and medulla oblongata and is just lateral to the facial nerve (VII).
   Sensory pathway: Ear -> Vestibulocochear Nerve -> Pons -> Thalamus -> Temporal lobe -> Information processing
9. **CN IX – the glossopharyngeal nerve** is a sensory nerve that carries input from chemical "tasters' that insure quality food (for us, this nerve senses taste from our tongue). The glossopharyngeal nerve extends from the lateral and proximal region of the medulla oblongata. This nerve is also just inferior to the vestibulocochlear nerve (VIII).
   Sensory pathway: Tongue -> Glossopharyngeal Nerve -> Medulla oblongata -> Thalamus -> Insular lobe -> Information processing
10. **CN X – the vagus nerve** is a motor nerve that carries outgoing signals that control actions in Brainington's two satellite cities -Thoracium and Abdominium (for us, this nerve controls several systems in our thorax and abdomen, such as cardiovascular, respiratory and digestive systems). The vagus nerve extends from the lateral side of the medulla oblongata and is just inferior to the glossopharyngeal nerve (IX).
    Motor pathway: Temporal lobe -> Medulla oblongata -> Vagus Nerve -> Thorax and Abdomen -> Involuntary Movement
11. **CN XI – the accessory nerve** is a motor nerve that carries outgoing signals that control the entire movement of the city (for us, this nerve stimulates the sternocleidomastoid and the trapezius muscles to move our head around). The accessory nerve extends from the spinal cord but runs superiorly to the medulla oblongata where it leaves the brain just inferior to the vagus nerve (X).

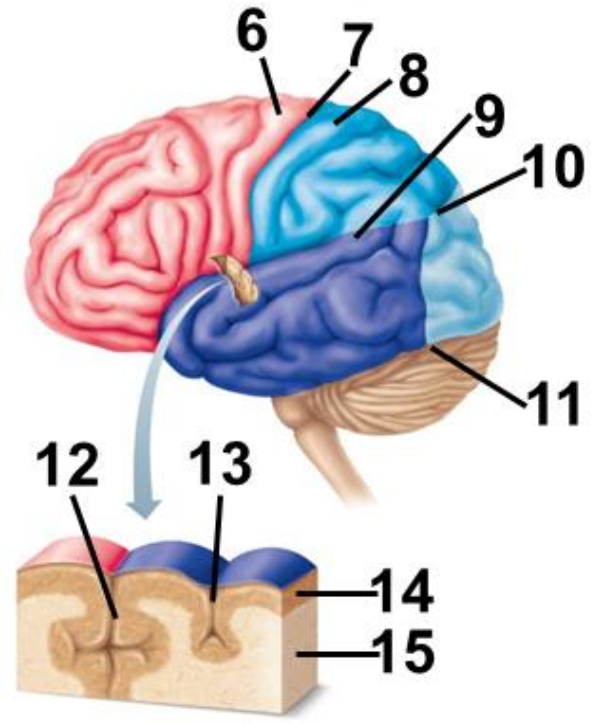
Motor pathway: Frontal lobe -> Spinal cord -> Accessory Nerve -> Neck muscles -> Movement

12. **CN XII – the hypoglossal nerve** is a motor nerve that carries outgoing signals that control food processing machinery for the city (for us, this nerve stimulates the muscles that control tongue movement). The hypoglossal nerve extends from the medulla oblongata and is just medial to the vagus nerve (X).
Motor pathway: Frontal lobe -> Medulla oblongata -> Hypoglossal Nerve -> Tongue muscles -> Movement



Exercise 1: Identification

Identify the structures of the cerebral hemisphere in the image to the right.



1._____

2._____

3._____

4._____

5._____

6._____

7._____

8._____

9._____

10._____

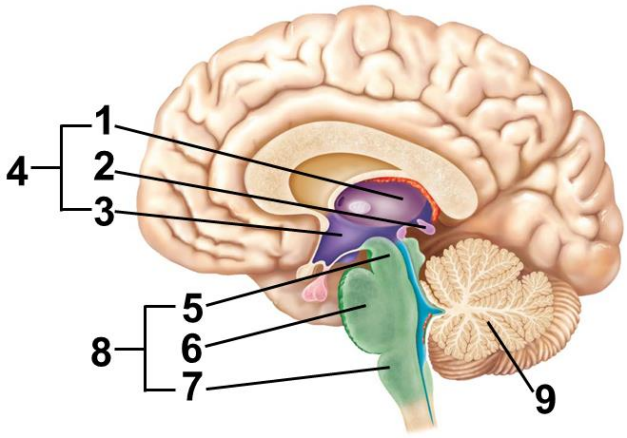
11._____

12._____

13. _____

14. _____

15. _____



Word Bank:		
a. Lateral sulcus	f. Temporal lobe	k. Occipital lobe
b. Fissure	g. Parieto-occipital sulcus	l. Central sulcus
c. Postcentral gyrus	h. White matter	m. Sulcus
d. Frontal lobe	i. Precentral gyrus	n. Transverse cerebral fissure
e. Cerebral cortex	j. Parietal lobe	o. Insular lobe

Identify the regions of the brain and their respective centers in the image to the right.

1._____

2._____

3._____

4._____

5._____

6._____

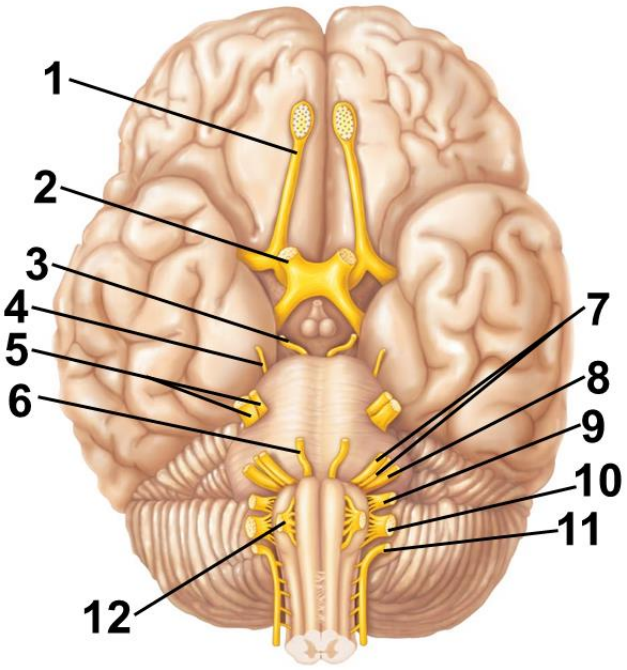
7._____

8._____

9._____

Word Bank:		
a. Midbrain	d. Hypothalamus	g. Pons
b. Cerebellum	e. Brain stem	h. Diencephalon
c. Epithalamus	f. Thalamus	i. Medulla oblongata

Identify the cranial nerves in the figure to the right.



1._____

2._____

3._____

4._____

5._____

6._____

7._____

8._____

9._____

10._____

11._____

12._____

Word Bank:

a. Vestibulocochlear nerve	e. Accessory nerve	i. Trigeminal nerve
b. Glossopharyngeal nerve	f. Abducens nerve	j. Oculomotor nerve
c. Trochlear nerve	g. Olfactory nerve	k. Vagus nerve
d. Optic nerve	h. Hypoglossal nerve	l. Facial nerve

Exercise 2: Matching

Match the lobe of the cerebral hemisphere with its nerve and function. Some lobes will have more than one function and be incorporated with more than one nerve. Also, some nerves will be associated with more than one lobe.

Cerebral hemisphere lobe	**Match with Function & Cranial Nerve**	**Function**	**Cranial Nerve**
Frontal Lobe		A. Controls Eye Movement	K. Olfactory nerve
Parietal Lobe		B. Smiling, Chewing, Frowning	L. Vagus nerve
Temporal Lobe		C. Interprets Smell	M. Abducens nerve
Occipital Lobe		D. Sensation from the visceral organs	N. Optic nerve
Insular Lobe		E. Interprets sound	O. Vestibulocochlear nerve
		F. Interprets smell	P. Trigeminal nerve
		G. Controls neck movements	Q. Facial nerve
		H. Interprets body sensations	R. Trochlear nerve
		I. Interprets taste	S. Accessory nerve
		J. Interprets sight	T. Glossopharyngeal nerve
			U. Hypoglossal nerve
			V. Oculomotor nerve

Match the cranial nerve with its function, the region of the brain that it **directly** extends from, and whether or not it sends nerve impulses to the thalamus before they are routed to the correct lobe of the cerebral hemisphere. Some nerves will have more than one function.

Cranial Nerve	**Matching Terms**	**Function**	**Region of brain extending from**	**Send impulses to thalamus?**
Olfactory Nerve		M = Motor	TL = Temporal Lobe	Y = Yes
Optic Nerve		S = Sensory	T = Thalamus	N = No
Oculomotor Nerve		B = Both	MB = Midbrain	
Trochlear Nerve			P = Pons	
Trigeminal Nerve			MO = Medulla Oblongata	
Abducens Nerve			SC = Spinal Cord	
Facial Nerve				
Vestibulocochlear Nerve				
Glossopharyngeal Nerve				
Vagus Nerve				
Accessory Nerve				
Hypoglossal Nerve				

Exercise 3: Critical thinking questions:

1. When you work out, your heart rate and breathing rate increase. What lobe of the cerebral hemisphere and cranial nerve are involved in altering these rates?

2. When you go to the dentist for a filling or root canal, which cranial nerve is your dentist numbing before performing this activity?

3. You just heard and interpreted some great news! This makes you smile. Which cranial nerves and lobes of the cerebral hemisphere are you using for hearing and interpreting sound and smiling?

4. You're at a heavy metal concert! You're listening to music, banging your head, and singing along (you're using a lot of facial muscles to do this). What three cranial nerves are being used here? Which two lobes of the cerebral hemisphere are being used?

5. You're skiing downhill really, really fast. You're keeping careful to keep your balance and you're looking to stay away from exposed rocks. This means you're moving your eyes and head to keep your balance and interpret what you see. Which two cranial nerves are being used right now?

6. Bell 's palsy (loss of some taste and paralysis of facial muscles) is caused by what nerve dysfunction?

7. How do you think motor cranial nerves travel through the skull to reach their effector organs? What types of structures do they pass through? Name some.

Exercise 4. Nervous System Review questions

1. Which cranial nerves are you using when you interpret taste?

   A. Facial and Hypoglossal nerves
   B. Facial and Glossopharyngeal nerves
   C. Hypoglossal and Glossopharyngeal nerves
   D. Facial and Trigeminal nerves

2. Which of the following actions is **NOT** stimulated by the facial nerve?

   A. Smiling
   B. Winking
   C. Chewing
   D. Frowning

3. The sensation of photon energy (what we see) is transmitted by the:

   A. Optic nerve
   B. Abducens nerve
   C. Oculomotor nerve
   D. Trochlear nerve

4. Chewing is a _____ function of the _____ nerve.

   A. Motor; Facial
   B. Sensory; Trigeminal
   C. Motor; Accessory
   D. Motor; Trigeminal

5. Which of the following nerves does **NOT** receive motor information from the primary motor cortex?

   A. Facial nerve
   B. Trigeminal nerve
   C. Oculomotor nerve
   D. Accessory nerve