THE CORTICOSPINAL AND CORTICOBULBAR TRACTS:

AN ANIMATED THREE-DIMENSIONAL INSTRUCTIONAL AID

APPROVED BY SUPERVISORY COMMITTEE

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DEDICATION

Dedicated to my loving husband, John Morse, for his infinite devotion and support,

and to my family for always being there.

# THE CORTICOSPINAL AND CORTICOBULBAR TRACTS:
# AN ANIMATED THREE-DIMENSIONAL INSTRUCTIONAL AID

by

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THESIS

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The complex pathways of the neural tracts, from the cerebral cortex, through the complex anatomy of the brainstem, can be difficult for medical students to visualize and challenging for instructors to convey. Text references, 2-dimensional illustrations, and anatomical cross-sectional photographs have been the most useful teaching aids available for the lecture room. Although this material is fundamentally useful, medical students often find them ineffective for comprehending the 3-dimensional aspect of the subject. Based on the success of the first animated neural tract by Chris Akers in his thesis project <u>The Spinothalamic Tract: An Animated 3-dimensional Instructional Aid</u> (Akers, 2003), the goal of this project was to

continue assisting instructors in teaching the concepts of the corticospinal and corticobulbar tracts by producing a digitally animated, 3-dimensional instructional aid. An animation of this nature and content will be a valuable addition to the existing study material available to medical students.

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## LIST OF DEFINITIONS

3D animation – The display of a series of images, or frames, of digital three-dimensional objects that creates the illusion of movement over time.

Adobe® Photoshop® – Professional software designed for image-editing, photo retouching, and production of high quality images for print or web.

Adobe® Premiere® Pro – Software designed for professional digital video editing.

AVI – (Audio Video Interleaved) A common Microsoft video file format for encoding pictures and sound for digital transmission.

Discreet® 3ds max™ – Professional 3D animation software designed for modeling and rendering 3-dimensional objects in a digital environment.

JPEG – (Joint Photographic Experts Group) A compression technique for color images and photographs that balances compression against loss of detail in the image.

MOV – (Movie) A QuickTime movie motion file format.

QuickTime® movie – A platform independent format of time-based data.

TIF – (Tagged Image File) a file format for storing bitmapped images.

# CHAPTER ONE
# Introduction

*Goal*

The goal of this thesis project was to create a digitally animated, 3-dimensional instructional aid that would assist instructors of neuroanatomy to present the corticospinal and corticobulbar tracts to first year medical students. This tool would enhance the current teaching material by allowing a visually challenging topic to be displayed in a simple, yet informative manner.

The primary objective of this project was to incorporate the existing teaching materials such as anatomical cross-sectional photographs into a digital, 3-dimensional model of the spinal cord, brainstem, and brain. This not only allows the students to see the path of the neural tracts through the cross-sections, but also to appreciate the relationship of the tracts to the 3-dimensional anatomy of the brain. Another objective was to produce a clear and understandable animation that was simple to navigate. With the final format of the animation as a QuickTime® movie, the instructor may utilize it in a lecture setting while able to play and pause it as desired to emphasize key points of interest. The animation was designed based on the template developed by Chris Akers, a graduate of the Biomedical Communications Graduate Program at The University of Texas Southwestern Medical Center at Dallas, and documented in his thesis <u>The Spinothalamic Tract: An Animated 3-Dimensional Instructional Aid</u> (Akers, 2003). For the purpose of this thesis, only the corticospinal and corticobulbar tract animations were completed.

This thesis document contains the methods and processes of creating this animation as well as a detailed description of the corticospinal and corticobulbar tracts and their clinical significance.

*Background*

The University of Texas Southwestern Medical Center at Dallas offers a course in medical neuroscience to its first year medical students. This course is taught by a collaborative effort from departments of Physiology, Center for Basic Neuroscience, Neurology, Internal medicine, Cell Biology, and Biochemistry. The course focuses on the fundamentals of human neuroanatomy and physiology, and the practical application of these concepts to diagnosis of physiological diseases. An integral aspect of this course is understanding the complex pathways of twelve neural tracts.

The corticospinal and corticobulbar tracts are the first of the descending spinal pathways that students are exposed to in this course. Also known as the pyramidal tract, this pathway consists of fibers concerned with the control of voluntary, discreet, and skilled movement, especially of those in the distal parts of the limbs. Pathological processes that damage the corticospinal and corticobulbar tract systems are extremely important causes of disability and suffering, hence a thorough understanding of this process has obvious clinical relevance for medical students.

The corticospinal and corticobulbar tracts are a two-neuron system consisting of upper motor neurons in the primary motor cortex and lower motor neurons in the anterior horn of the spinal cord. The upper motor neuron axon extends from the brain down to the spinal cord, and the lower motor neuron axon extends from the spinal cord to the skeletal muscles of the arms or legs.

The upper motor neurons reside in the precentral gyrus of the frontal lobe also called the motor strip which control movements of the face and mouth are located near the Sylvian or lateral fissure, and neurons which control the muscles of the thighs and legs are located near the medial longitudinal fissure and within the central sulcus. Many textbooks illustrate this phenomenon graphically using a distorted human figure called the homunculus (see Fig. 2-8) The homunculus has very a large face and mouth because there are many upper motor neurons that innervate these parts of the body. The axons that extend from these upper motor neurons traverse the deep matter and coalesce to form the internal capsule. They then descend through the midbrain in the cerebral peduncle. The axons of the corticospinal tract then condense to form the pyramids, and they are arranged in a very orderly fashion. Axons that innervate the muscles of the face are located medially, and this is known as the corticobulbar tract. The axons that form the corticobulbar tract exit at various levels of the brainstem to synapse with lower motor neurons in the cranial nerve nuclei.

The axons that will innervate the legs are located laterally within the cerebral peduncle, giving rise to the lateral corticospinal tract. These axons then aggregate to form the pyramids in the medulla, thus the pyramidal tract is used as an alternate name for the corticospinal tract. About 75 - 90 % of corticospinal tract axons cross to the other side in the distal medulla. This is a very distinctive area known as the pyramidal decussation, which separates the medulla above from the spinal cord below. The remaining ipsilateral fibers give rise to the ventral corticospinal tract and it contains the axons from the 10-25% of neurons whose axons did not cross over at the pyramidal decussation. The upper motor neuron axons then synapse on lower motor neurons in the anterior horn of the spinal cord. The axons of these alpha motor neurons then exit the spinal cord via the ventral root. The ventral root then joins the dorsal root to form the spinal nerve, which finally innervates the skeletal muscle.

*Significance*

Considering the complex anatomy of the brain and the specific path of neural tracts, it is very important for medical students to have a proper understanding and visualization of these concepts.  The teaching aids currently used by instructors vary in scope and range in media, from illustrations to computer-based applications. Textbook illustrations vary in complexity from simple schematic diagrams to full color drawings. Computers have provided the opportunity for multimedia presentation to medical students. The directors of this course now provide study material in an interactive format via the Internet, where students are able to view photographic cross-sections of the brain and identify the neural tracts and related anatomy with rollovers. Although the illustrations, photographs, and didactic material are adequate, they lack a key element; they fall short of conveying the 3-dimensional aspect of the brain anatomy. This presented a need for a more effective teaching tool.

In his thesis project, <u>The Spinothalamic Tract: An Animated 3-dimensional Instructional Aid</u> (Akers, 2003), Chris Akers not only addressed the need above by providing a clear depiction of this particular pathway, but also set the groundwork for future illustration. In following his path and based on the success of the first animated neural tract, the primary objective of this thesis project was to integrate anatomical cross-sectional photographs into 3-dimensional modeling. This digital 3-dimensional animation allows the students to follow the path of one of the major descending pathways from the primary motor cortex to alpha motor neurons of the spinal cord, later innervating the skeletal muscles of the limbs. This production will also complement the first completed animation of the spinothalamic tract by providing the instructors and students a representative of both sensory and motor neural pathways.

*Limitations*

Twelve neural pathways are presented in the medical neuroscience course and each pathway is equally challenging for medical student to fully comprehend. This project focused on only one neural tract, the corticospinal and corticobulbar tracts, which are the first motor pathway presented in lecture and a fundamental representation for the other descending tracts. The animation was designed and developed based on the template created by Chris Akers (Akers, 2003).

*Production Methods*

The final product is a QuickTime® movie that combines photographs, illustrations, and 3-dimensional digital animation. In keeping the same presentation style as the first completed movie, this animation is divided into two sections. One section allows the viewer to play the animation, with appropriate stops in the animation for labeling of relevant and specific anatomy structures. The second section allows the viewer to play the same animation continuously, without labels. The cross-sectional photographs were obtained from Dr. Gerald P. Kozlowski, the coordinator of the medical neuroanatomy course at University of Texas Southwestern Medical Center at Dallas, as .JPEG files. However, some of these photographs (C8 and S1 level slides) were low in quality and had already been colorized and outlined for use in the lecture hall; therefore, they were not easy to manipulate. . After consulting with Dr. Kozlowski and obtaining permission of use from the publishing company (Appendix C), cross-sectional photographs from <u>Neuroanatomy: An Atlas of Structures, Sections, and Systems</u> (Haines, p. 76-122) were used instead. These photographs are very similar to the slides used in the neuroanatomy course, and close attention was paid to select photographs from the same exact level and location within the brain, brainstem, and spinal cord. The photographs were scanned into the computer and manipulated with Adobe® Photoshop® 6.0. The illustrations that were integrated into the animation were produced in Adobe® Photoshop® 6.0. Some of them were already produced by Chris Akers and were used with his permission. The additional illustrations were produced in accordance to Chris Akers' in order to preserve the same color scheme and overall design elements. The animation was storyboarded and produced in Discreet® 3ds max™ 4.2. The animation clips were rendered as AVI files and edited in Adobe® Premiere® Pro 1.5. The final animation was saved as a QuickTime® movie and burned to a CD-R disc. An informal evaluation of the animation was conducted with a test group of first year medical students.

# CHAPTER TWO
# Review of the Literature

*Existing Instructional Aids*

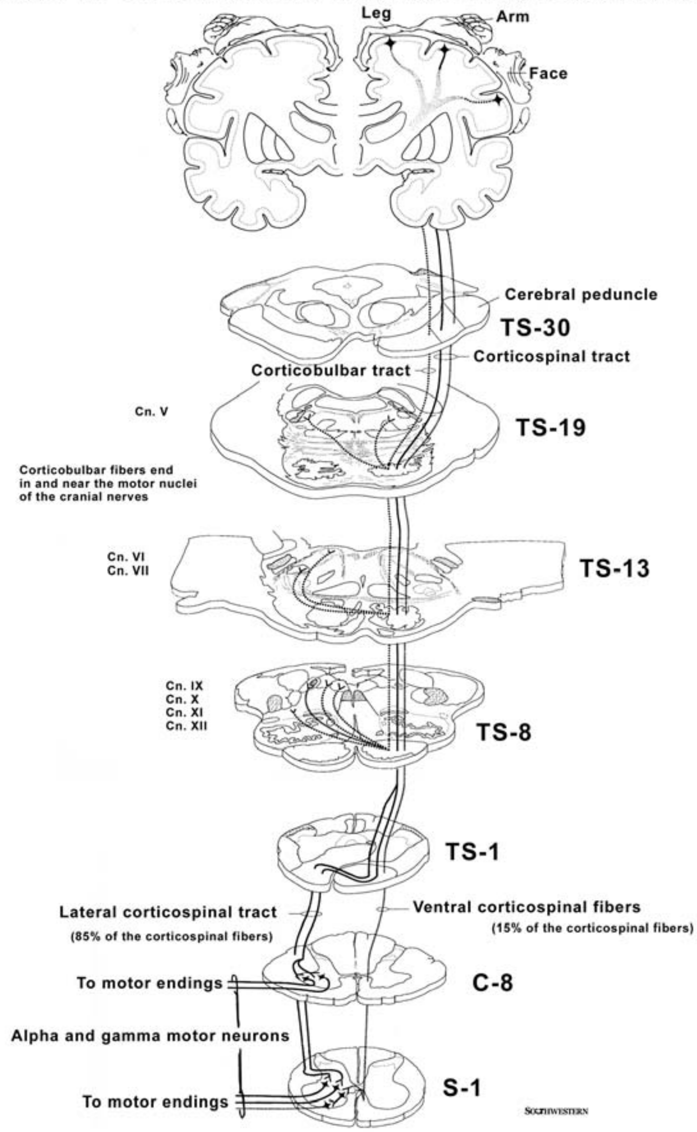
Pertaining to the subject of the neural tracts, there is sufficient didactic, illustrative, and photographic reference material. However, there is very little in the way of animations, interactive presentations, or study aids. The few existing CD-ROM references depict the tracts with limited 3-dimensional aspects.

The course directors have recommended Neuroscience, Second Edition, by Purves *et al,* as the course textbook, along with a handout of neural tract illustrations. For the laboratory portion of the course, Neuroscience: An Atlas of Structures, Sections, and Systems by Duane E. Haines has been recommended and used.

Neuroscience provides an in-depth literary explanation of the definitions, physiological mechanisms, and anatomical depictions of each neural pathway. The text is supplemented with charts, graphs, photographs, and color illustrations. The color illustrations devoted to the corticospinal and corticobulbar tracts include the spinal cord, brainstem, and cerebral cortex represented in a cross-sectional format.

In addition to these textbooks, the course directors have provided the students with black and white ink illustrations of the neural tracts (Fig. 2-1) as well as slides (Fig. 2-2 through 2-8).

## DIAGRAM OF THE CORTICOSPINAL AND CORTICOBULBAR TRACTS




### Lateral corticospinal tract

***Origin:*** Precentral gyrus (area 4), postcentral gyrus (areas 3, 1, 2), premotor area (area 6).

***Course:*** Through internal capsule, cerebral peduncles and pyramids - decussates at junction of spinal cord medulla - descends throughout length of spinal cord in lateral funiculus.

***Termination:*** Gray matter throughout length of spinal cord contralateral to cells of origin.

### Ventral corticospinal tract

***Origin:*** Same as lateral corticospinal tract.

***Course:*** Runs with fibers of lateral corticospinal tract through internal capsule, cerebral peduncles and pyramids - does not decussate with lateral corticospinal tract in caudal medulla - fibers contiue into spinal cord ipsilateral to their cells of origin and descend in the ventral funiculus, perhaps as far as mid-thoracic levels.

***Termination:*** As individual axons reach their level of termination in the thoracic region, they cross the midline to synapse in gray matter contralateral to their cells of origin.

### Corticobulbar tract

***Origin:*** Same as lateral corticospinal tract.

***Course:*** Runs with fibers of lateral corticospinal tract through internal capsule, cerebral peduncles, and pyramids.

***Termination:*** Motor and sensory cranial nerve nuclei.

**Figure 2-1** One of the twelve neural tract handouts for the medical neuroanatomy course.

Integrated into the illustrations, are depictions of cross-sectional illustrations of the spinal cord, brain stem, midbrain, and cerebral cortex. The illustrations of these sections are closely based on the cross-sectional slides provided to students in the laboratory.

Neuroanatomy by Haines is a reference manual that consists primarily of cross-sectional photographs of the spinal cord, brainstem, and cerebral cortex. These photographs are supplemented with detailed black and white ink illustrations that clarify the cross-sections for easier recognition of anatomical regions.

The course directors have taken advantage of the current computer technology in providing study material to students on the Internet. An Internet site on the medical school server has been provided where students can access a variety of didactic and image based study materials. Cross-sectional photographs of the spinal cord, brainstem, and cerebral cortex are available for students to access with rollover information. The rollovers provide anatomical labeling and visual clarification of the cross-sectional anatomy visible in the photographs.

The use of anatomical cross-sectional photographs as a teaching aid is essential and is the primary choice of the directors of the medical neuroanatomy course. More so, the integration of these cross-sections with color illustrations has proven to be a very useful method of demonstrating the different neural pathways. Sylvius 2.0: Fundamentals of Human Structures CD-ROM, a companion to the Purves et al text, has taken this concept a step further by providing an animation with a light that follows the flow along the neural tract to the cortex. Also included is an interactive 360˚ view of the brainstem anatomy.

Students consistently find it difficult to visualize the 3-dimensional aspect of the pathway as it navigates through the complex anatomy. Although current study materials are useful, they all lack a key element; they fall short of effectively representing the anatomical position of the neural tract at each cross-sectional level of the spinal cord, brainstem, and cerebral cortex in respect to the 3-dimensional anatomy.

As shown by Chris Akers' successful 3-dimensional representation of the spinothalamic tract, the use of 3D computer animation can enhance the effectiveness of existing instructional aids immensely. The 3D animation allows for the integration of cross-sectional photographs into a 3-dimensional model, enabling student to view the neural pathway in a true 3-dimensional space, and to evaluate the spatial relationship of the tract relative to the cross-sectional anatomy.

*Anatomy Overview*

Movement (motion) is one of the fundamental properties of animal life. In simple unicellular animals, motion depends on the contractility of protoplasm and the action of accessory organs: cilia, flagella, and so forth. Rudimentary multicellular animals posses primitive neuromuscular mechanisms; in more advanced form of animal life, reflective motion is based on the transmission of impulses from a receptor through an afferent neuron and ganglion cell to motor neurons and muscles. This same arrangement is found in the reflex arc of higher animals, including humans, in whom the spinal cord has further developed into a central regulating mechanism. Superimposed on these reflex circuits, the brain is concerned with the initiation and control of movement and the integration of complex motions.

The motor system in humans controls a complex neuromuscular network. Commands need to be sent to many muscles, and several ipsilateral and contralateral joints must also be stabilized. The motor system includes cortical and subcortical areas of gray matter; the corticobulbar, corticospinal, corticopontine, rubrospinal, reticulospinal, vesibulospinal, and tectospinal descending tracts; gray matter of the spinal cord; efferent nerves; and the cerebellum and basal ganglia. Feedback from sensory systems and the cerebellar afferents further influences the motor system (Waxman, p.189).

Descending projections from higher centers control the primary brainstem and spinal cord circuitry and are essential for producing voluntary, goal-oriented movements. The projections originate in several structures within the brainstem that participate in the motor system and in the motor areas of the cerebral cortex. Two particular important components in the brainstem, the vestibular nucleus and the reticular formation, are responsible for much of the postural stability that is prerequisite for any movement. The motor and premotor areas of the cerebral cortex are responsible for planning movements and executing them in efficiently. The cortex exercises this influence by projections onto both the brainstem centers and the interneurons and motor neurons of the spinal cord and cranial nerve motor nuclei (Purves, p.331).

The descending tracts that deliver efferent impulses from the brain to the spinal cord are divided into two groups: 1) the corticospinal and 2) all others. Motor pathways involve two neurons, referred to as the upper and lower motor neurons. The pyramidal cells of the motor cortex, as well as the neurons in subcortical motor nuclei that give rise to other descending motor pathways, are called upper motor neurons. The anterior horn motor neurons, which actually innervate the skeletal muscles (their effectors), are called lower motor neurons (Marieb, p.446)

The corticospinal tracts are the major motor pathways particularly concerned with the control of voluntary, discreet, skilled movement, especially those of the distal parts of the limbs. Their neurons originate from pyramidal cells in the cerebral cortex, where they are widely distributed in the motor and sensory cortices, including the precentral gyrus or primary motor cortex.

Corticospinal axons leave the cerebral hemispheres by passing through the massive subcortical fiber systems of the corona radiata and posterior limb of internal capsule in the forebrain, lateral to the third ventricle and the ventral lateral nucleus, and dorsal to the putamen and globus pallidus (Fig. 2-2).

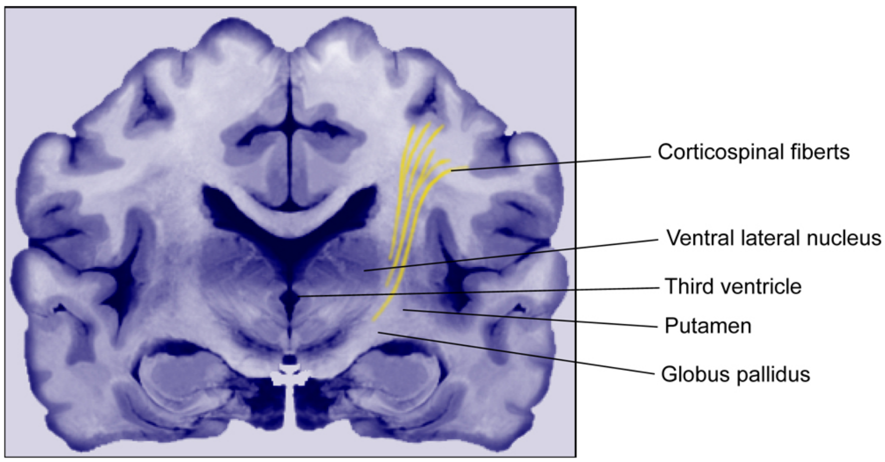



**Figure 2-2.** Location of the corticospinal and corticobulbar tracts at the level of the cerebral cortex and forebrain.

At the level of the midbrain, the axonal fibers enter the crus cerebri (cerebral peduncles), bordering the substantia nigra caudally. The crus cerebri is composed of the temporopontine fibers dorsally, corticospinal and corticobulbar fibers medially, and frontopontine fibers ventrally (Fig. 2-3). The axons of the corticospinal tract are arranged in a very orderly fashion. They are arrayed somatotopically in both the internal capsule and the cerebral peduncles. Thus, axons that control arm, trunk, and leg muscles are distributed from rostral to caudal in the posterior limb of the internal capsule; those that control muscles of the face course more rostrally in the genu (the bend or "knee") of the internal capsule. In the cerebral peduncles, the fibers that control facial muscles are located medially; those that control the leg are more located more laterally (Purves, p.321).

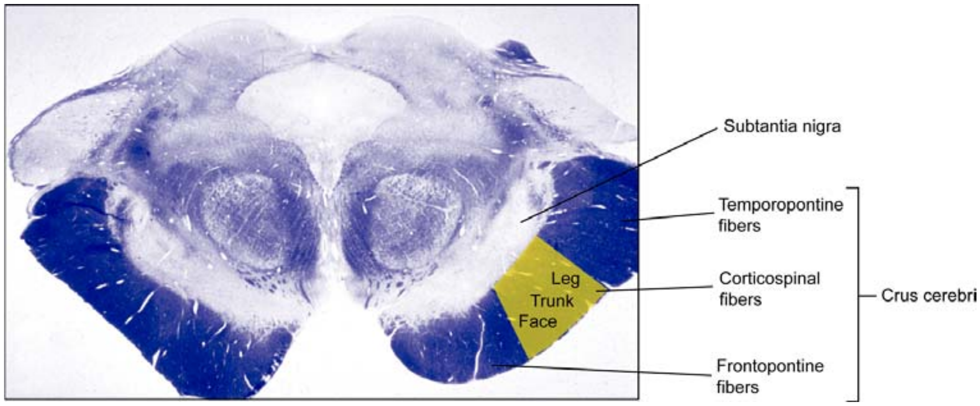



**Figure 2-3.** Location of the corticospinal and corticobulbar tracts at the level of the midbrain.

The axonal fibers of the corticospinal tract pass through the ventral portion of the pons where they become scattered among the pontocerebellar fibers and the nuclei of the pontine gray matter (Fig 2-4).

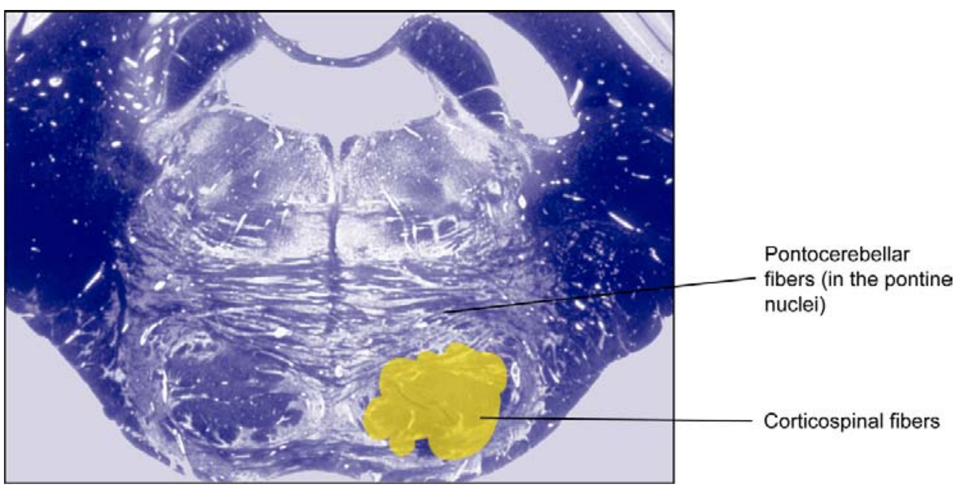



**Figure 2-4.** Location of the corticospinal and corticobulbar tracts at the level of the pons.

The axons that innervate the muscles of the face also innervate the reticular formation and the red nucleus, and are known as the corticobulbar tract. Their upper motor neurons are located near the lateral fissure of the brain, within the sensorimotor cortex where the face is represented. Their axons pass through the posterior limb of the internal capsule and the middle portion of the crus cerebri. The corticobulbar tract axons exit the pathway at their appropriate levels in the brainstem to their targets, the somatic and brachial efferent nuclei, where they synapse with their lower motor neurons in the cranial nerve nuclei (fig. 2-5).

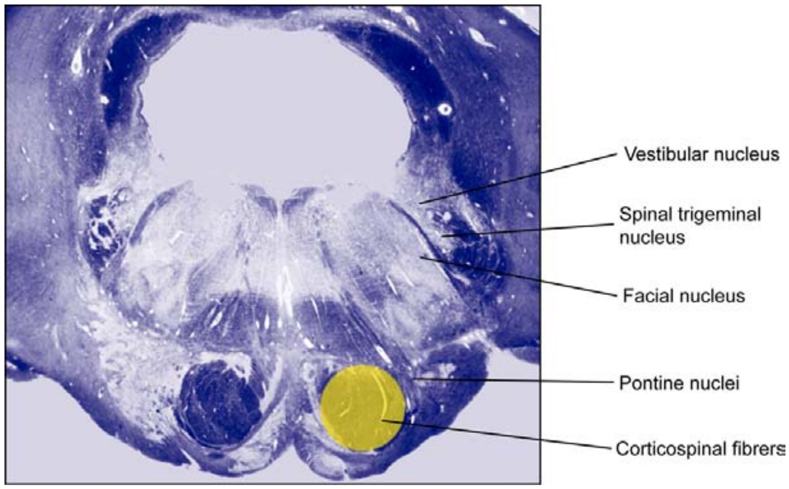



**Figure 2-5.** Location of the corticospinal tract and cranial nerve nuclei the level of the pons.

The axons destined to reach the spinal cord coalesce again on the ventral surface of the medulla oblongata where they form two prominent columns called the pyramids (Fig 2-6). For this reason the term pyramidal tract is used alternatively for the corticospinal tract. The name of the tract refers to the pyramidal shape of the axon bundles in ventral surface of the medulla, not the pyramidal shape of the cells in the motor cortex that give rise to these bundles.

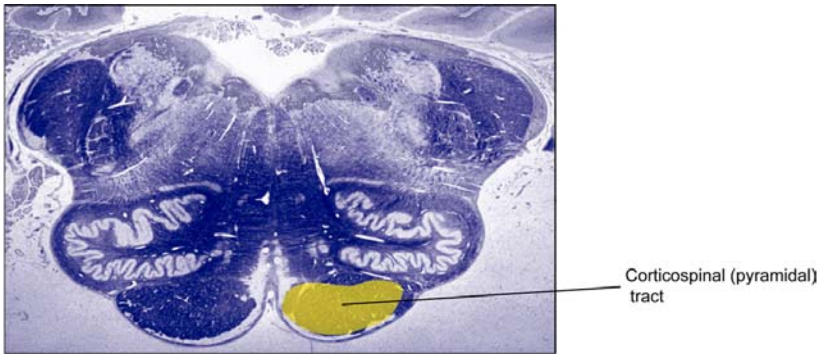



**Figure 2-6.** Location of the corticospinal (pyramidal) tract at the level of the medulla.

At the caudal end of the medulla, about 75-90% of the corticospinal axons decussate, or cross over, and enter the lateral columns of the spinal cord where they form the lateral corticospinal tract. This is a very distinctive area on the cross section know as the pyramidal decussation (Fig. 2-7). These contralateral axons originate largely from the parts of the motor cortex that represent the limbs and they terminate preferentially on lateral cell groups in the ventral and intermediate portions of the spinal gray matter.

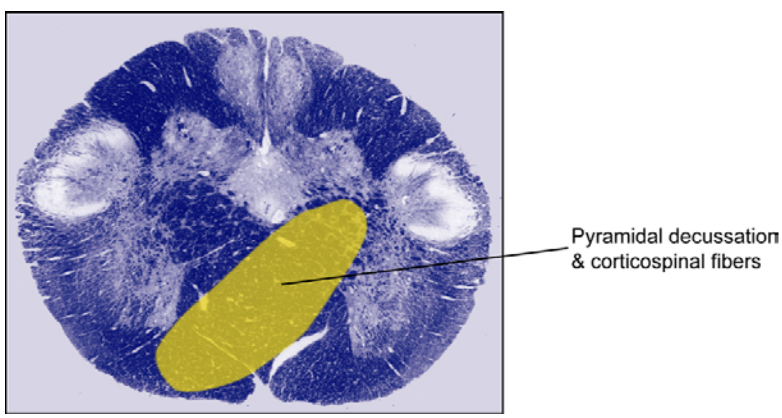



**Figure 2-7.** Location of the corticospinal fibers and pyramidal decussation at the level of the medulla.

The remaining 10-25% of the fibers remain ipsilateral and pass directly into the spinal cord, lateral to the ventral median fissure to form the ventral corticospinal tract (Fig. 2-8).

These axons originate from the parts of the motor cortex that represent the neck, shoulder and trunk region. They terminate on neurons in the medial part of the ventral horn and intermediate zone. Many ventral corticospinal axons also have branches that cross the midline of the spinal cord to innervate the medial cell groups in the other hemicord.

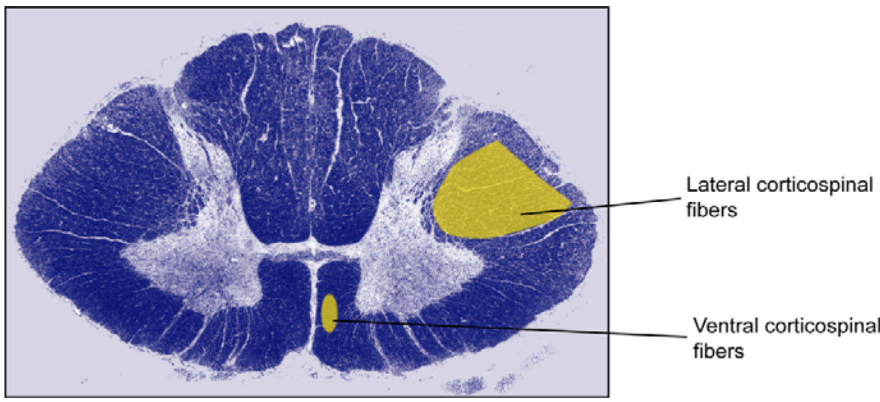



**Figure 2-8.** Location of the ventral and lateral corticospinal fibers at the level of the spinal cord (C8).

The corticospinal tracts are also called the direct pathways since their axons descend without synapsing from the pyramidal cells of the primary motor cortex all the way to the spinal cord. Once at their departure level of departure in the spinal cord, these axons synapse with interneurons, which in turn will synapse with lower motor neurons, which in turn exit the spinal cord via the ventral root, that eventually innervate their respective skeletal muscles.

*Clinical Significance*

As one of the major descending motor pathways, injuries to the corticospinal and corticobulbar tracts are of significant clinical importance as they greatly impact the well being of patients, causing extreme disability and suffering. Pathological processes that can damage the corticospinal and corticobulbar tracts range from strokes, traumatic brain injury due to accidents, and disorders such as amyotrophic lateral sclerosis (ALS or Lou Gehrig's

Disease). In all cases, paralysis and loss of the ability to control movement is a major outcome.

Damage to the descending motor pathways gives rise to a set of signs and symptoms called the upper motor neuron syndrome. Injuries of this nature are common since a large area of the cortex is occupied by motor neurons, and because motor pathways extend all the way from the cerebral cortex to the spinal cord. Damage anywhere along the length of these pathways produces characteristic deficits in the ability to control movements (Purves et al, p.325). Examples of such deficits are flaccid paralysis and loss of tone in the muscles.

Hereditary spastic paraparesis is an inherited degenerative disorder (autosomal dominant) in which progressive weakness affects the legs, leading to marked stiffness of gait. Degeneration of the lateral columns, including the lateral corticospinal tract, chiefly affects the thoracic spinal cord, causing a spastic paraparesis (weakness in both legs) with hyperreflexia and extensor plantar response (Crossman et al, p.84).

Amyotrophic lateral sclerosis (ALS), is a devastating neuromuscular condition caused by the thickening of neural tissue in the motor tracts of the lateral columns and anterior horns of the spinal cord. It is characterized by progressive muscle atrophy, fasciculations, and increased reflexes. Approximately 30,000 Americans currently have the disease, with the annual incidence rate of one to two cases per 100,000. The disease is most commonly diagnosed in middle age and affects more men than women. It usually presents with problems in dexterity or gait resulting from muscle weakness, and difficulty in speaking or swallowing is the initial symptom in the bulbar form of the disease. Over a period of months or years, patients with ALS develop severe, progressive muscular weakness and other symptoms caused by loss of function in both upper and lower motor neurons. Patients become completely disabled, often requiring ventilatory support and gastrostomy. Death usually occurs within five years of diagnosis and is attributed to respiratory failure or cachexia (severe state of wasting).

# CHAPTER THREE
# Methodology

The primary objective of this project was to incorporate the clarity and effectiveness of anatomical cross-sectional photographs into the 3-dimensional aspect of digital animation. The final product is a QuickTime® movie, which may be used during lecture to supplement existing presentation material. The corticospinal and corticobulbar tracts were the only neural tracts chosen to be completed for the purpose of this project, based on the existing template developed by Chris Akers (Akers, 2003). In this chapter, the development and production of the final animated movie is discussed.

*Concept*

Adequate material on the subject of neural tracts is available for presentation to students. Traditionally, anatomical cross-sectional photographs have been used to teach this subject. Some sources combine these photographs with ink illustrations or full-color illustrations of the complex anatomy through which the tracts travel. Prior to Chris Akers' digital presentation (Akers, 2003), and the companion CD-ROM to Purves, *et al* (Sylvius 2.0) there was essentially no existing material that utilized 3-dimensional animation to convey these concepts.

One of the major concerns of first year medical students in the neuroanatomy course was the inadequacy of existing study material due to its inability to convey the 3-dimensional aspects of neural tracts through the complex anatomical regions. These concerns, along with possibilities of enhancing the ability of instructors to present this material more effectively, prompted Chris Akers to consider a solution for his thesis project. After discussions with Dr.

Kozlowski, the course director for the medical neuroanatomy course, Chris Akers developed the idea of presenting the subject in a digital format. It's objective was to intergrate the portion of the material that the students find useful with the 3-dimensional concept that was so desperately lacking. A clear and easily navigable digital animation of the neural tracts would address these growing need precisely. Chris Akers' presentation of the spinothalamic tract, the first of the twelve neural pathways to be animated, proved to be a very successful and effective tool. It was well received by the students, and Dr. Kozlowski used it the following year during his lectures on the neural pathways.

Based on the success of the first animated neural tract, and the need for the other neural tracts to be presented in 3-dimensional formats, I decided to follow Chris Akers' path in representing the corticospinal and corticobulbar tracts. These particular tracts were chosen based on the suggestions and input of Dr. Kozlowski, who was interested in the representation of a descending motor pathway, in order to complete and complement the original animation of the spinothalamic tract, an ascending sensory pathway.

*Planning*

As mentioned earlier, the corticospinal and corticobulbar tracts were chosen for this project. The project was designed based on the template developed by Chris Akers in his representation of the spinothalamic tract. In order to preserve a cohesive quality, the same color palette and overall design was used as in Chris Akers' animation.

Since the final movie was intended for demonstration in a lecture hall setting, it was saved onto a CD-ROM. This format not only preserved the high-resolution quality of the movie, it also allowed for easy playback options during lecture. Also, since the simple functions of play, pause, stop, rewind, and fast-forward were to be used by the instructor, the

QuickTime® movie format was selected. This format allows for easy navigation and the large file can be copied to a lecture hall computer. In addition, the movie may be copied to and played directly from a CD-R on any computer that has a CD player. QuickTime® is a common digital movie format and is supported by factory installed software on most computers.

After initial meetings with committee members, a detailed outline of the project goals, objectives, and actions was created. This outline provided a clear and organized approach to each step of the planning process and proved to be a very beneficial guide in assembling the whole project together.

*Storyboards*

In preparation for the project, planning was carefully executed in the form of hand rendered storyboards (Appendix A). These storyboards served as a visual guide of the contents and helped keep the goal of the project in focus. Sequential frame-by-frame accounts of the visual content were illustrated, as well as a description of the action involved at each stage of the animation. Thus, final animation decisions were made prior to the production stage. The storyboards were also an effective method of communication to the committee members. Everything necessary was included to clearly present the details of the project and provide a forum for discussion and suggestions.

For the most part, the storyboards were faithfully followed. However in the production stage, the decision was made to amend one minor detail. The original idea of incorporating a map of the homunculus on the coronal section of the cerebral cortex was excluded.

*Design*

Based on the same design concepts applied to Chris Akers' animated movie, decisions were made early in the planning stage to preserve the same integrity of color and design. The original background illustrations created by Chris Akers were used with his permission, and appropriate adjustments and modifications were made to better accommodate the animated scenes. The colors and textures of the models and backgrounds were chosen to direct the viewer's attention to the pathways of the corticospinal and corticobulbar tracts. Based on suggestions and discussions with Chris Akers, the transparent brainstem was achieved with a "glass" texture, and applied to a 3-dimensional model in Discreet® 3ds max™ 4.2., as an alternative to the flat Photoshop image that he has used. Also, the color of the brain was adjusted to a more realistic one, while a map was applied to represent the superficial arteries on the brain.

*Computer Software*

Adobe® Photoshop® 6.5 was used for photograph manipulation and modification of background illustrations. This program was also used to manipulate and improve the anatomical cross-sectional photographs that were integrated into the 3-dimensional model, along with the introductory and background images for portions of the animation.

The 3-dimensioanl animation program Discreet® 3ds max™ 4.2 was used to construct, manipulate, and animate the 3D models. This program was used to build and model many components of the movie and animate the impulses traveling through the corticospinal and corticobulbar tracts to the skeletal muscles. The final animation clips were rendered as AVI files and edited in Adobe® Premiere® Pro 1.5.

Adobe® Premiere® Pro 1.5 was used to edit and label the final animation. Premiere® Pro is a non-linear editing application designed for editing digital video for the creation of DVD, video CD, videotape, and the web. This program was used to sequence and edit the animation clips, as well as add labels and leader lines. The final movie was exported from Premiere® as a QuickTime® movie (.MOV) and then copied to a CD-R.

*Anatomical Cross-Sectional Slides*

One of the first tasks of this project was to acquire anatomical cross-sectional images and prepare them for importation into the 3D software. The study guide handout, which is provided to medical students by the instructors (Fig. 2-8), contains ink illustrations of cross-sections of the spinal cord, brainstem, and cerebral cortex. Since the cross-sectional photographs originally utilized to produce this handout were still available, these were also utilized in this project in order to maintain a consistency throughout the study material for this course.

The cross-sectional photographs were obtained from Dr. Kozlowski, as JPEG files. However, some of these photographs (C8 and S1 level slides) were low in quality and had already been colorized and outlined for use in the lecture hall; therefore, they were not easy to manipulate. After consulting with Dr. Kozlowski and obtaining permission of use from the publishing company (Appendix C), cross-sectional photographs from <u>Neuroanatomy: An Atlas of Structures, Sections, and Systems</u> (Haines p. 76-122) were used instead. These photographs are very similar to the ones used in the neuroanatomy course, and close attention was paid in selecting photographs from the same exact level and location within the spinal cord.

The photographs were scanned into the computer at a relatively high resolution of 300 dpi. The images were then imported into Adobe® Photoshop® for adjustments and cropping. In Photoshop®, the cross-sectional images were colorized with the hue/saturation tool to a cool, purple-blue color. With the rubber stamp tool, the images were touched up to remove debris, fill in holes or gaps, or replace anatomical material that was a casualty of the original laboratory preparation (Fig. 3-1).

**A** **B**

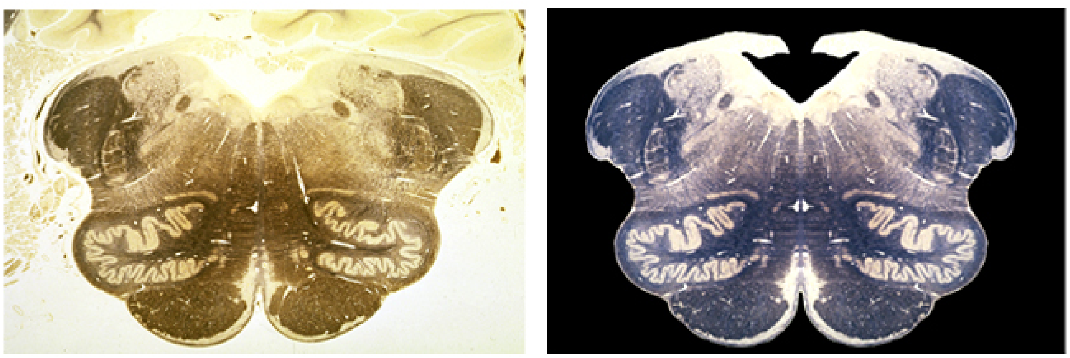


**Figure 3-1.** Photoshop® touch up of the original slide scan (A) to the final image prepared for use in 3D software (B).

The sagittal section of the cerebral hemispheres at the level of mid thalamus, which was not available through the original set of slides obtained, was photographed originally by Chris Akers from a preserved brain using a digital camera. For the purpose of this production, and after consulting with Dr. Kozlowski, the same photograph was used with Chris Akers' permission (Fig. 3-2).

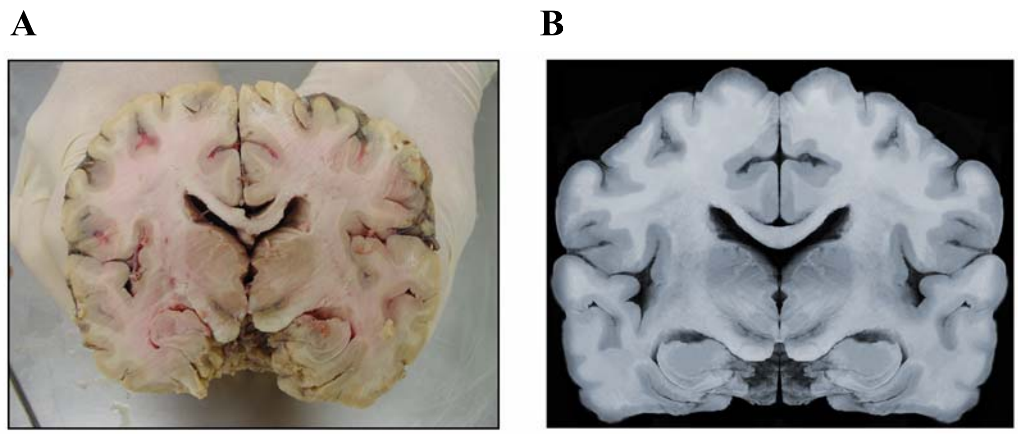



**Figure 3-2.** Preserved specimen of the brain photographed (A) the final image for use in the 3D software (B). (Courtesy of Chris Akers)

Each of the cross-sectional slide images was then reduced to no more than 1000 by 1000 pixels at 300 dpi, depending on the shape and cropping of the individual slide, and each was saved as a .TIF file.

*Title Screen / Credits Screen*

The title screen of this animation is an introduction to the subject and content of the animation, and was followed closely based on the template provided by Chris Akers. To maintain a consistency throughout the animation, the title screen image was based on a black background. In 3ds max®, 3-dimensional models were positioned and rendered as .TIF files at a relatively high resolution of 3000 by 2000 pixels at 72 dpi. The images were imported, touched up, and compiled into layers of a Photoshop® file. The layers allowed for easy manipulation and masking of separate components and they were then flatten onto a single layer. The image was selectively blurred with a blur tool and blur filter and manipulated with the dodge/burn tools. A monotone, rectangular image of the three-dimensional model brain surface was placed on the left side of the illustration as a design element, as it was intended to be repeated on the title screen of the other neural tracts. The color of this rectangular image was changed to a different hue in order to distinguish this animation form Chris Akers (Fig. 3-3.)

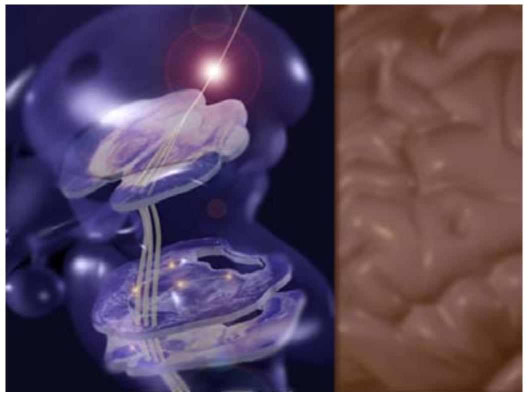


**Figure 3-3.** Title screen / credit screen image.

This image was repeated on the credits screen and both the title and credits consist of a sans-serif font, Miriam. All text was carefully placed in the title safe zone in order to avoid undesirable cropping from post-production output.

*Background Illustrations*

The same background illustrations that were originally produced by Chris Akers were used for this animation as well. However, there were some adjustments made and integrated to the original illustrations in order to better accommodate the new pathways depicted. The illustration of a backlit male torso containing a spinal cord, spinal nerves and brachial plexus was preserved. The musculocutaneous nerve, legs and the sacral plexus were painted using the airbrush tool, and added on in separate layers in Photoshop®. The same color palettes and effects were applied to create a uniform overall look (Fig. 3-4). The final image was exported from Photoshop® as a .TIF file of 1800 by 1500 pixels at 150 dpi.  Two additional illustrations were produced based on this modified illustration, consisting of an abducted leg and arm, to demonstrate the skeletal muscle contractions once the corticospinal tract terminated at those muscular motor end plates.

**A** **B**

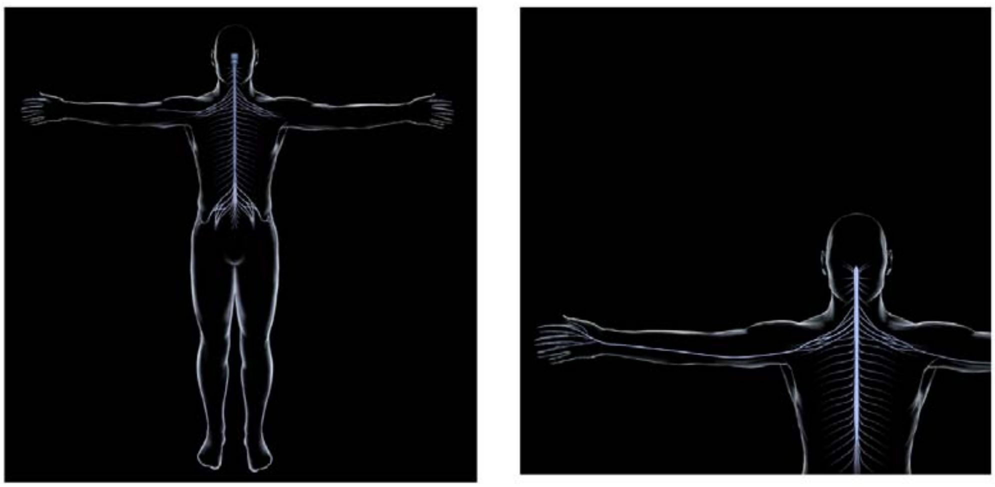


**Figure 3-4.** Photoshop® illustration of the background modified (A) based on the original illustration (B).

One of the major challenges that Chris Akers encountered involved the view of the anatomical cross-sections positioned within a partially visible brainstem. Although the 3-dimensional model of the brainstem was anatomically accurate, due to natural anatomical variation, the cross-sectional photographs did not fit the cross sections of the 3-dimensional brainstem model. This would have been strikingly obvious to the viewer during the animation sequence. At the time, the structure of the 3-dimensional model of the brainstem did not lend well to opacity effects applied in the 3D software, so the decision was made to produce an illustration of the brainstem to serve as a background image.  Therefore, the 3-dimensional models of the cross-sections were superimposed over an illustration of the brainstem in order to give the impression of the desired effect. However, during the development of this project, with the help of new gained knowledge and better software updates, a "glass" texture was created for the brainstem by manipulating the opacity and specular levels in the material editor of 3ds max® (Fig. 3-5).

**A** **B**

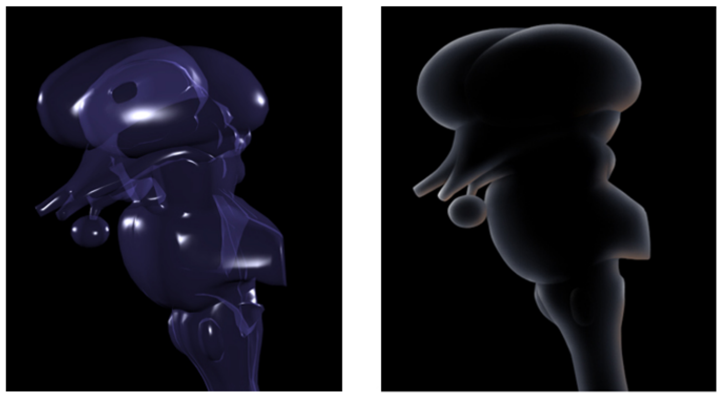


**Figure 3-5.** 3-dimensional model of the brainstem with the "glass texture (A) An illustration of the brainstem used as a background previously (B).

Once the desired look was achieved, the 3-dimensioanl models of the cross-sections were placed inside the brainstem, and adjusted in size to fit as closely as possible inside the brainstem model.

*Animation*

One of the first tasks during the animation phase of this project was the collection of 3-dimensional models. Originally, the models for the cerebral hemispheres, cerebellum, and the brainstem were obtained from Blausen Medical Communications (Houston, Texas) and Zygote Media (Provo, Utah) respectively, and utilized by Chris Akers in his animation. The same models were used again in this project, and they were imported as 3ds max® .MAX files, resized, and arranged anatomically. The color of the brain was adjusted to a more realistic one, while a map was applied to represent the superficial arteries on the brain. The remaining components of the animation were modeled in 3ds max®.

The incorporation of anatomical cross-sectional photographs into the animation was an important objective of this project. This task was accomplished by producing 3-dimensional cross-sections of the brainstem model and applying the previously prepared cross-sectional images (Chapter 3: *Anatomical Cross-Sectional Slides*) to these sections.

First, the cross-sectional photos were applied as maps onto planes in 3ds max®. Using these images as a guide, a spline was constructed around the surface contour of each of the cross-sections and adjusted with the bezier corners tool. These splines were then extruded, and the areas that needed to be cut out where subtracted using the boleen tool in order to create the 3-dimensional look for each cross-section. Once all the models were created, the anatomical cross-sectional images were applied to the top surface of each of the 3-dimensional sections (Fig. 3-6).

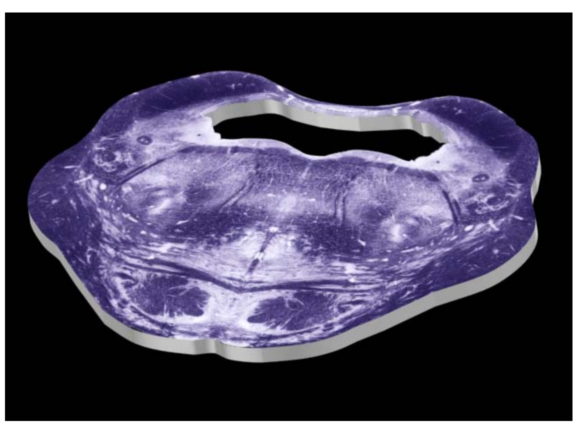


**Figure 3-6.** 3-dimensional model of a slide section with mapped cross-sectional image.

As mentioned earlier, one of the unexpected challenges that Chris Akers encountered during his animation production was that the 3-dimensional models created from the cross-sectional photographs did not fit the contours of the 3-dimensional brainstem model. Even though they both are anatomically accurate, the difference is due to natural anatomical variation. Since the main objective of this instructional aid was to incorporate the anatomical cross-sectional photographs into a 3-dimensional environment, it was necessary to adjust the brainstem model to be more accommodating to the anatomical cross-sectional models. To rectify the situation, Chris Akers created two sets of 3-dimensional cross-sections. One set was produced to fit within the shape of the brainstem model exactly, but with no cross-sectional photographs applied to them. These were used in scenes where the opacity of the brainstem model was opaque and the outline contours of the cross-sections were more important. The other set was produced to fit the exact contours of the cross-sectional photographs but did not fit the brainstem model. These sections were used in scenes where they were superimposed over the illustration of the brainstem (Fig. 3-5 B)

However, during the production of the corticospinal tract animation, this issue was bypassed by applying a “glass” texture to the 3-dimensional brainstem model achieved by adjusting the material opacity and specular levels (Fig 3-4 A). This allowed for the placement of the 3-dimensional models inside the brainstem, and more freedom to move the camera around the objects. The size of each 3-dimensional section was scaled to fit as closely inside the brainstem model. Even though the outside contours of the cross-sectional models still did not match the brainstem model exactly, the differences were much more subtle and unnoticeable (Fig. 3-7).

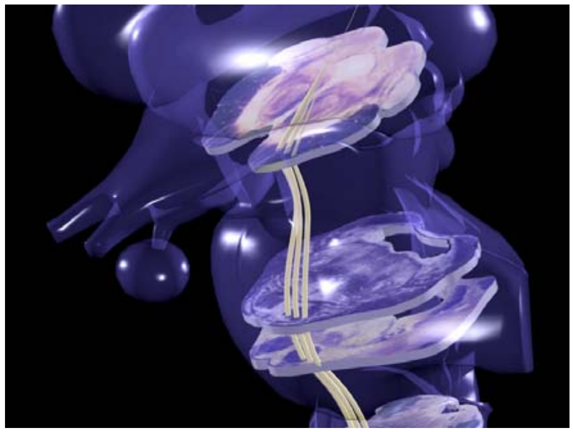


**Figure 3-7.** Slide sections placed inside the 3-dimensional model of the brainstem.

In addition to the production of 3-dimensional cross-sections, the spinal nerves and ganglia that approach the cervical vertebral cross-section were constructed in 3ds max®. They were created with a series of formed and molded cylinders along with the application of a gradient map to fade the ends of the nerves. These models were originally constructed by Chris Akers and were reused with his permission and slightly modified. The paths of the corticospinal and corticobulbar pathways were created with splines and a shape was applied to them. They were later adjusted with loft modifiers. A yellow color was applied as a material and given a slightly less opacity.

One of the challenges of this project was illustrating the effect of the corticospinal and corticobulbar tracts on the motor end plates of distal limbs and facial muscles, respectively. Creating 3-dimensional models for the biceps and tensor fasciae latae muscles was simple enough, but illustrating the arm and leg movements once the muscles were contracted proved to be more difficult. To animate the movement of the arms and the legs, a 3-dimensional model of the entire human body needed to be created in 3ds max® and then manipulated at the proper joints in order to convey a "true" 3-dimensional movement. The same applied to the facial muscles, where a complete, 3-dimentioanl face with all the detailed musculature was needed to animate any proper movement in the face. However, due to the intended scope of this project a 3-dimensional model was not pertinent to show the "true" movements of the limbs and instead a 2-dimensioanl representation of the arm and leg, along with facial muscle activation was animated to fulfill the scope of this project.

In order to show arm and leg movements, the background illustrations (Fig. 3-4 A) were modified, representing a contracted arm and an adducted leg (Fig. 3-8 A and B).

**A** **B**

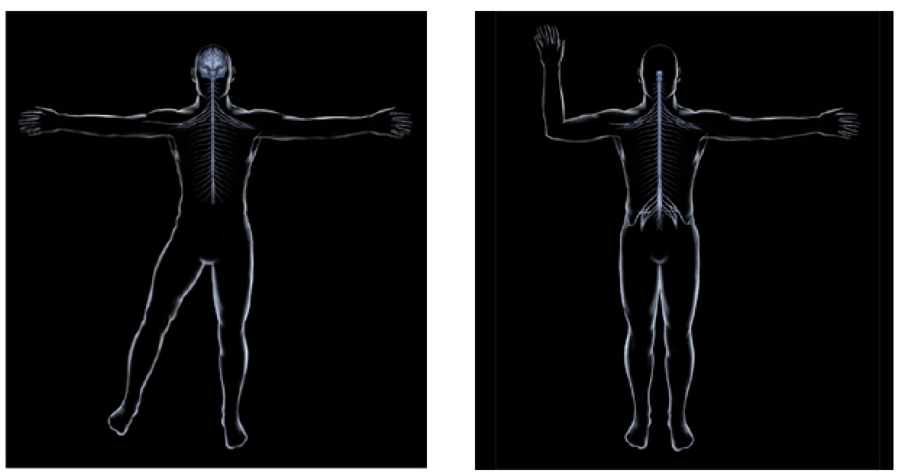


**Figure 3-8.** Modified background illustrations representing an adducted leg (A) and contracted arm (B)

During the animation of the corticospinal tract, the background illustrations fade from one 2-dimensioanl illustration to the next, implying movement based on muscle contraction.

As for the facial muscles, a modified 2-dimensional illustration of the face with its musculature was produced (Fig. 3-9 A). During the animation of the corticobulbar tract, three omni lights were placed on the face illustration, representing areas of muscle activation at the end of the corticobulbar tract animation (Fig. 3-9 B).

A B

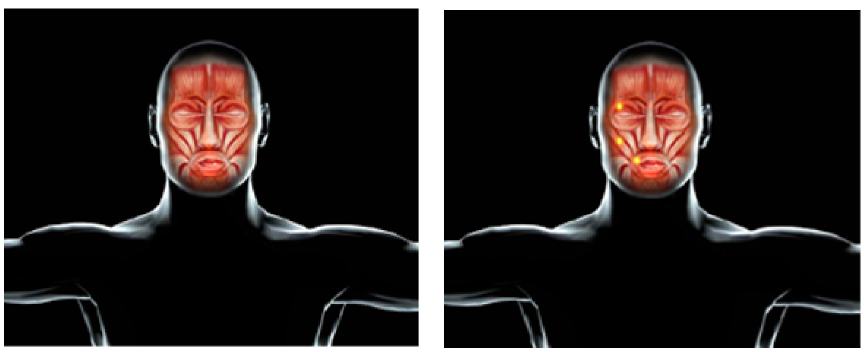


**Figure 3-9.** Modified background illustration of the face (A) and areas of facial muscle activation.

The next task was to prepare these 3-dimensional components for animation. The 3-dimensional models were placed in tangent with appropriately positioned background images that were mapped to planes. A camera and lights were added to the scene and positioned. Several spline paths were created that span the entire path of the corticospinal and corticobulbar tracts from their point of origin in the cerebral cortex, to their branches in the midbrain and spinal cord, and out through the spinal nerves to the musculocutaneous nerve of the arm and the superior gluteal nerve of the leg. As there are two subdivisions of the corticospinal tract (ventral and lateral) beside the separate path that the corticobulbar tract follows, naming each path and nerve impulse accurately was very essential and proved to be immensely beneficial during readjustments of each scene. An omni light with a glow lens effect was assigned to each path to represent the neural impulses. This glowing light quickly travels the length of the path and repeats its action throughout the animation with the use of the parameter curve out-of-range (cycle) command and the multiplier option in the visibility track. Omni lights were also placed at the locations of the second and third neural synapses, and the terminal point of the corticospinal tract in the skeletal muscles of the arm and leg, the biceps and the tensor fascia latae muscles, respectively. A glow effect was also applied to each light and with the multiplier option in the visibility tracts they flashed corresponding to nerve impulse synapses. At the end, over forty omni lights were created and placed at various locations within the scenes, so accurate naming of each light was extremely important during production.

The camera was set to follow neural impulses along the path of the corticospinal and corticobulbar tracts from the primary motor area of the cerebral cortex, to the midbrain and medulla, descending though the spinal cord and eventually reaching the motor end plates of the skeletal muscles in the arm and leg. With the use of the visibility tracks, the camera is able to follow the neural impulses as they travel through the 3-dimensional cross-sections within the brainstem and the brain. Also, the camera’s field of view (FOV) was manipulated in several instances to create the zooming-in effect without physically moving the camera. This proved to be extremely beneficial as it reduced the number of paths and targets that needed to be created for each camera movement, hence reducing the file size and ultimately the rendering time.

Due to the large size of the animation file, it was necessary to split it into nine scenes in 3ds max® while in production. Each of these scenes were rendered at 600 by 800 pixels at 30 frames per second, and saved as AVI movie files. The Microsoft MPEG Video Codec V.2 was selected for the save option and the animation compression set on high quality.

*Editing*

Upon final approval from the committee members, it was necessary to edit the animations clips along with transitions and anatomical labels. The movie clips that were rendered from 3ds max® (AVI files) were imported into Adobe® Premiere® Pro 1.5 and into a media bin designated for movie clips. The illustrations for the title screen and credits screen were imported into a media bin for images. The clips and still images were dragged into video tracks and arranged sequentially. With the razor tool and cross-fade tool, appropriate cuts and cross-fades were applied to the video clips to provide smooth and visually pleasing transitions from one scene to the next.

As it was decided in Chris Akers project, and in order to preserve the same editing format, the final movie includes two versions of the same animation; one without anatomical labels followed by one with labels. Additionally, each neural tract would be presented separately with its appropriate labels, so that the path of the corticobulbar tract would animate in its entirety followed by the corticospinal tract. This decision was made after preliminary reviews by the committee members with the viewers needs in mind as it would have been too confusing to observe all the events of both tracts occurring simultaneously.

The version without labels was completed first and then all movie clips, stills, and transitions were collectively copied and placed along the video tracks after the original version. In the copied version, still images were edited into the video clips for breaks in time where anatomical labels and leader lines were added. The text was carefully placed within the title-safe zone to avoid cropping in final output. The final animation was exported from Premiere® Pro as a QuickTime® movie at 600 pixels by 800 pixels at 30 frames per second, with Sorenson compression set at 90% quality.

# CHAPTER FOUR
## Evaluation

In order to assess the animation's effectiveness, an informal evaluation was conducted. The completed animation was shown to a group of twenty-one first year medical students at Albany Medical Center. The animation was loaded onto one of the student labs computer workstation, and the intended purpose of this animation was explained to the students before hand. The questionnaire designed by Chris Akers was used and presented to the students. It consisted of six statements, each with the response choices of *strongly agree, agree, no opinion, disagree*, and *strongly disagree*. In conjunction with the questions, a space was provided for additional comments and/or suggestions (Appendix B).

The questions and responses were as follows:

1. The animation is clear and easy to understand.

| Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 10 | 11 | 0 | 0 | 0 |

2. Seeing the animation in lecture would have been helpful for learning the tract.

| Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 14 | 7 | 0 | 0 | 0 |

3. The handout is preferred over the animation for learning the tract.

| Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 1 | 0 | 11 | 6 | 3 |

4. A combination of the animation and the handout would be the most helpful way to explain the tract.

| Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 18 | 3 | 0 | 0 | 0 |

5. The cross-sections in the animation are clear and understandable.

| Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 7 | 11 | 3 | 0 | 0 |

6. It is easy to follow the path of the corticobulbar and corticospinal tracts throughout the animation.

| Strongly Agree | Agree | No Opinion | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 6 | 14 | 1 | 0 | 0 |

Overall, the responses were favorable. The students all agreed that the animation was clear and easy to understand. Also, they all agreed that viewing the animation presented in lecture would have been helpful for learning the tracts. In response to whether the lecture handout is preferred over the animation, half of the students had no opinion or the rest disagreed, with only one person preferring the handout to the animation. This equal split in opinion was not surprising as the animation was not intended to replace the handouts in class, but it was designed to be used as an instructional aid along with the rest of the study material provided by the instructors. The success of the intended use was further reemphasized where all of the students agreed that a combination of the animation <u>AND</u> the handout would be the most helpful way to study the tracts. Most agreed that the cross-sections were clear and understandable, but a few students had no opinion. Almost all of the students felt that it was easy to follow the path of the corticospinal and corticobulbar tracts throughout the animation. Only one student had no opinion.

Over half of the students commented that they would have preferred a slower version of the animation that included more labels. Also, there were several who suggested the use of different colors for different tracts. The use of voice over narration was also mentioned for improving the animated movie. Some also suggested installing the animated movie on student computers at the library for use in the future.

# CHAPTER FIVE
# Conclusions and Recommendations

*Conclusion Based on Evaluation*

The goal of this thesis project was to create an animated 3-dimensional instructional aid to assist instructors in presenting the neural tracts to first year medical students. The primary objective of this project was to take the complicated anatomical pathways of the corticospinal and corticobulbar tracts and present them it in a clear and concise manner. Another objective was to incorporate anatomical cross-sectional photographs into digital 3-dimensional models of the brain and brainstem. The final animation was designed to be presented in a lecture hall and easily controlled and navigated by the instructor. The final animation movie contains two versions of the same animation. The first version of the animation is without pauses or labels and was intended to serve as a general overview of the particular pathway. The second version of the animation includes pauses and anatomical labels intended where the instructor is able to deliver a more detailed description of the content. Each neural tract was animated separately so that the viewer (students) is not overwhelmed by all the events occurring simultaneously in each scene. Anatomical labeling was kept to a minimum to maintain the concept of simplicity, so only general anatomy and key points of the corticospinal and corticobulbar tracts were labeled. This animation was based on the template designed and developed by Chris Akers.

The animation was informally evaluated on its own merits rather than for the specific intended use as a lecture hall instructional aid. Nonetheless, the evaluation by the first year medical student test group indicated that the goal of the project was achieved. The results of the questionnaire indicated that the animation is a useful instructional aid for the presentation of the corticospinal and questionnaire indicated that the animation is a useful instructional aid for the presentation of the corticospinal and corticobulbar tracts. Additionally, the students found the incorporation of cross-sectional photographs useful and the animation to be clear and easy to understand. Their responses indicate that the animation is visually helpful in solving the 3-dimensional inadequacies of textbooks and handouts. In conjunction with didactic study material, the students responded that the animation would be a valuable tool in learning the corticospinal and corticobulbar tracts. They also indicated that a slower version with additional anatomical labeling and voice over narration would be useful as a stand-alone study guide.

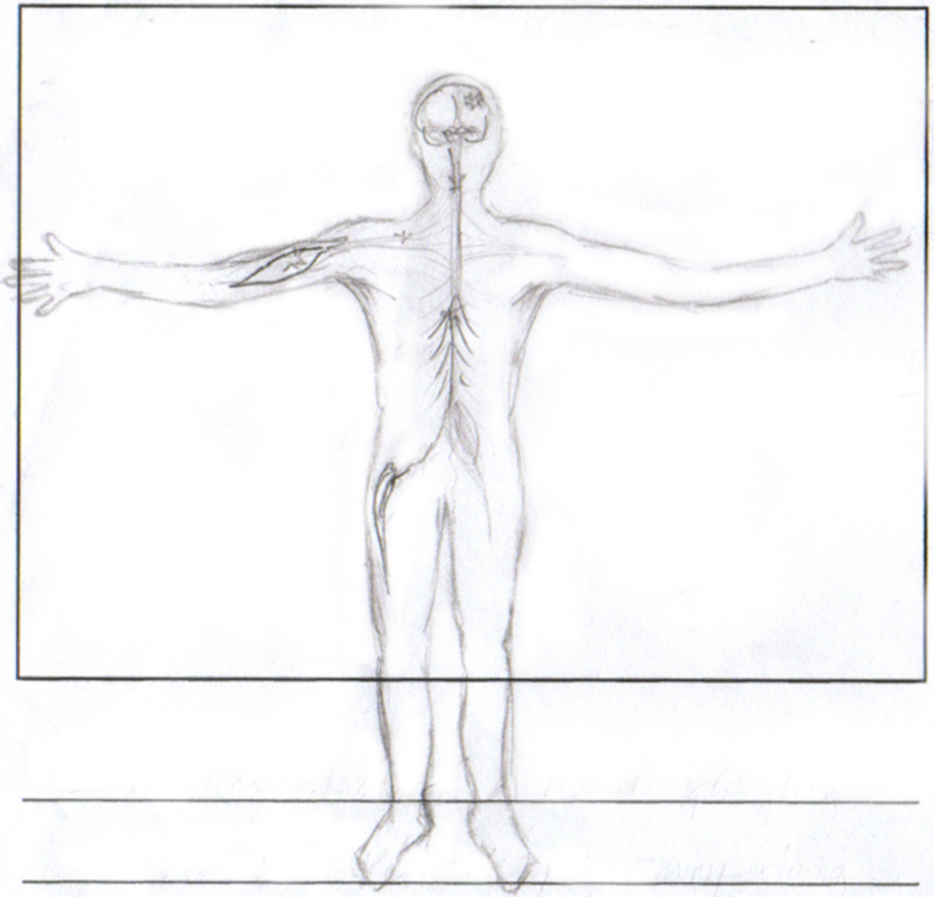
### *Suggested Areas of Further Study*

Many students participating in the evaluation expressed interest in seeing the remaining neural pathways animated. As with this project, the template designed by Chris Akers could be modified in animating each of the remaining neural tracts. By preserving the same design elements in the following projects, all the animated tracts could eventually be assembled into a comprehensive instructional aid.

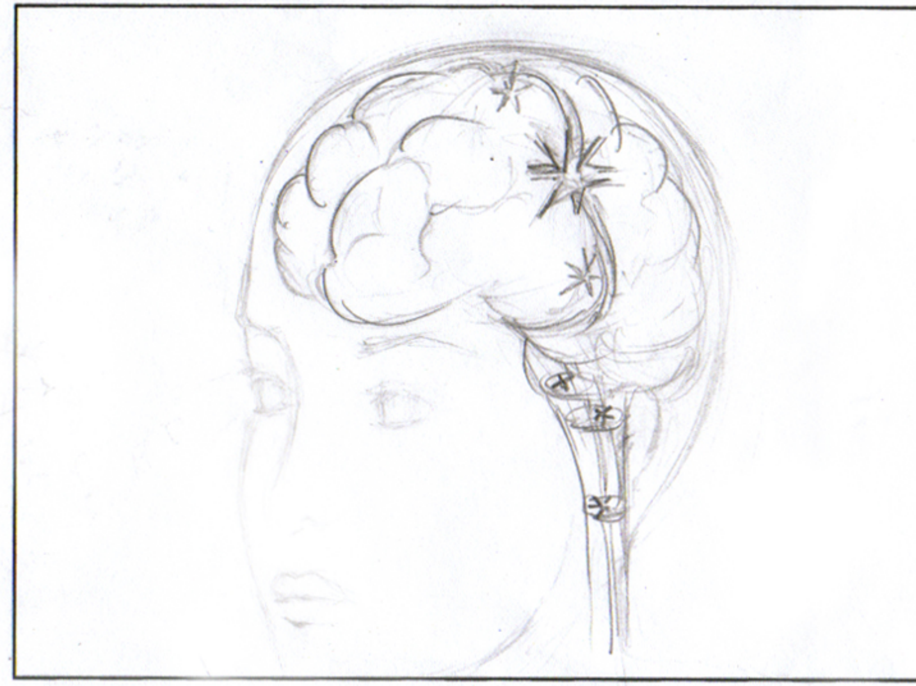
Although this animation was intended for lecture hall presentation by an instructor, it could be expanded into a multimedia format, which could be directly targeted towards first year medical students. The multimedia package could include an interactive section that would allow the student to access 3-dimensional cross-sections of the spinal cord, brainstem, and cerebral hemispheres and view 3-dimensional, labeled features of the anatomy via rollovers that are similar to the web format. These concepts could be extended to the other neural tracts, which would provide the student with a CD-ROM (or DVD-ROM) study aid that encompasses all of the neural tracts.

# APPENDIX A
## Storyboards

1



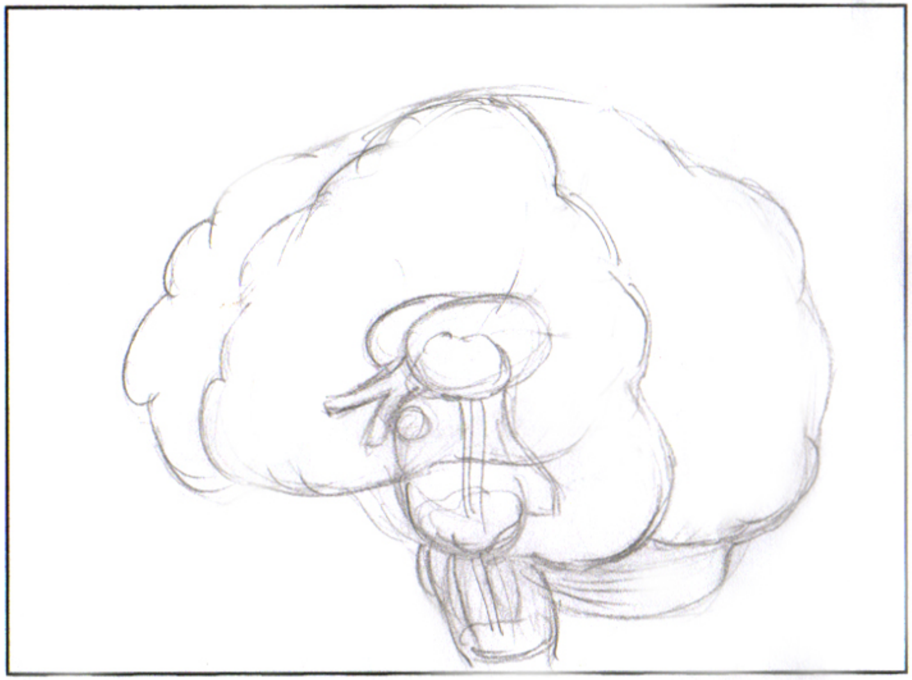
2



- Complete body outline present with extended arms ; neural system visible
- A burst of light in the Brain travels down the SC to terminate as 2 Impulses on the arm + leg muscles
- Scene fades away . . .

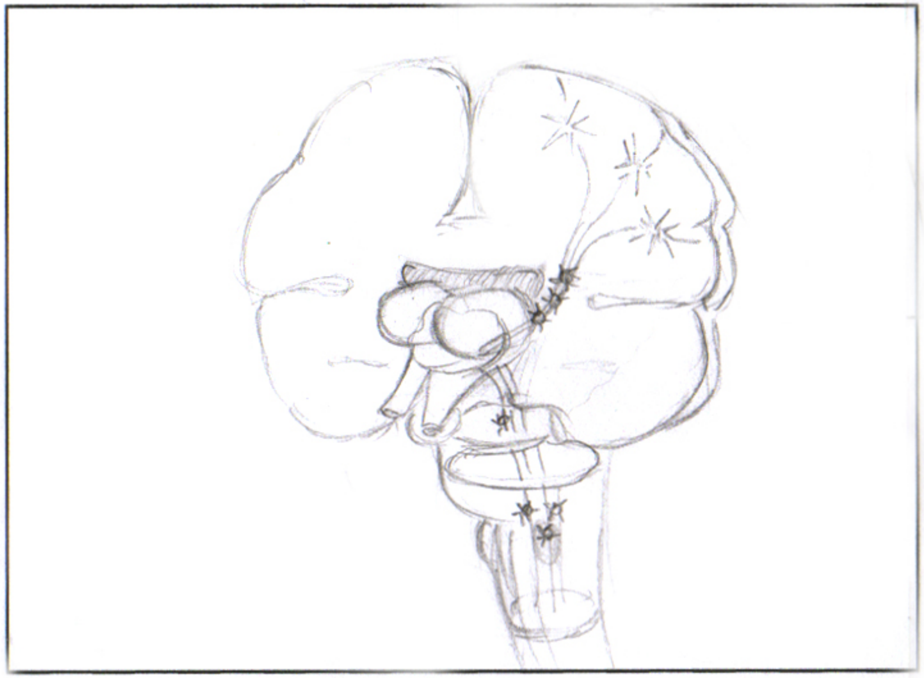
- New frame : Camera shows the head at a 3/4 position (Just show Brain - - -)
- 3 bursts of light go off in the primary motor cortex area
- The streaming of neural impulses flow down the spinal cord
- opacity of Brain begins to decrease - - -

3



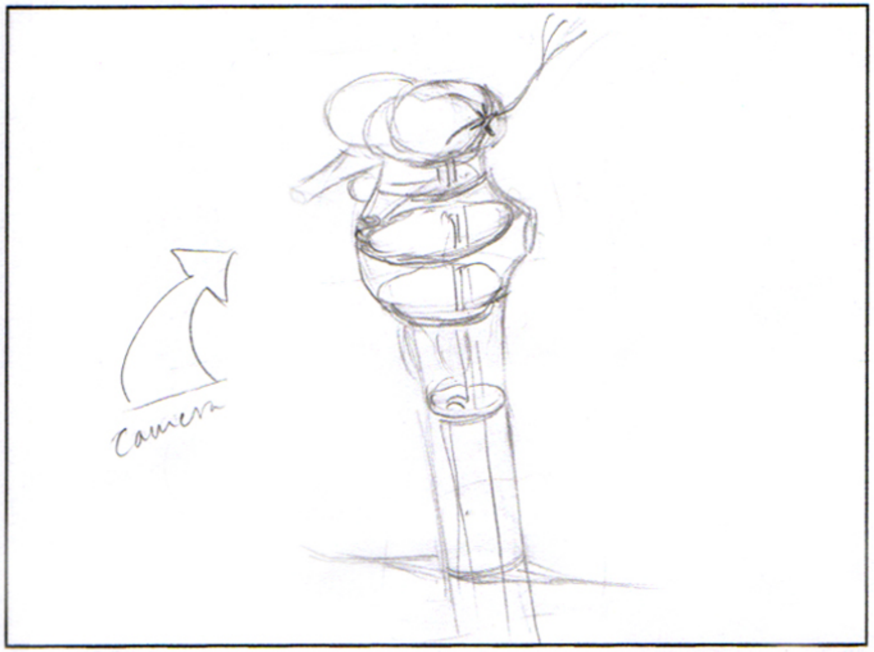
- The Brain continues to fade away making the brain section more visible
- The Brain stem will also become more visible, w/ a "glass" texture where different cross-sections visible.

4



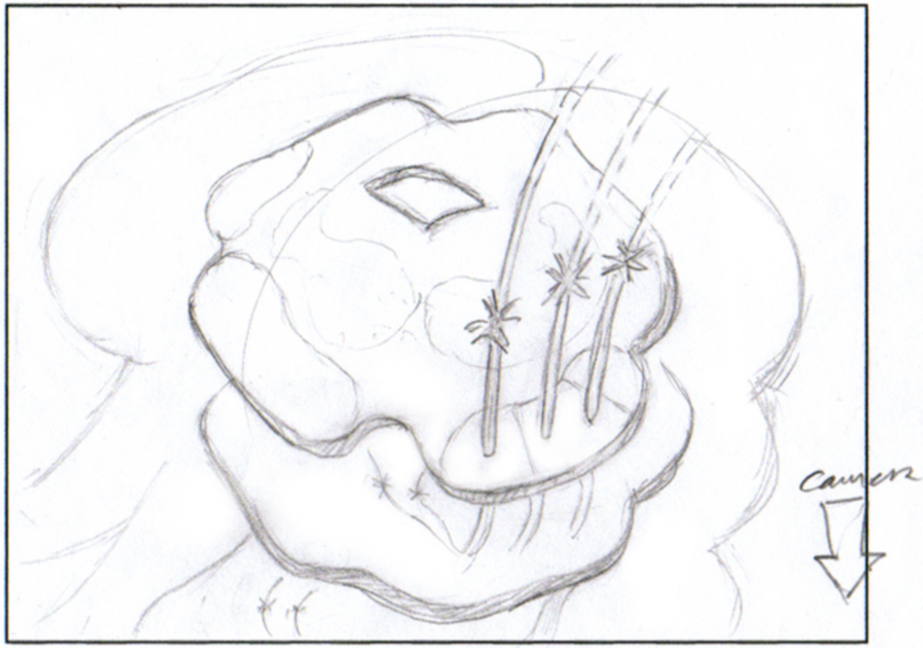
- The Brain has completely faded away w/ cross Section in full view (TS-36)
- The 3 neural impulses from the motor cortex region converge down a path towards the 1st cross section (TS-30)
- The Brain section (TS-36) Begins to fade away...

5



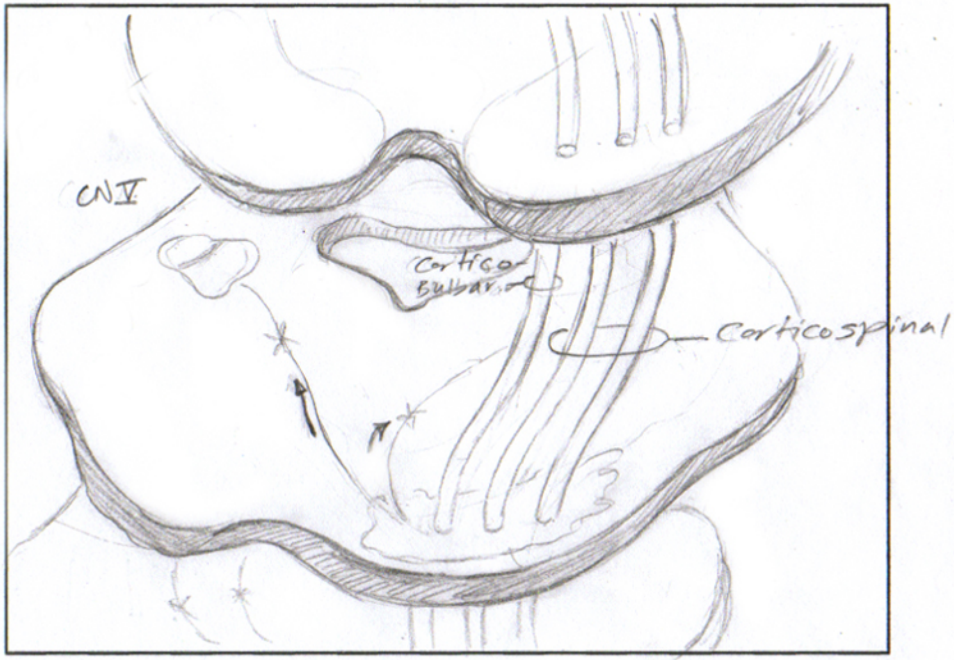

- "Gloss" brain stem is completely exposed once TS-36 has faded away
- Cross sections of mid brain, Pons + medulla and the path of the CS + CB tracts are visible through the brain stem
- Neural Impulses continue to travel down the pathways
- Camera rotates + zooms on TS-30 ---

6




* Thalamus region (TS-30)
- New scene; Camera starts on the TS-30
- The CS + CB tracts appear through out the animation as semi-opaque with branches at each level to CN centers
- Camera pauses at each level, then moves down to the next ---

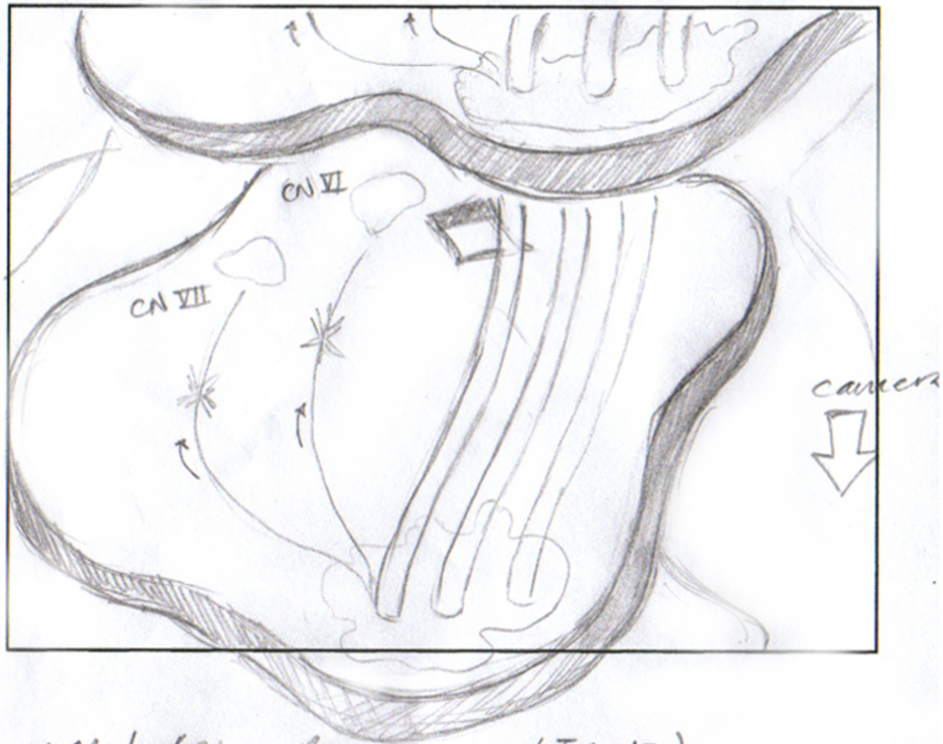
7




*Midbrain region: (TS-19)

- Camera moves down to the next level
- Appropriate title appear
- Bursts on neural impulses continue to travel down the tracts + branches
- Camera pauses + moves down to the next level ---

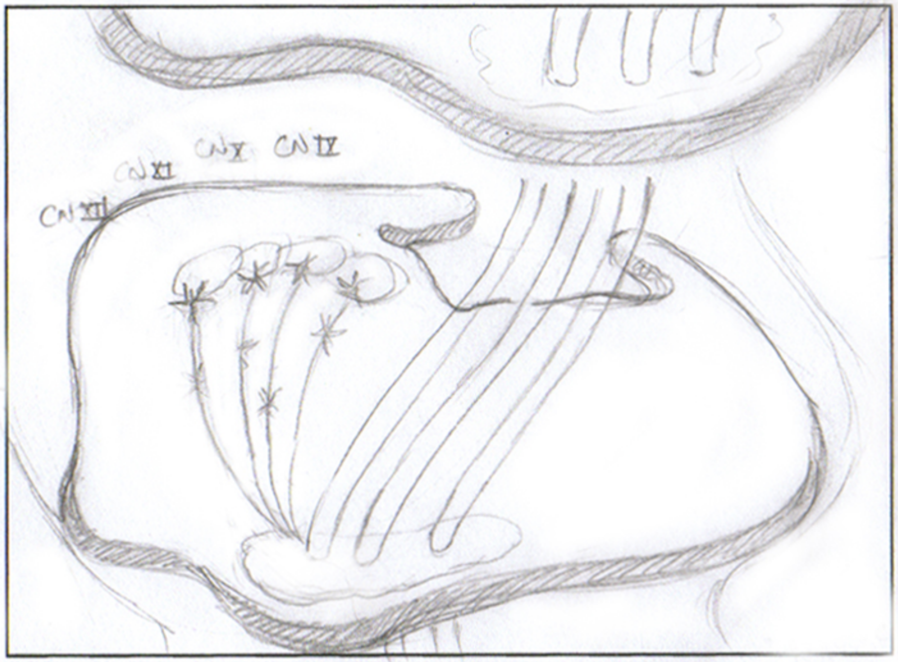
8




*Mid brain Region: (TS-13)

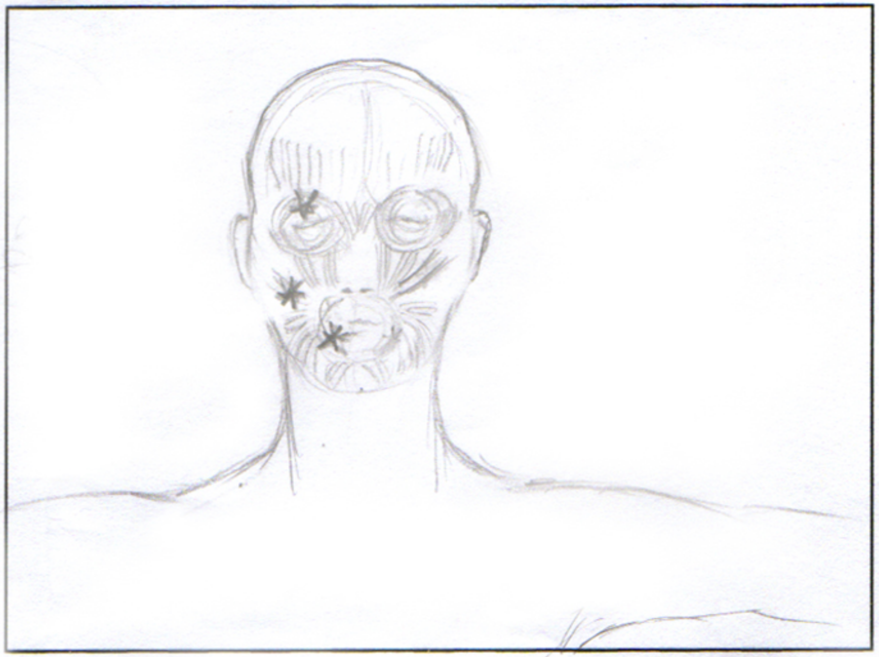
- Camera moves to the next level
- Appropriate titles appear
- Neural impulses continue to travel from pathways to the smaller branches.
- Camera moves to the next level---

9



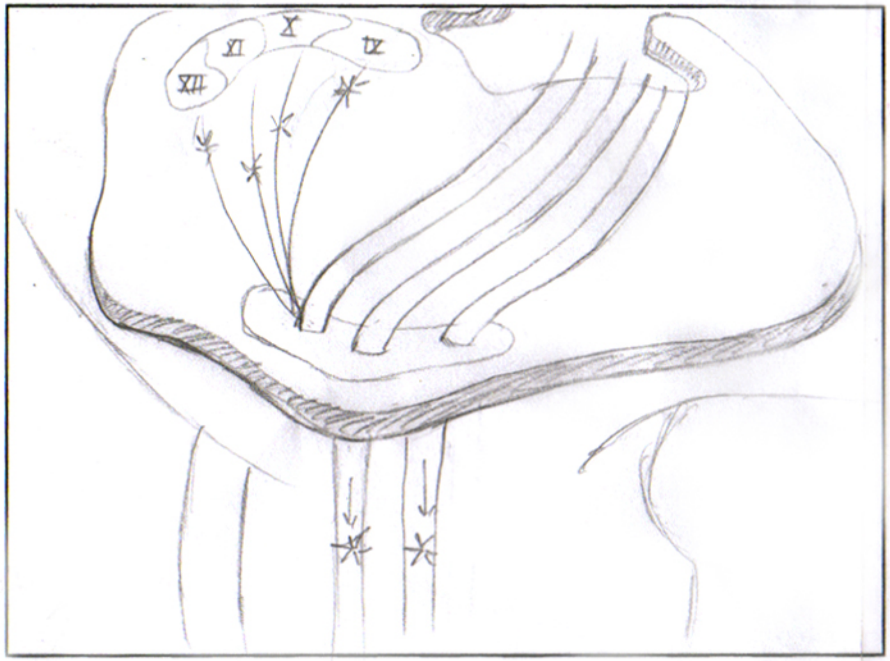

* Pons Region: (T5-8)
- Camera moves down to the next level
- Appropriate titles appear
- This is the last level of CB tract;
- Impulses continue to travel through all tracts + branches
- camera cuts / fades from this scene to the next ---

10



- New scene fades in
- facial muscles are visible on the background image of the head
- 3 bursts of light pulsate representing the activation of facial muscles (on the contralateral side)
- This scene is the end of the CB tract
- Scene fades out ---

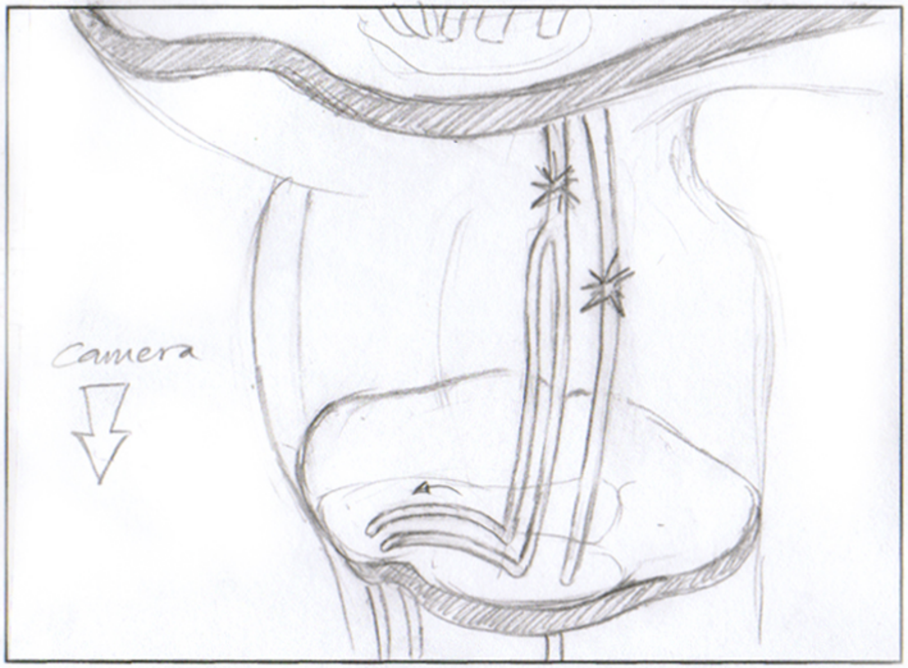
11




* Pons Region (TS-8) - - -

- New scene fades in, picking up from the last scene before head shot
- CS tracts continue beyond this level
- w/ neural impulses continuosly pulsating
- camera moves down to next level - - -

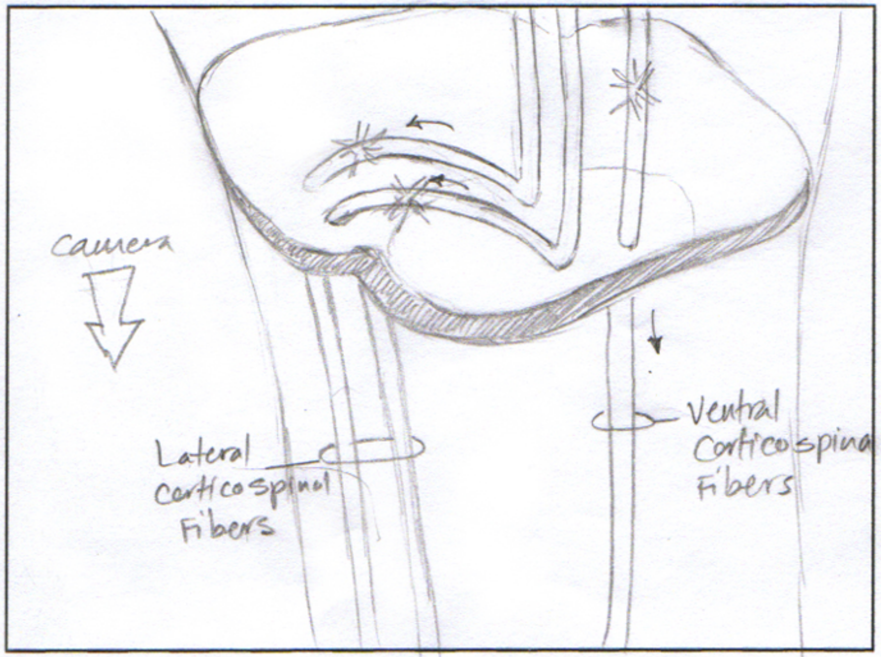
12




* Medulla Region, (TS-1)

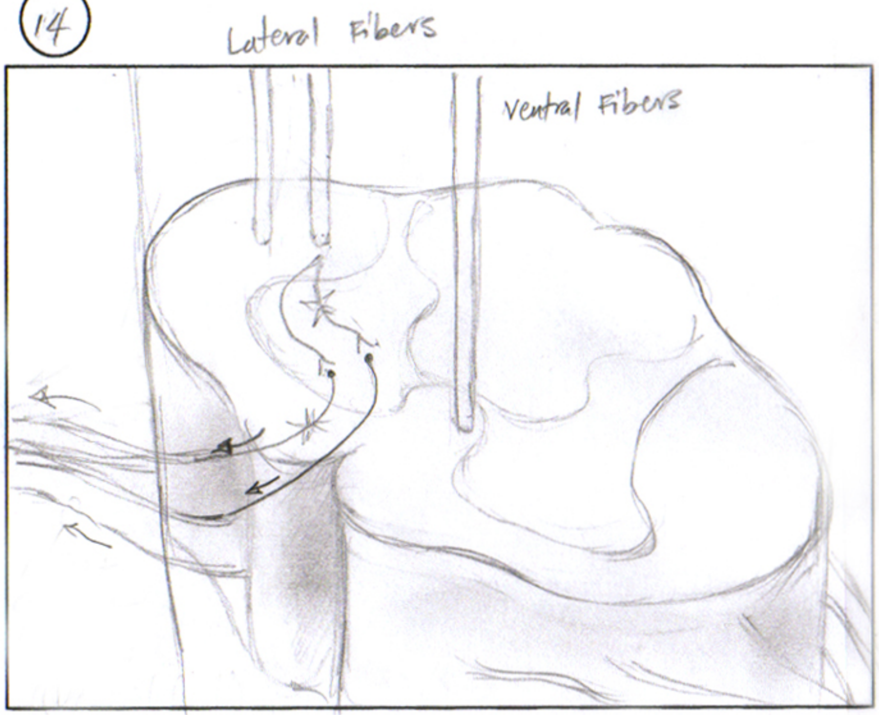
- The Cortico spinal tract divides into the lateral & ventral branches after the lateral branches cross over in the medulla (TS-1 section)
- Camera moves down to the next scene - - -

13



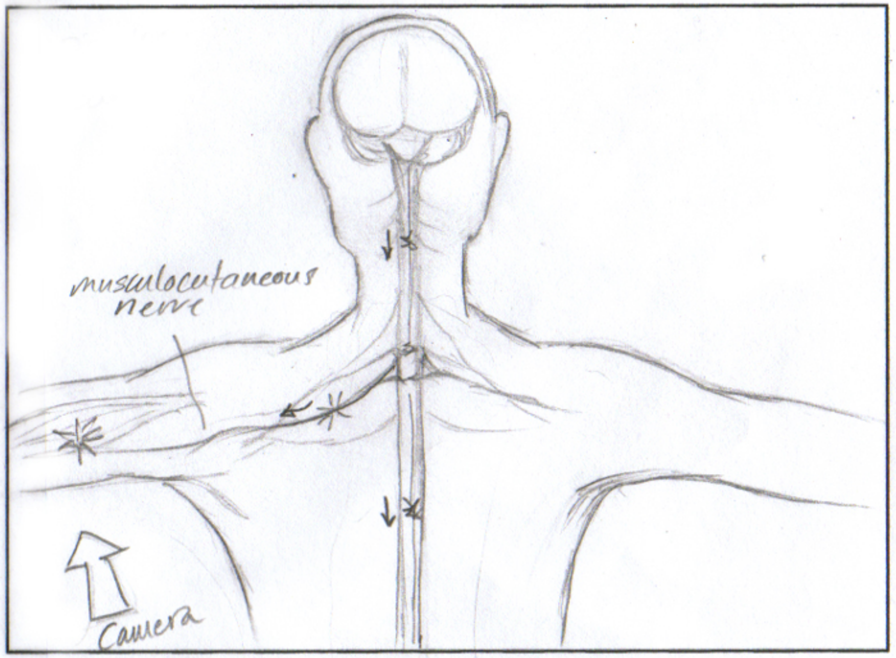

- The lateral + Ventral Cortico spinal fibers continue their path with down the SC.
- neural impulses continue to pulsate
- down their path
- Camera zooms out to span down the path of SC ...
- camera zooms back in on the next level (C-8) ...

14



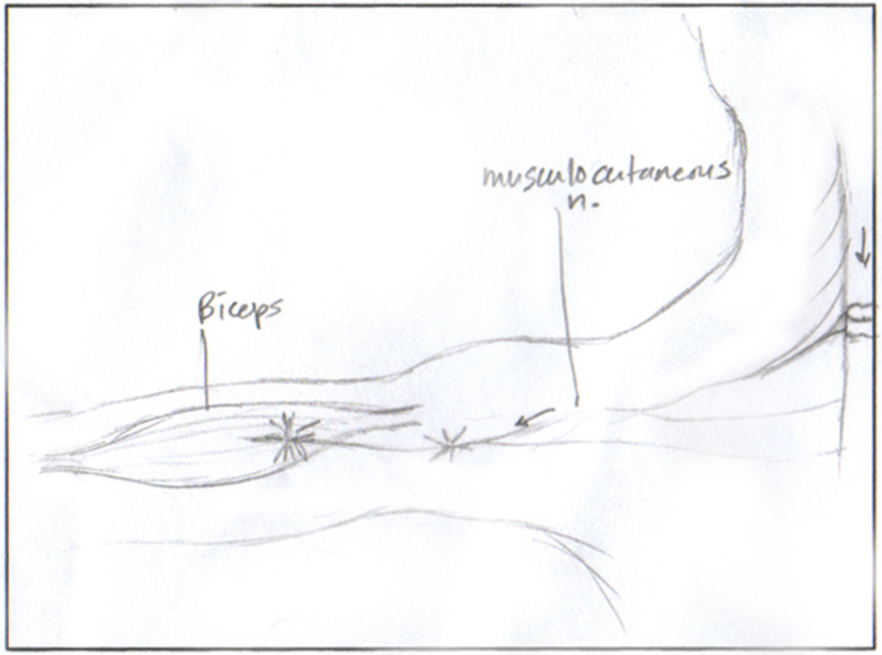

* Spinal Cord: (C8)
- the lateral CS fibers synapse w/ 2° neurons, and they in turn continue to send impulses to alpha & gamma motor neurons exiting the SC.
- Camera zooms out a bit as the whole frame dissolves → cut to next frame

15



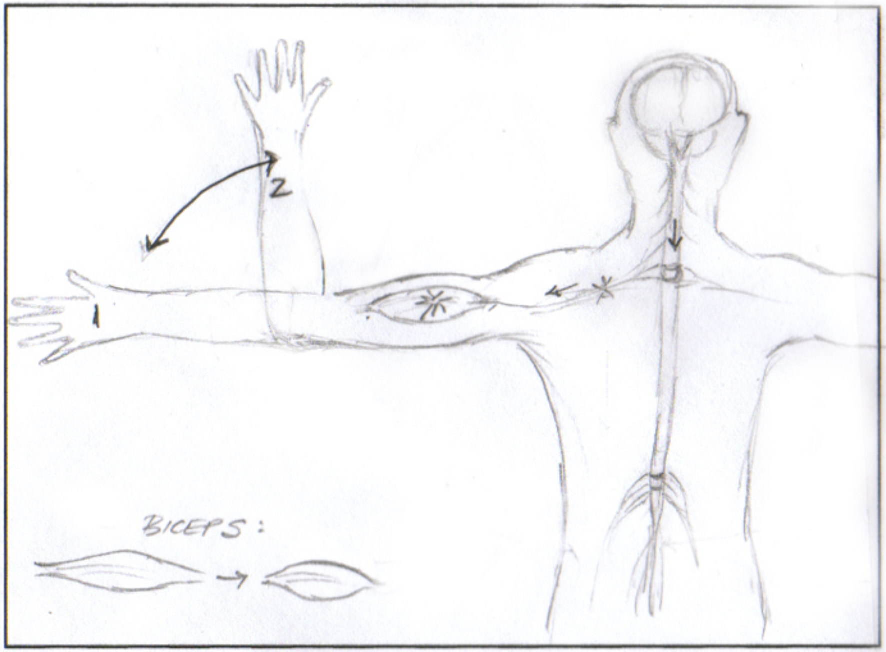

- New Scene : outline of the upper body reappears, w/ Brain + SC + continuos neural impulses traveling
- the camera zooms in towards the arm to the left + the biceps muscle
2 pulses on the biceps muscles (w/ varying intensity) indicate muscle activation

16



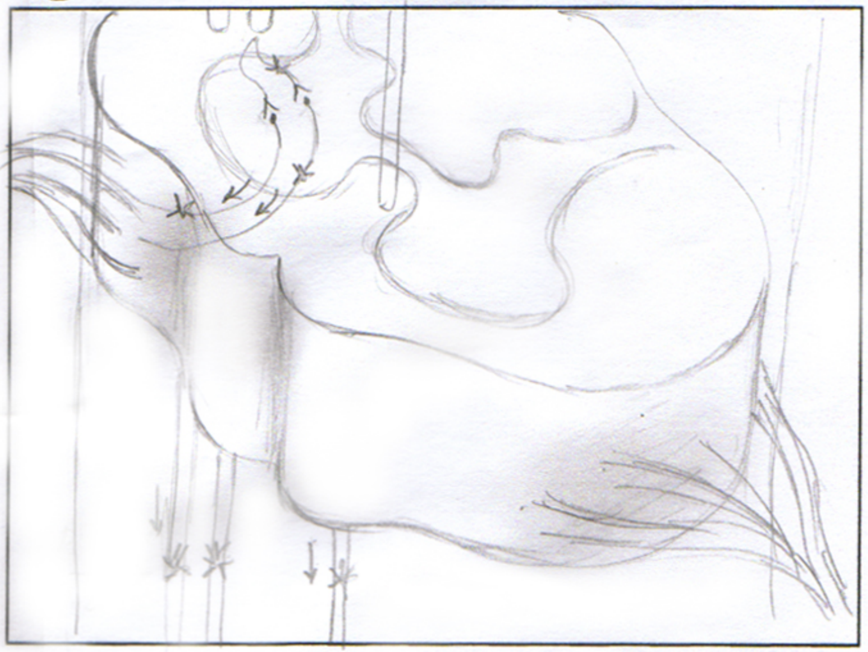

- The neural impulse continue to travel from the C-8 section of SC through the brachial plexus + down the musculo-cutaneous nerve, terminating in the biceps.
- Camera zooms out a bit to reveal more of the upper body / arm region

17



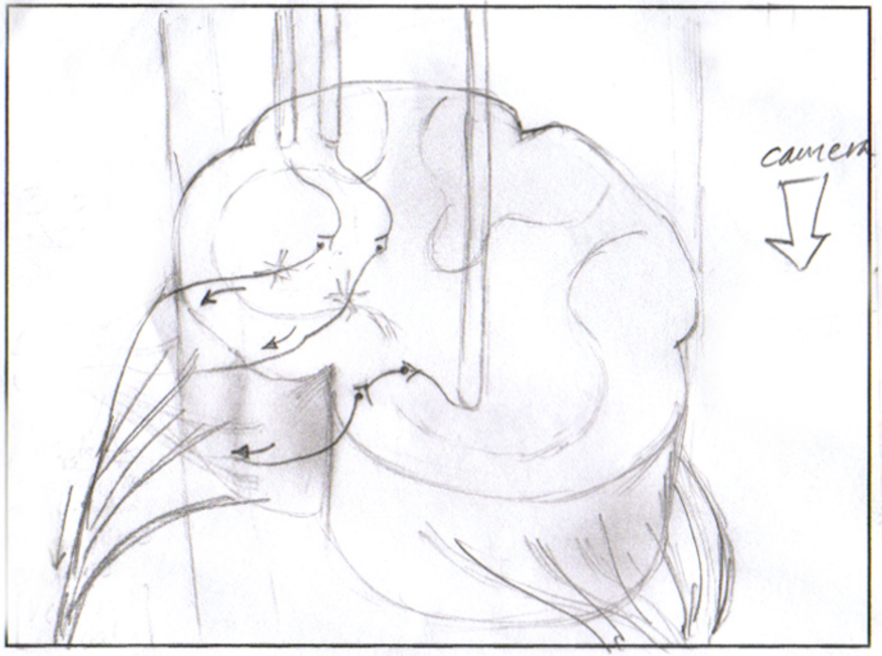

- The activation of the biceps are further shown by actual animation of muscle contraction (change of shape)
- Once the biceps are contracted,
- arm movement is animated by fading out the extended arm background w/ the contracted arm image
- Scene fades out ---

18



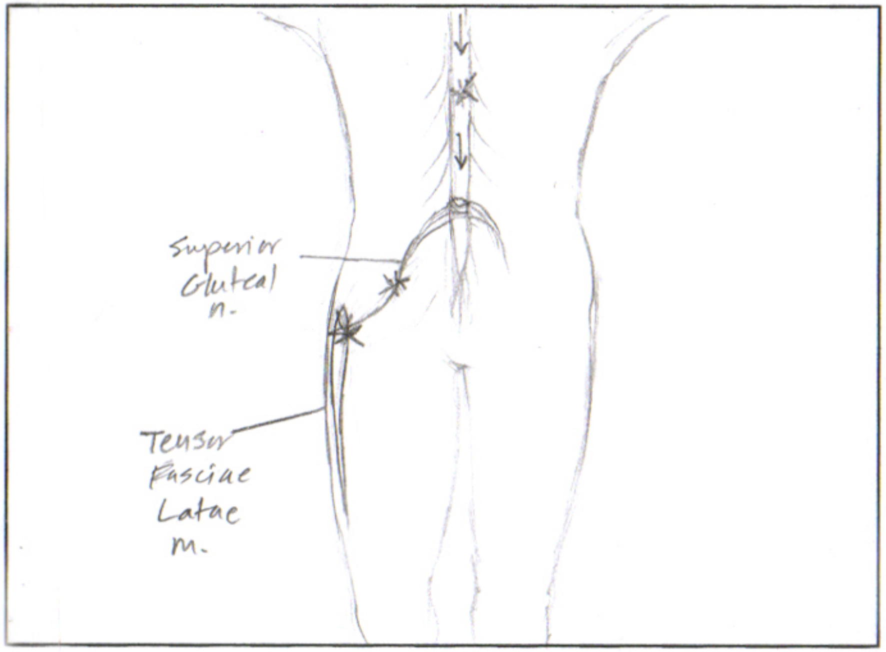
- New Scene, back at the C-8 level---
- neural impulses continue to travel through lateral & ventral SC tracts down the spinal cord
- Camera zooms out & spans down the spinal cord to the next level (S-1) ---

19



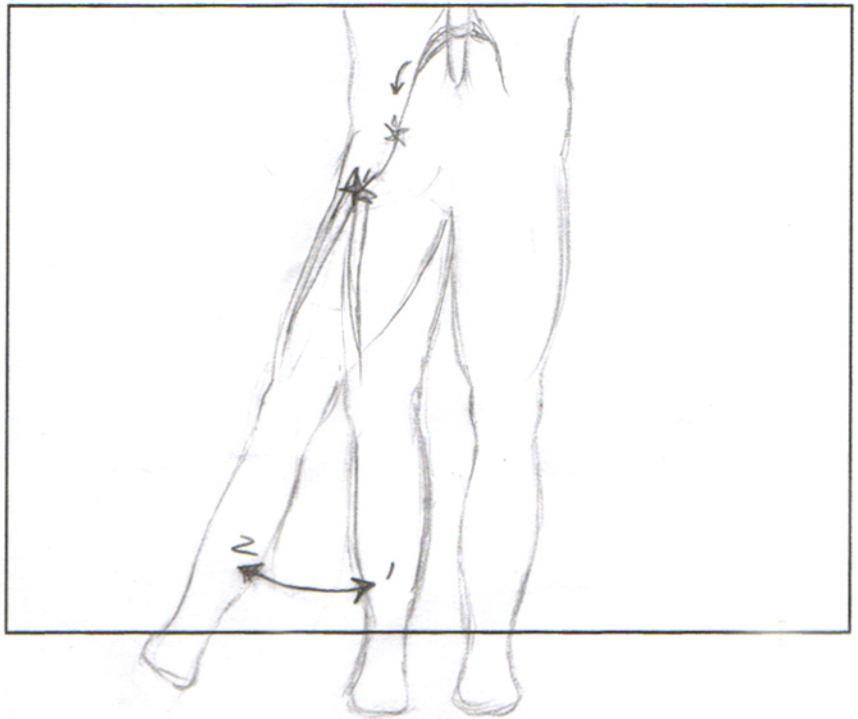

* Spinal Cord (S-1)
- Camera zooms in on the S-1 level
- Neural impulses move from the lateral ventral SC fibers to 2° + 3° neurons out through the sacral plexus (ventral roots)
- Camera zooms out + fades to next scene---

20



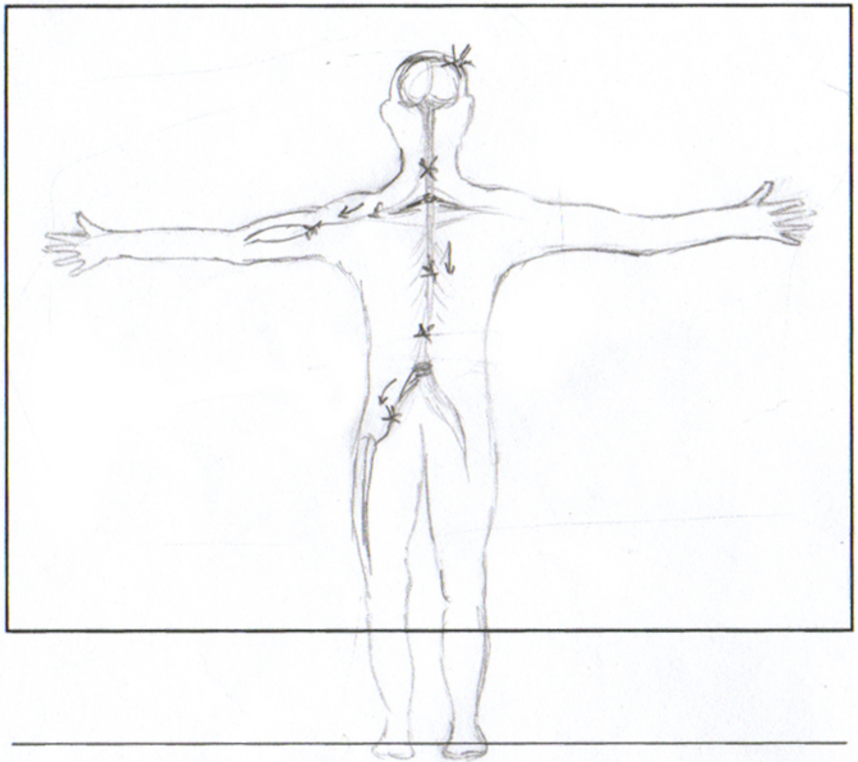

- Lower half the body (background image) appears w/ the tensor fascia latae muscle
- Neural impulses continue to travel through the superior gluteal nerve to the tensor muscle
- 2 varying intensity pulses on the tensor muscle indicates muscle activation

21




- Camera zooms out to show the entire lower body & legs
- Once the tensor muscle is activated the leg movement is animated by fading out the standing background to an abducted leg position
- The tensor muscle moves w/ the animated leg
- scene fades out ...

22



- new scene (same as scene 1)
- scene 1 is repeated w/ the whole body present (including the 2 muscles)
- A bright impulse originating from the brain travels down the SC, ending as a brighter impulse on the leg + arm muscles
- End of animation

# APPENDIX B
# Questionnaire

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

| | STRONGLY AGREE | AGREE | NO OPINION | DISAGREE | STRONGLY DISAGREE |
|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☒ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation.. | ☒ | ☐ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

cool! it would have been very useful in lecture. are there more tracts animated?

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

| | STRONGLY AGREE | AGREE | NO OPINION | DISAGREE | STRONGLY DISAGREE |
|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ■ | ☐ | ☑ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

very good! would have been useful earlier in the semester!

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

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|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☐ | ☑ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

More lables could be helpful or a slower animation for better identification of structures. Very good!

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

| | STRONGLY AGREE | AGREE | NO OPINION | DISAGREE | STRONGLY DISAGREE |
|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☒ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☒ | ☐ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

VERY GOOD ☺

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☒ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☒ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

not a replacement or a stand alone study material, but an excellent visual aid to accompany lecture. Good job!

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

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| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☒ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation.. | ☐ | ☒ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

It would be good if you have the whole picture showing when the nerves are firing and not just a section. It would definitely have helped to use this in studying. Good job!

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

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| 1. The animation is clear and easy to understand. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☐ | ☒ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☒ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

THIS ANIMATION WOULD BE VERY USEFUL AS AN EXTRA LEARNING GUIDE FOR MEDICAL STUDENTS AS IT SHOWS THE 3-DIMENTIONAL ASPECT OF INTERNAL STRUCTURES MUCH MORE CLEAR THAN ANY TEXT OR INSTRUCTOR HANDOUT. GREAT IDEA!

THANK YOU FOR YOUR TIME!

THE CORTICOSPINAL & CORTICOBULBAR TRACTS:
A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

| | STRONGLY AGREE | AGREE | NO OPINION | DISAGREE | STRONGLY DISAGREE |
|---|---|---|---|---|---|
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| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☑ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

Very Good !
Ideas for the future : different Colors ...
More lables ...
Rollovers ? ...

THANK YOU FOR YOUR TIME!

THE CORTICOSPINAL & CORTICOBULBAR TRACTS:
A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

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| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☑ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☐ | ☑ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation.. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

more labeling could be helpful as we 1st years go much more in dept covering a lot more structures. However very well done and a great visual aid for lecture

THANK YOU FOR YOUR TIME!

## THE CORTICOSPINAL & CORTICOBULBAR TRACTS:
## A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

---

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|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☒ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☒ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☒ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

Well Done!

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☑ | ☐ |
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| 5. The cross-sections in the animation are clear and understandable. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☑ | ☐ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

GREAT ANIMATION, ESPECIALLY LIKED THE "GLASS" MIDBRAIN/ SPINAL CORD!

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| | STRONGLY AGREE | AGREE | NO OPINION | DISAGREE | STRONGLY DISAGREE |
|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☐ | ☐ | ☑ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

SLOWER TO ENABLE BETTER UNDERSTANDING OF WHERE THINGS ARE: OTHERWISE . V. GOOD.

THANK YOU FOR YOUR TIME!

## THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 1. The animation is clear and easy to understand. | ☐ | ☑ | ☐ | ☐ | ☐ |
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| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

Do animated dots with slower motion

Use different colors for different tracts.

THANK YOU FOR YOUR TIME!

## THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 1. The animation is clear and easy to understand. | ☐ | ☒ | ☐ | ☐ | ☐ |
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| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☒ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☒ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☐ | ☒ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☒ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

3 Colors for the three diff. tracts

Go more slowly through animation

THANK YOU FOR YOUR TIME!

## THE CORTICOSPINAL & CORTICOBULBAR TRACTS:
## A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☑ | ☐ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

slower motion of nerve travelling & different, more distinguishable colors in the program.

THANK YOU FOR YOUR TIME!

# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

| | STRONGLY AGREE | AGREE | NO OPINION | DISAGREE | STRONGLY DISAGREE |
|---|---|---|---|---|---|
| 1. The animation is clear and easy to understand. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 2. Seeing the animation in lecture would have been helpful for learning the tract. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 3. The handout/ other study material is preferred over the animation for learning the tract. | ☐ | ☐ | ☑ | ☐ | ☐ |
| 4. A combination of the animation and the handout would be the most helpful way to explain the tracts. | ☑ | ☐ | ☐ | ☐ | ☐ |
| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☑ | ☐ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

Great effort. Could be very helpful in lecture especially if one could pause & play the animation for a slower viewing
Can this be loaded on the student computers?

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| 5. The cross-sections in the animation are clear and understandable. | ☐ | ☐ | ☑ | ☐ | ☐ |
| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☐ | ☑ | ☐ | ☐ |

Additional comments and/or suggestions:

Perhaps voice over narration could help with lack of enough labeling... A solid animation though — keep up the good work!

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| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☑ | ☐ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

Not a replacement for normal Text; but an excellent aid for Comprehending the basic science

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# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

excellent job - animation could be slower ; perhaps best used in lecture along other study materials

THANK YOU FOR YOUR TIME!

THE CORTICOSPINAL & CORTICOBULBAR TRACTS:
A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

INSTRUCTIONS: *Please fill in the square that best corresponds to your level of agreement to the following questions.*

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| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☐ | ☑ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

not sufficient by itself, great for lecture use, slower animation, more labels, great job!

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# THE CORTICOSPINAL & CORTICOBULBAR TRACTS: A 3-DIMENSIONAL ANIMATED INSTRUCTIONAL AID

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| 6. It is easy to follow the path of the corticospinal & corticobulbar tracts throughout the animation. | ☑ | ☐ | ☐ | ☐ | ☐ |

Additional comments and/or suggestions:

well done! Perhaps narrating the animation could be helpful as a more stand alone study material

THANK YOU FOR YOUR TIME!

# APPENDIX C
## Permission Letter

May 13, 2004

From: Roshi Mehdibeigi
2609 State Route 22, 2nf floor
Cambridge, NY 12816
(817) 692-6396 residence
(518) 677- 5236 fax

To: Marie Wayne
Lippincott Williams & Wilkins
530 Walnut St.
Philadelphia, PA 19106
(800) 638-3030
(215) 521-8466 fax

To whom in my concern,

I, Roshi Mehdibeigi, request your kind permission to use seven cross-sectional, black and while photographs from Duane E. Haines Neuroanatomy: An Atlas of Structures, Sections, and Systems, fifth edition. These images are: fig. 5-2 on page 76, fig. 5-4 on page 80, fig. 5-8 on page 88, fig. 5-12 on page 96, fig. 5-17 on page 106, fig. 18 on page 108, and fig. 5-25 on page 122.

I am currently a graduate student at The University of Texas Southwestern Medical Center at Dallas, in the Biomedical Communications Graduate Program. The purpose of my usage is strictly educational and not for profit. I will be utilizing these photographs in my Master of Arts thesis *"The Corticospinal and Corticobulbar Tracts: An Animated Three-dimensional Instructional Aid"*. If permitted, these photographs will be scanned into the computer and heavily manipulated with *Adobe Photoshop* to be colorized, scaled, and clarified. They will then be applied as mapped images onto three-dimensional objects created in *Discreet 3D Studio Max*. The final product will be an animated digital movie which I will present as my masters thesis.
Please be reassured that I fully intend to provide due credit to the author and publishing company for their permission in my thesis document and animation movie.

Should you have any further questions and concerns please do not hesitate to contact me. I truly appreciate your consideration and permission in advance.

Sincerely,

Roshi Mehdibeigi

R. Mehdibeigi

May 13, 2004

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Marie Wayne date: 5/13/04

all figures must be original to our publication


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## REFERENCES


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# VITAE

Roshanak "Roshi" Mehdibeigi was born in Tehran, Iran, on November 2, 1974, daughter of Azam Azadizad and Abbas Mehdibeigi. After spending her early childhood in Arlington, Texas, she and her family moved back to Iran in the summer of 1979. By the spring of 1990, they would move back to Texas, where she graduated from Macarthur High School in Irving, Texas in 1992. She began attending University of Texas at Arlington in August of 1992, majoring first in architecture, and then in premedical sciences. During the academic year of 1995-96, she received the International Education Fund scholarship, and attended the University of Sheffield in Sheffield, England as part of a study abroad program. She received a Bachelor of Science in Biology in May of 1997, and continued her study for a master's degree in biology. By the end of her first year in the biology graduate program, she had decided to pursue a career in medical illustration. She began working at the University of Texas Southwestern Medical Center at Dallas as a research assistant, while fulfilling course requirements for acceptance to medical illustration graduate programs. In October of 2000, she applied to the Biomedical Communications Graduate Program at the University of Texas Southwestern Medical Center at Dallas and was accepted. She began the graduate program in May of 2001, and was married to John Morse in May of 2002. She received the Vesalius Trust scholarship in 2003, and was awarded the degree of Master of Arts in Biomedical Communications in August of 2004. Since that time she has moved to New York, and is currently employed at Albany Medical Center in Albany, New York.

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