**Interactive Spinal Cord Atlas**

**The Goal**
This interactive Spinal Cord Atlas is one of a series of atlases that are used in Mind, Brain and Behavior 1, the first-year neuroscience course at the University of Massachusetts Medical School. Our goal in designing the atlases is to create a learning tool that guides students in integrating basic and clinical information about nervous system structure and function, while also providing a framework for student-driven learning.

**Using the Atlas**
The spinal cord atlas is enabled for commenting in Adobe Reader 7. This means that using Reader 7 (but not earlier versions of Reader), students can add their own comments and drawings to the atlas, as well as using the interactive features provided by the teacher.

**Atlas Credits**
I thank the Brain Atlas Project’s co-authors Charlene Baron MEd and Sam Gorstein MS3 for their assistance in conceptualizing and producing this atlas, and Ken Wolf MD for reviewing its content. Members of the classes of 2007, 2008, and 2009 have provided numerous helpful suggestions that were incorporated into this current version. The atlas is based on myelin-stained sections of the human spinal cord that were prepared by Paul I. Yakolev MD.

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What kinds of information do most of these small diameter, thinly myelinated or unmyelinated axons carry?

What components of the autonomic nervous system are present in the sacral levels of the spinal cord, and what structures do they innervate?

Is this the dorsal (posterior) or ventral (anterior) surface of the spinal cord? How did you decide?

This is the S4 or S5 spinal cord segment. However this part of the cord is enclosed by the L1 or L2 vertebral bones. What's going on?
Clarke's nucleus and the dorsal spinocerebellar tract, which is formed by its axons and conveys key information to the cerebellum concerning movements of the ipsilateral lower limb, are NOT present caudal to the L2 segment. Yet the L4 and L5 segments receive a lot of inputs concerning the foot and ankle.

Describe how this information will reach Clarke's nucleus.

How would you test the integrity of this tract (and the other components of the system it is part of) in a patient? Name two tests. Where on the patient would you perform them?

What is the location of muscles that are innervated by motor neurons located laterally (STAR) in the ventral horn gray matter? What muscles are innervated by motor neurons located more medially (CIRCLE)?

Which of the deep tendon (muscle stretch) reflexes might be absent or difficult to elicit if this level of the cord were damaged?

What kinds of sensory information does this tract convey?
You can identify this segmental level of the spinal cord because Clarke's nucleus (also called the nucleus dorsalis or column of Clarke), which is circled in YELLOW, is at its largest. It makes a big bulge in the gray matter that pushes up into fasciculus gracilis. Be sure that you identify the column of Clarke in this section. The column of Clarke extends from T1 to L2, but it is much larger in the lower (more caudal) segments.

What nucleus contains the cell bodies of axons that travel in this tract? Do they carry information concerning the same side of the body or the opposite side? about the ARM or the LEG?

If a meningioma compresses the anterior lateral spinal cord here, at this level, what SENSORY abnormality is the patient's neurologic exam most likely to reveal?

What axons travel here? Where are their cell bodies? What can you say about their connections and functions?
If this region is damaged at this level, and on this side, name 3 signs or symptoms that the patient is likely to show on neurologic exam.

Where are the cell bodies of these axons located? On which side of the nervous system, and in what structures?

Neurons whose cell bodies are located here send their axons outside the CNS to synapse with what specific cells? Do those axons cross the midline?

There is a ventral as well as a dorsal spinocerebellar tract, but we won't discuss it further in this atlas because its functions and clinical importance remain unclear.

OPTIONAL INFORMATION
A central lesion in the spinal cord like the one shown in RED would impair what kinds of sensation? On which side of the body, or on both sides? Given this level of the spinal cord, roughly where would you expect that sensation is lost? (You can consult a Dermatome Map for specific information.)
What space are these structures located in?

Many axons traveling in this tract will synapse in nucleus gracilis. In what part of the CNS is that nucleus located? What kinds of sensation are these axons essential for? Will these axons cross the midline before they synapse?

In a few words, what kind of information do these axons bring to the cerebellar cortex? Will they cross the midline before synapsing there?

Several years after a spinal cord lesion in the region indicated by the filled area, would you expect the patient to show upper motor neuron or lower motor neuron signs/symptoms in the lower extremity? Would they be present ipsilateral or contralateral to the lesion?

The central canal of the spinal cord, is enormously enlarged in this section. This is not normal, and we're not really sure of the cause.
Please don’t be concerned with the details of identifying Mid-Thoracic vs this Upper Thoracic level of the spinal cord. What IS important is that you identify the major tracts, and think about what happens if there is disease or injury affecting the thoracic cord.

A Short Case
A 67-year-old man has a year-long history of progressive weakness of his right leg. He has also noticed numbness and tingling in his left leg.

Neurologic exam demonstrates:
- Weakness, exaggerated deep tendon (muscle stretch) reflexes, and increased tone in the right leg and foot, and a dorsiflexor plantar response (up-going toe) on the right.
- Decreased joint position sense in the right leg and foot.
- Decreased pinprick sensation on the left side of the trunk from about 2.5 cm (1 in) below the level of the nipple on down, including the entire left leg and foot.

Other parts of the exam were reported as normal.

Can you localize the lesion? In other words, can you say approximately WHERE in the spinal cord the damage is? Review WHAT STRUCTURES are damaged to produce each sign and symptom.
Injury to the T1 - T2 cord could produce Horner's syndrome. Why? Can you list several of the signs and symptoms that collectively make up Horner's syndrome?

Which side of the patient would be affected - the same or the opposite side? What are some other ways that a Horner's syndrome could be produced?

Patient with unilateral lesions of the thoracic spinal cord below T1 routinely present with significant paralysis of the ipsilateral lower leg and foot, less weakness of hip muscles, and no apparent weakness of intercostal or abdominal muscles. How might we explain this "gradient of weakness"? (note that the anterior corticospinal tract doesn't extend far enough caudal in the spinal cord to be the answer). By the way, why isn't the hand affected by lesions below T1?
Describe how you could you test for the integrity of this tract (and the large structure in which its axons synapse). On actual exam, you discover that the patient has signs and symptoms of upper motor neuron paralysis because the corticospinal tract has been interrupted. Will you be able to detect deficits produced damage to the indicated tract? Why or why not?

Axons in the spinothalamic tract are arranged according to the body region represented. Axons carrying information about the leg and foot are located more lateral than axons carrying information about the trunk. Axons concerned with the upper extremity are added medialy.

QUESTION: Do these axons carry information about the ipsilateral or contralateral side. If they have crossed, where did this occur?

BEWARE: This huge expansion of the ventral horn gray matter is not the intermediolateral column. Compare its size with the intermediolateral column in the T2 thoracic segment.

If you look at a section stained with a basic dye, you'd discover this area contains the cell bodies of some large MOTOR NEURONS. Note their position, way out lateral. Can you guess where the skeletal muscle they innervate is located?
What signs and symptoms is a patient likely to show if she has a large demyelinated area (an MS plaque) in the region that is filled-in here?

If a patient has a recent lesion that has damaged motor neurons at the C5,6 segmental level of the spinal cord but spared the corticospinal tracts, what specific muscles do you expect will have reduced strength?

What about the tone of these muscles? Do you anticipate that it will be increased or decreased?

Which of the following reflexes would likely be abnormal? Describe...
Biceps, Brachioradialis, Patellar tendon, Plantar response

Would you anticipate observing: clonus? fasciculations? denervation atrophy 4 months later?

This patient has a Lower Motor Neuron lesion. Compare the signs/symptoms with an Upper Motor Neuron lesion.

Clinically, the lateral corticospinal tract is the single most important descending motor pathway in the CNS. However, you should be aware of other descending pathways -- originating not from the cerebral cortex but from brainstem nuclei -- that also influence the activity of motor neurons. The best-understood of these pathways in humans are the reticulospinal and vestibulospinal tracts. These tracts are located in the ventral, medial white matter of the spinal cord (we do not ask you to memorize their locations for this course). They are involved primarily in posture, gait, and balance, and they influence motor neurons that innervate trunk and proximal muscles of the limbs.

MORE NEUROANATOMIC INFO

MORE CLINICAL INFO
(1) Have the axons of ganglion cells that travel in these two tracts crossed the midline yet? Will they cross the midline before they synapse in nucleus gracilis and cuneatus?

(2) Branches of axons running in **fasciculus cuneatus** also will synapse in the external (also called lateral or accessory) cuneate nucleus. What is the significance of these connections?

This is the approximate location of the anterior corticospinal tract. Unlike axons in the much larger lateral corticospinal tract, these axons did not cross the midline in the pyramidal decussation. The tract is indicated in dashes because it is variable in size (1 in 6 of us don't seem to have one), and because it decreases in size as it runs caudal in the cervical cord, and apparently ends completely in upper thoracic segments.

**MORE INFORMATION**

This section is rostral to the cervical enlargement. Notice how skinny the dorsal horns are. Why might this be? At this level, sensory input to the cord comes from what part of the body surface?

Injury to the cord at this level can produce a Horner's syndrome as well as a number of other autonomic problems. Why is this the case? After all, there are no preganglionic autonomic neurons present in the cervical spinal cord.

Motor neurons present in the cord at C3,4 innervate the diaphragm. This is one reason that high cervical cord transection can be fatal (either immediately or later). You may have heard about actor Christopher Reeve, who had massive hemorrhaging in his upper cervical cord following a horseback riding accident. He was quadriplegic and had to be placed on a ventilator because he couldn't breathe on his own. He remained quadriplegic for the remainder of his life and could breathe without a respirator only after an electrical stimulation device was implanted in his diaphragm.

There's also a group of motor neurons present at this level whose axons travel rostral and join the 11th cranial nerve. What muscles do they innervate?
Atlas Features and How-to’s

To take advantage of many atlas features, you need to have Adobe Reader 7 or a more recent version installed on your computer. It is available as a free download http://www.adobe.com/products/acrobat/readermain.html

We suggest that after you open the atlas you go to View>Toolbars and select the Advanced Editing Toolbar (AET). This will give you easy access to many atlas features described below.

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