A sketch of the central nervous system and its origins

G. E. Schneider 2014

Part 4: Development and differentiation, spinal level

MIT 9.14 Class 8

a) CNS structure at the spinal level

b) Autonomic and enteric nervous systems

with questions on chapter 9

Survey of adult human spinal cord

- **Different levels**, illustrated
- **The sensory channels** (reflex, spinocerebellar and spinothalamic tracts, origin of dorsal column axons)
- **Major descending pathways** (cortico-, rubro-, reticulo-, and vestibulo-spinal)
- "**Propriospinal**" fibers

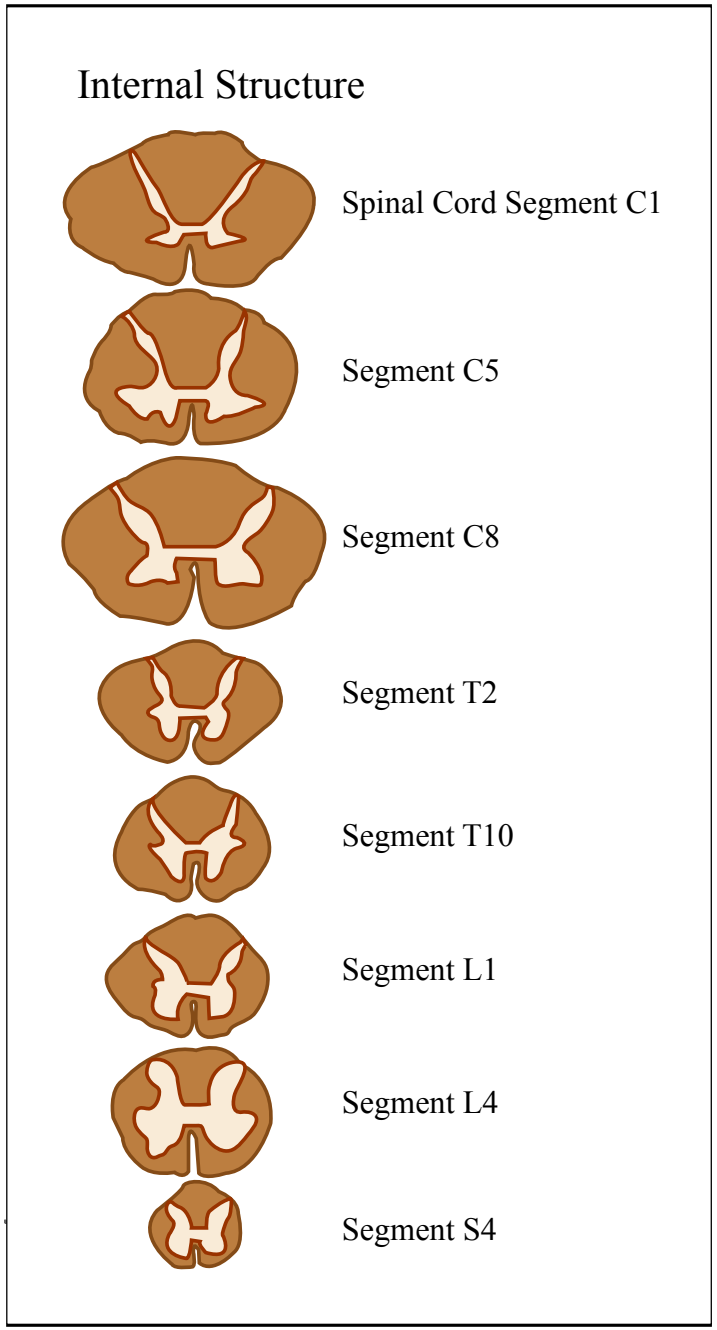
Questions, chapter 9

1) How do the dorsal, lateral and ventral columns of the spinal cord change from cervical to sacral levels? Why?

4) What is the lateral horn?

Human spinal cord, frontal sections from first cervical segment to fourth sacral segment.

The white matter, consisting mostly of myelinated axons, is depicted in darker brown in these sections.



Different levels, illustrated:
Note the following things

- Gray *vs.* white matter.
- Gray matter differences in dorsal and ventral horns
- ➢ Changes in amount of white matter, rostral to caudal
  - More and more descending axons leave the white matter
  - More and more ascending axons join the white matter
- Cervical and lumbar enlargements
  - *How large in the spinal cord of Brontosaurus ?* next slide!
- Presence of "lateral horn" in thoracic and upper lumbar cord

Figure removed due to copyright restrictions.

Spinal cords of turtle and Brontosaurus

Note that the lumbar enlargement of Brontosaurus was larger than the brain.

Questions, chapter 9

2) What did Bror Rexed add to the way anatomists describe spinal cord sections stained for cell bodies?

Spinal layers

Figures removed due to copyright restrictions.
Please see course textbook or:
Rexed, Bror. "A Cytoarchitectonic Atlas of the Spinal Coed in the Cat."
Journal of Comparative Neurology 100, no. 2 (1954): 297-379.

Cat spinal cord, Nissl stain of frontal section, 7th cervical segment, illustrating the layers specified by Rexed in his studies based on cytoarchitecture.

Questions, chapter 9

3) Describe some differences in cytoarchitecture of the dorsal horn and the ventral horn of the spinal cord. At what levels are these differences greatest?

Layers are clearest

at the enlargements

More comparisons

- Myelin
  - "A crucial vertebrate innovation" (Allman p. 78): Why myelin?
  - Not found in any invertebrate or in the jawless vertebrates (hagfish, lampreys)
- How does spinal cord of humans differ from spinal cords of other mammals?

  Because of greatest sensory acuity in fingers, and greater manual dexterity, more ascending axons in dorsal columns and more descending axons from neocortex in lateral columns.

Spinal cord cross section

Lumbar level, human

Figure removed due to copyright restrictions.
Please see course textbook or:
Brodal, Per. *The Central Nervous System, Structure and Function*.
3rd ed. Oxford University Press, 2003.

Lumbar spinal cord, rat, unstained section; chart showing layers of Rexed

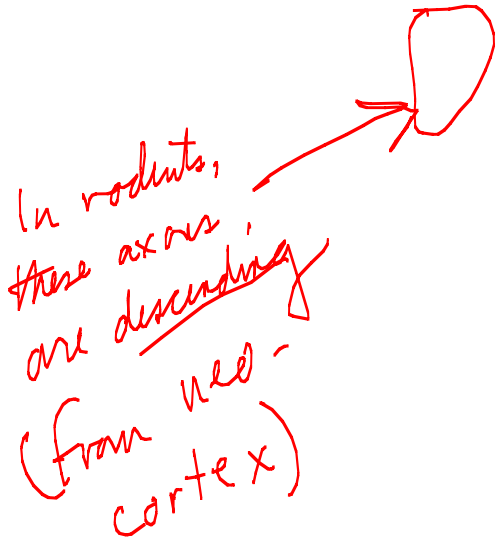


Figure removed due to copyright restrictions.
Please see:
Gibson, Sally J., Julia M. Polak, et al. "The Distribution of Nine Peptides in Rat Spinal Cord with Special Emphasis on the Substantia Gelatinosa and on the Area around the Central Canal (laminaX)." *Journal of Comparative Neurology* 201, no. 1 (1981): 65-79.

Fig 9-4

Survey of adult human spinal cord

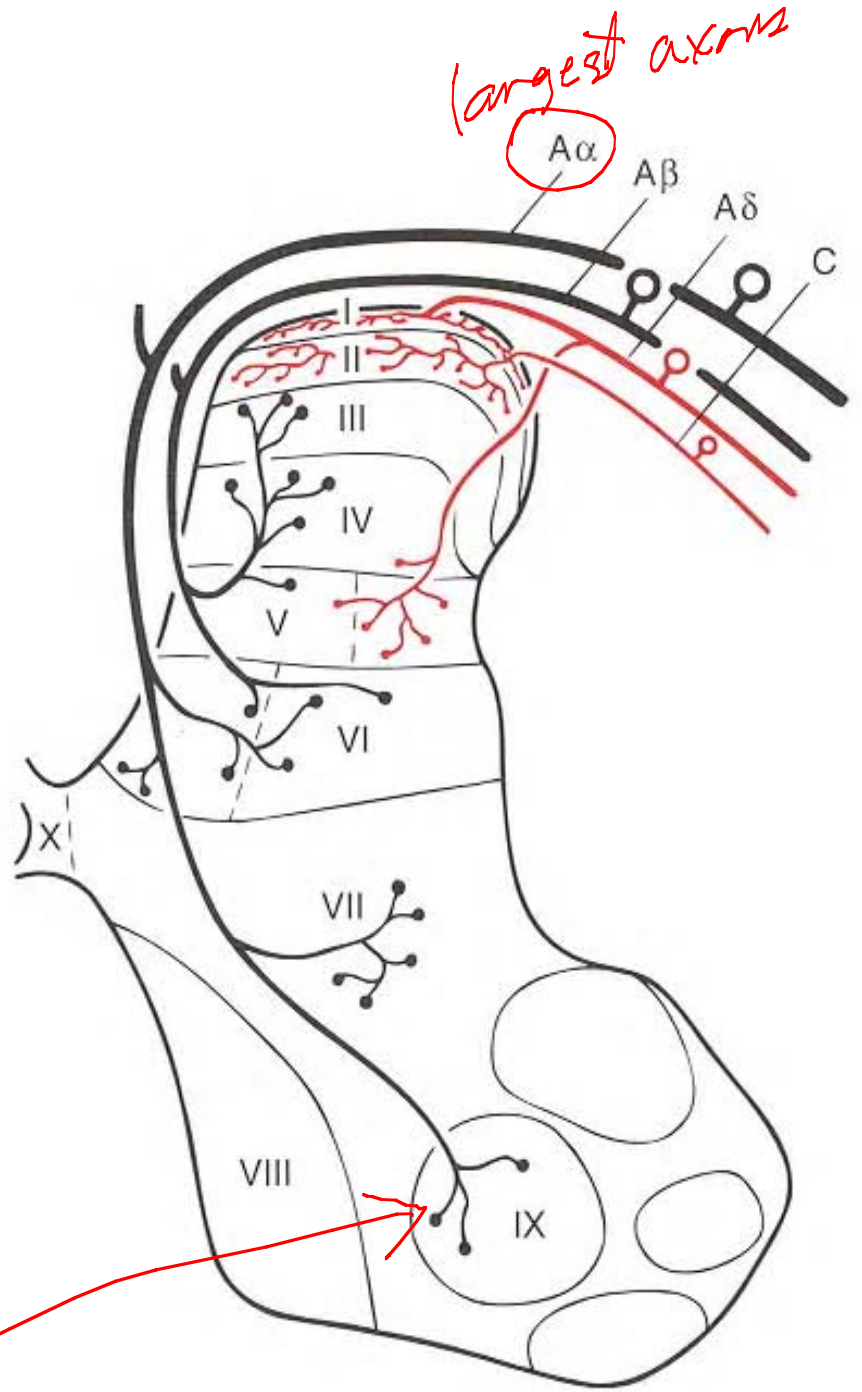
- **Different levels**, illustrated
- **The sensory channels** (reflex, spinoreticular & spinothalamic, and spinocerebellar tracts; origin of dorsal column axons)
- **Major descending pathways** (reticulo-, vestibulo-, rubro-, and corticospinal)
- "**Propriospinal**" fibers

Questions, chapter 9

5) Where do the largest axons in the dorsal roots originate? Describe two of their terminate sites within the spinal segment of their dorsal root.

Termination of dorsal root fibers

Largest axons in dorsal root come from stretch receptors in the striated muscles. They end on motor neurons that innervate the same muscles. This is the stretch reflex.

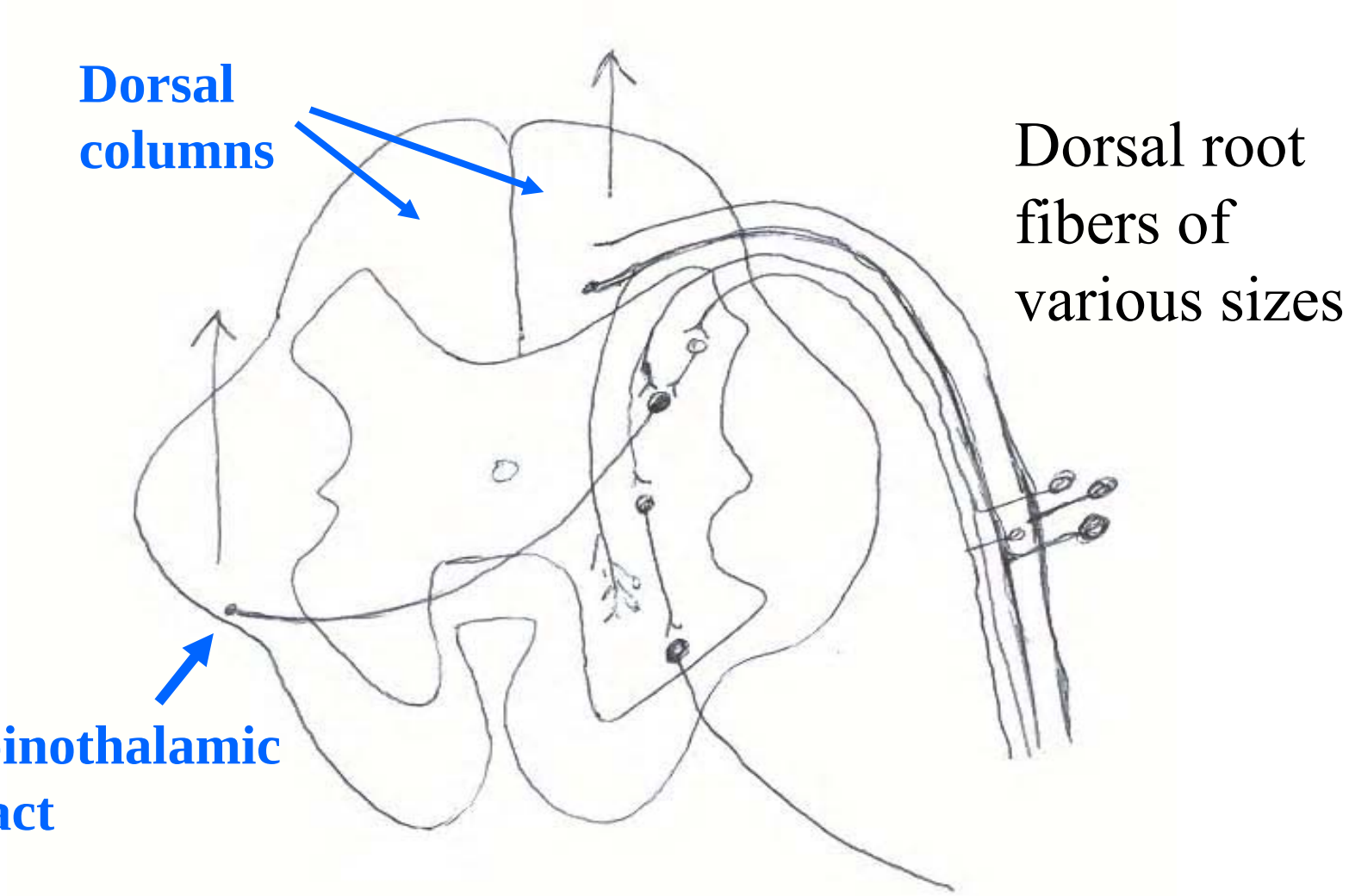


Questions, chapter 9

6) Describe the axons and connections of a withdrawal reflex (flexion reflex). at least 2 synapses, as illustrated in next picture

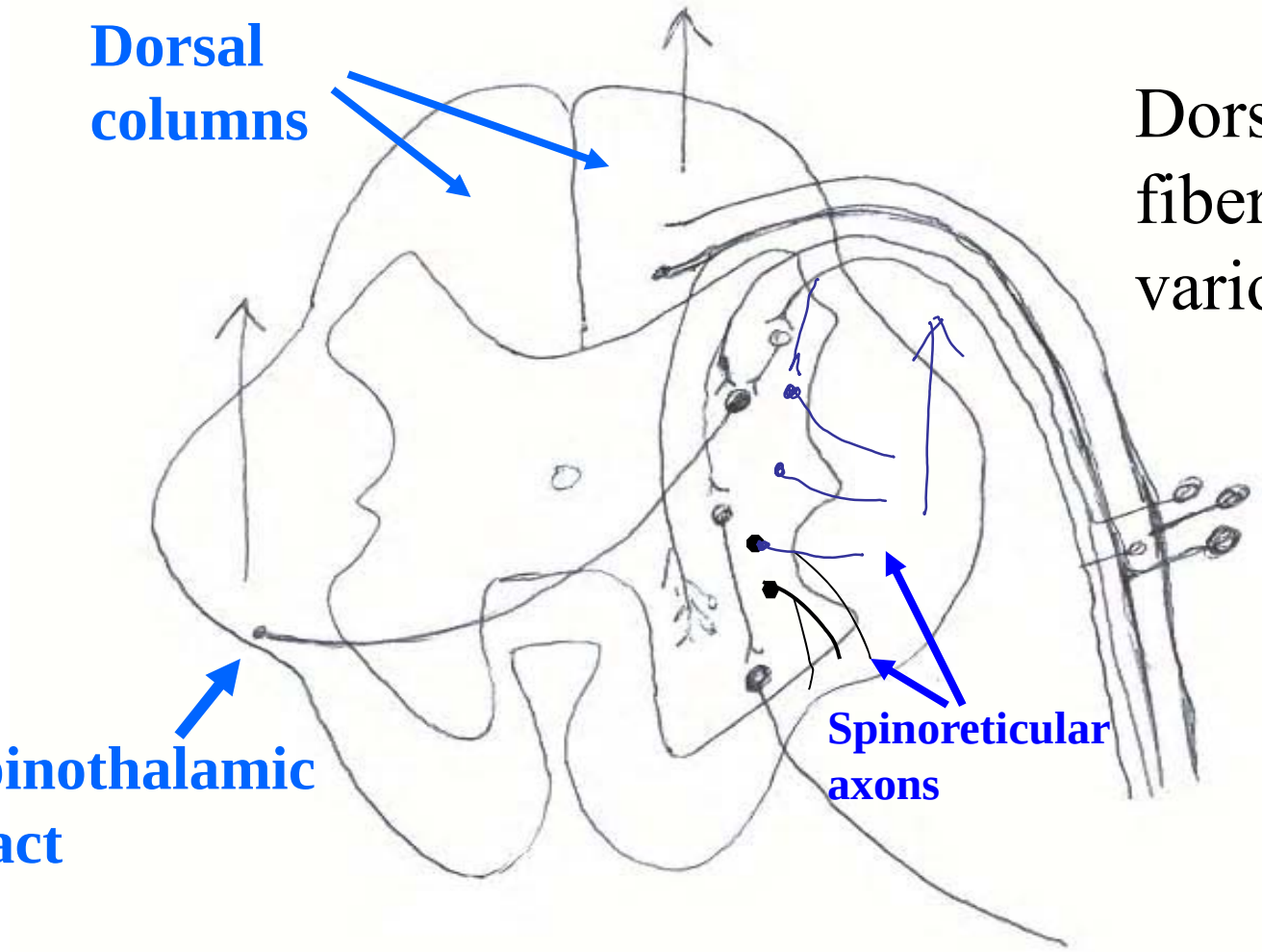
7) Describe the origins of the spinothalamic tract within a section of the spinal cord. Contrast this with the origins of the spinoreticular tract.

Adult spinal cord, schematic frontal section: reflex and lemniscal channels



Schneider, G. E. *Brain structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN:9780262026734.

Adult spinal cord, schematic frontal section: reflex and lemniscal channels



REVIEW

Remaining from very early chordates:

Spinoreticular fibers (on right in blue)

[from medical textbook]

Figure of the spinoreticular fibers that have been retained from very early chordates was removed due to copyright restrictions.
Please see:
Gray, Henry, and Susan Standring. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. Elsevier/Churchill Livingstone, 2008.

Spinoreticular axons include a few that reach thalamus

Figure of the spinoreticular fibers that have been retained from very early chordates was removed due to copyright restrictions.
Please see:
Gray, Henry, and Susan Standring. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. Elsevier/Churchill Livingstone, 2008.

Questions, chapter 9

8) Where do the longest axons of the dorsal columns originate and where do they terminate?

At the rostral end of the spinal cord: Termination of dorsal column axons

The dorsal column nuclei, namely, the gracile and cuneate nuclei (nuc. gracilis and nuc. cuneatus): Some textbooks define their location as in caudal hindbrain.

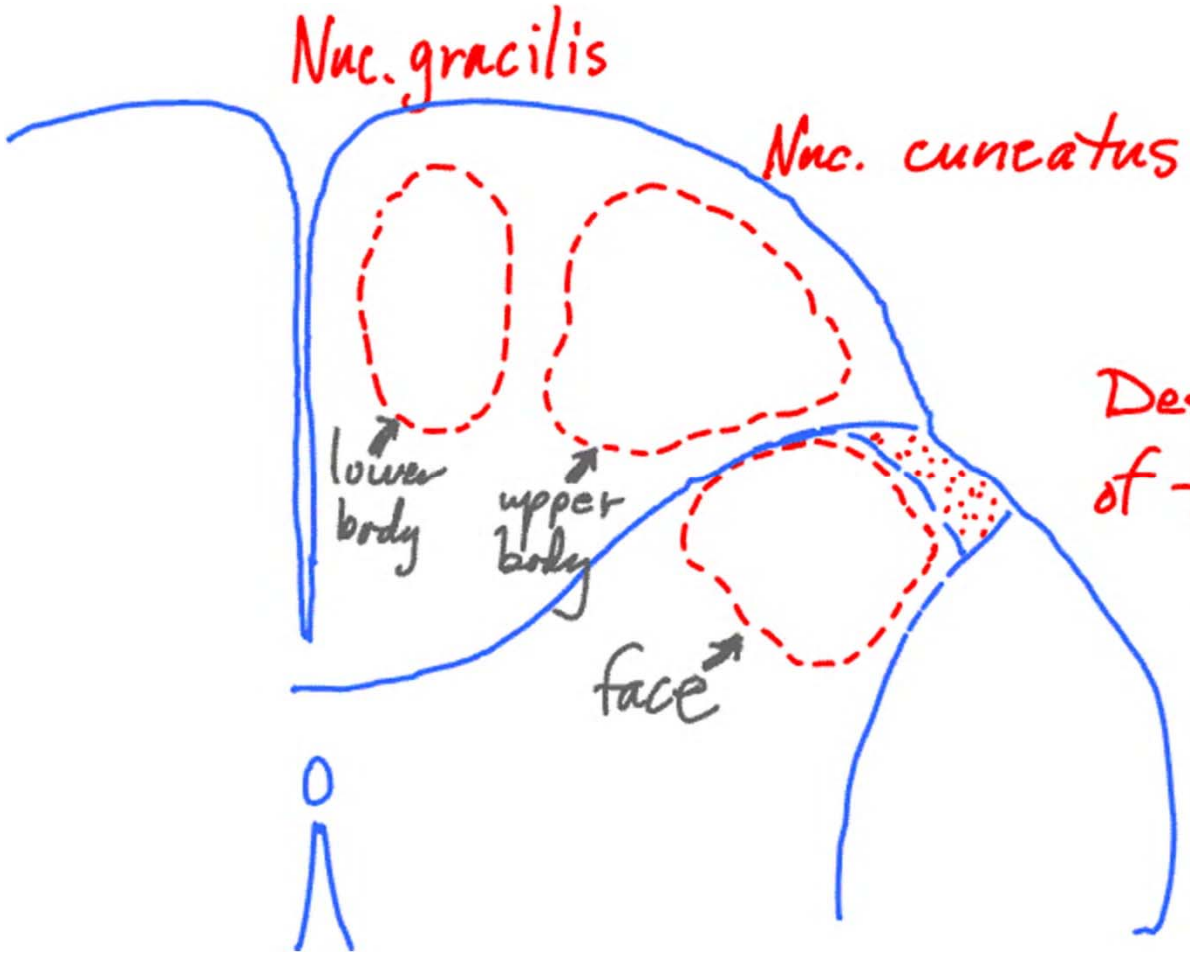
Where do the longest axons originate? tail region

Where to they terminate in the DCN? most medially, in nucleus gracilis

Questions, chapter 9

9) Explain how there is an organized representation of the surface of the entire body in cell groups at the dorsal-most end of the spinal cord.

The body surface represented at the hindbrain-spinal cord boundary



Descending nuc. of trigeminal nerve

descends from hindbrain into rostral cervical segments of Sp. Cord.

Questions, chapter 9

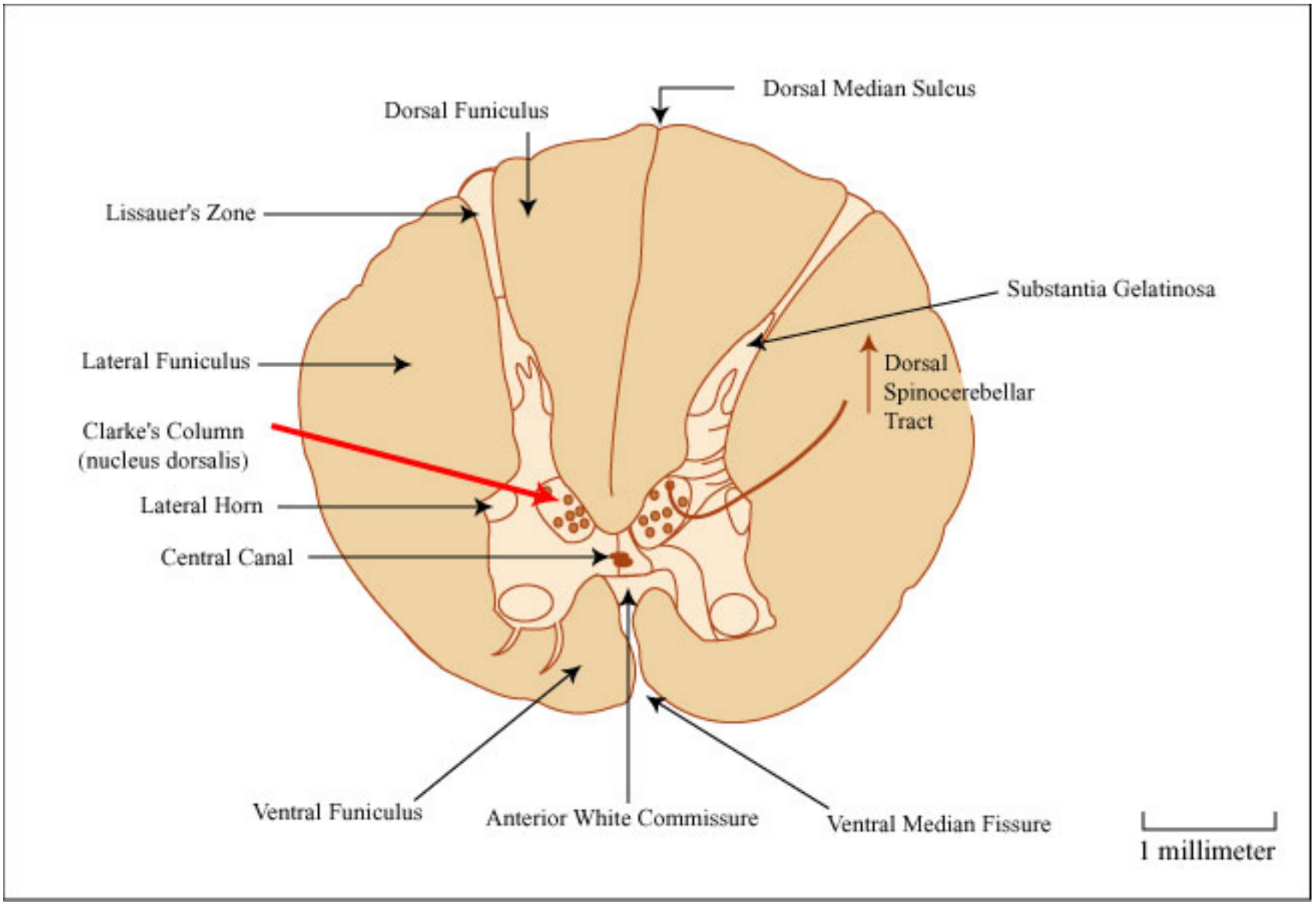
10) Describe the sources of axons terminating in Clarke's column (nucleus dorsalis) of the spinal cord from the lower limbs. What ascending fiber tract originates in Clarke's column?

Cerebellar channel:

Clarke's Column and the dorsal spino-cerebellar tract illustrated at 5th thoracic segment

(see Nauta & Feirtag, Fig. 64)

Carries information on joint movements from lower limbs & trunk



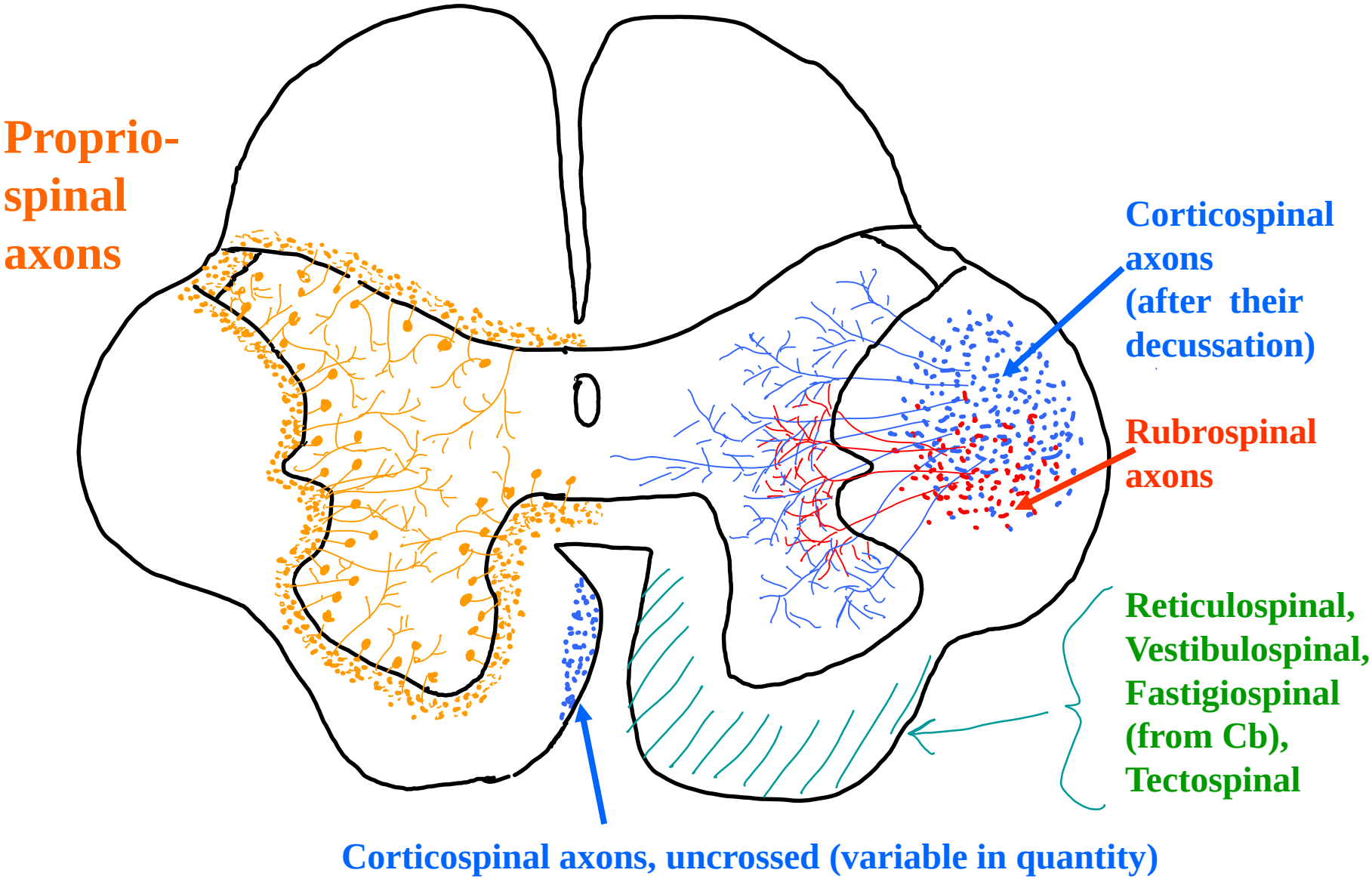
Clarke's Column and dorsal spino-cerebellar tract

Questions, chapter 9

11) What are propriospinal fibers? originate in, and terminate in spinal cord

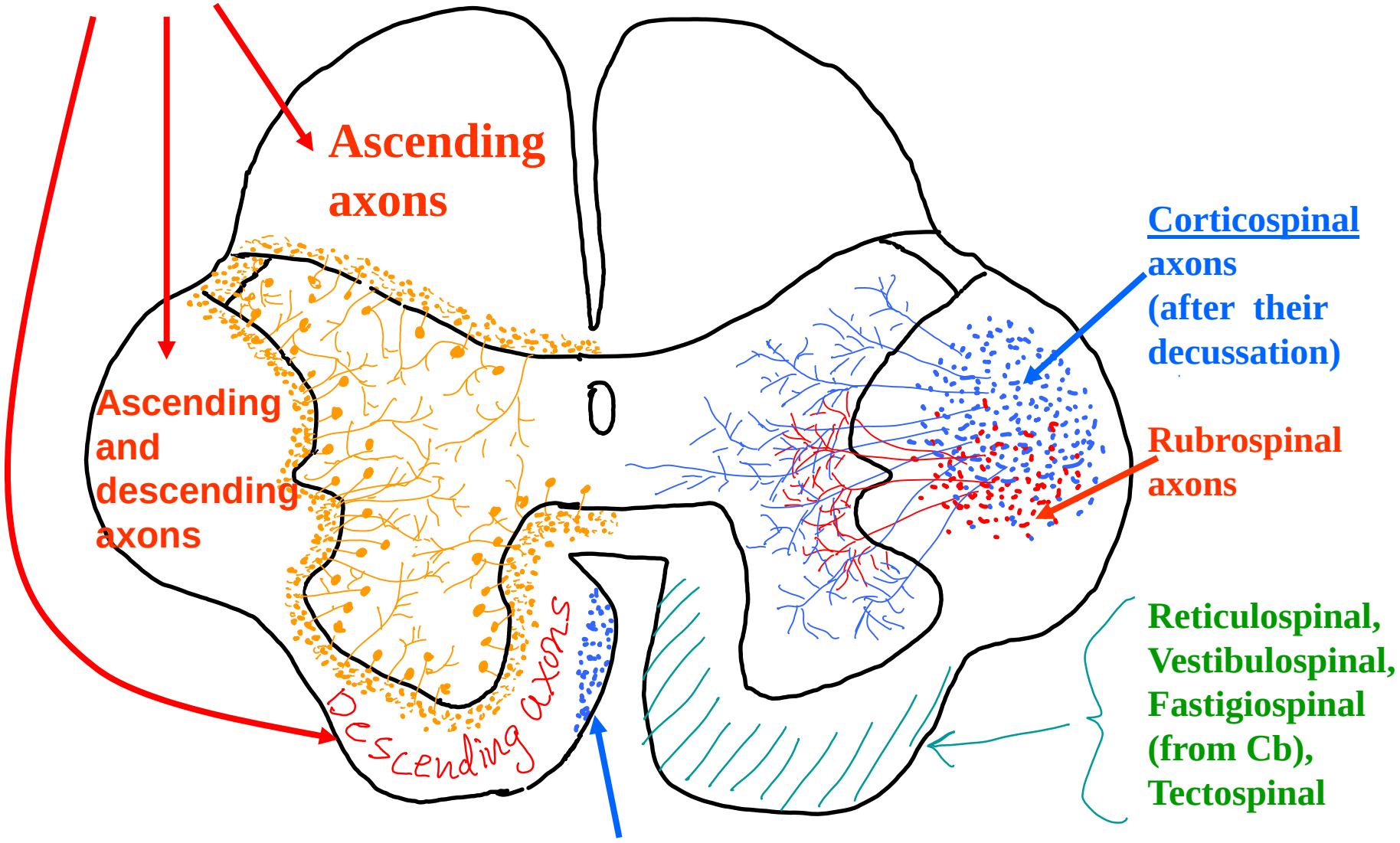
12) Movements of the limbs and other movements are controlled or influenced by a number of axonal groups that descend from the brain. What can you remember about these? (such as names and where they originate, and how many such pathways there are)

Adult spinal cord: some descending and intrinsic axons



Schneider, G. E. *Brain structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN:9780262026734.

Ascending and descending long axons of primate spinal cord



Next: Shift from the spinal cord to components of the PNS

Questions, chapter 9

13) The peripheral nervous system innervates glands and smooth muscles, also cardiac muscle, as well as skin and striated muscles. What is the system called that innervates the visceral tissues? What are the two divisions of that visceral nervous system?

Autonomic nervous system (ANS):

Dual innervation of smooth muscles and glands

- **Sympathetic nervous system** (thoraco-lumbar system)
- **Parasympathetic nervous system** (cranio-sacral system)

Questions, chapter 9

14) Contrast the functions of the two systems.
Briefly describe some examples.

Important functions of some autonomic pathways

GLAND, TISSUE	SYMPATHETIC FUNCTIONS	PARASYMP. FUNCTIONS
Iris	Dilates pupil (mydriasis)	Constricts pupil (miosis)
Lacrimal gland	Little effect on secretion	Stimulates secretion
Salivary glands	Secretion reduced; less watery	Secretion increased; watery
Sweat glands	Stimulates secretion (ACh)	Little effect
Lungs, bronchi	Dilates the lumen	Constricts
Heart	Speeds heart rate; increased ventricular contraction	Slows heart rate
Stomach, intestines	Inhibits motility & secretions	Stimulates motility, secretions
Anal sphincters	Constricts except with very intense activation	Relaxes
Sex organs	Orgastic contraction of ductus deferens, seminal vesicle, prostatic or uterine muscles; vasoconstriction	Vasodilation, engorgement of erectile tissue
Urinary bladder	Relaxes wall of bladder; constricts internal sphincter, inhibits emptying	Contracts bladder, relaxes sphincter, promotes emptying

Important functions of some autonomic pathways

GLAND, TISSUE	SYMPATHETIC FUNCTIONS	PARASYMP. FUNCTIONS
Adrenal medulla	Stimulates secretion	Little or no effect
Blood vessels, trunk & extremities	Constrict	---
Blood vessels, head	Dilate	---

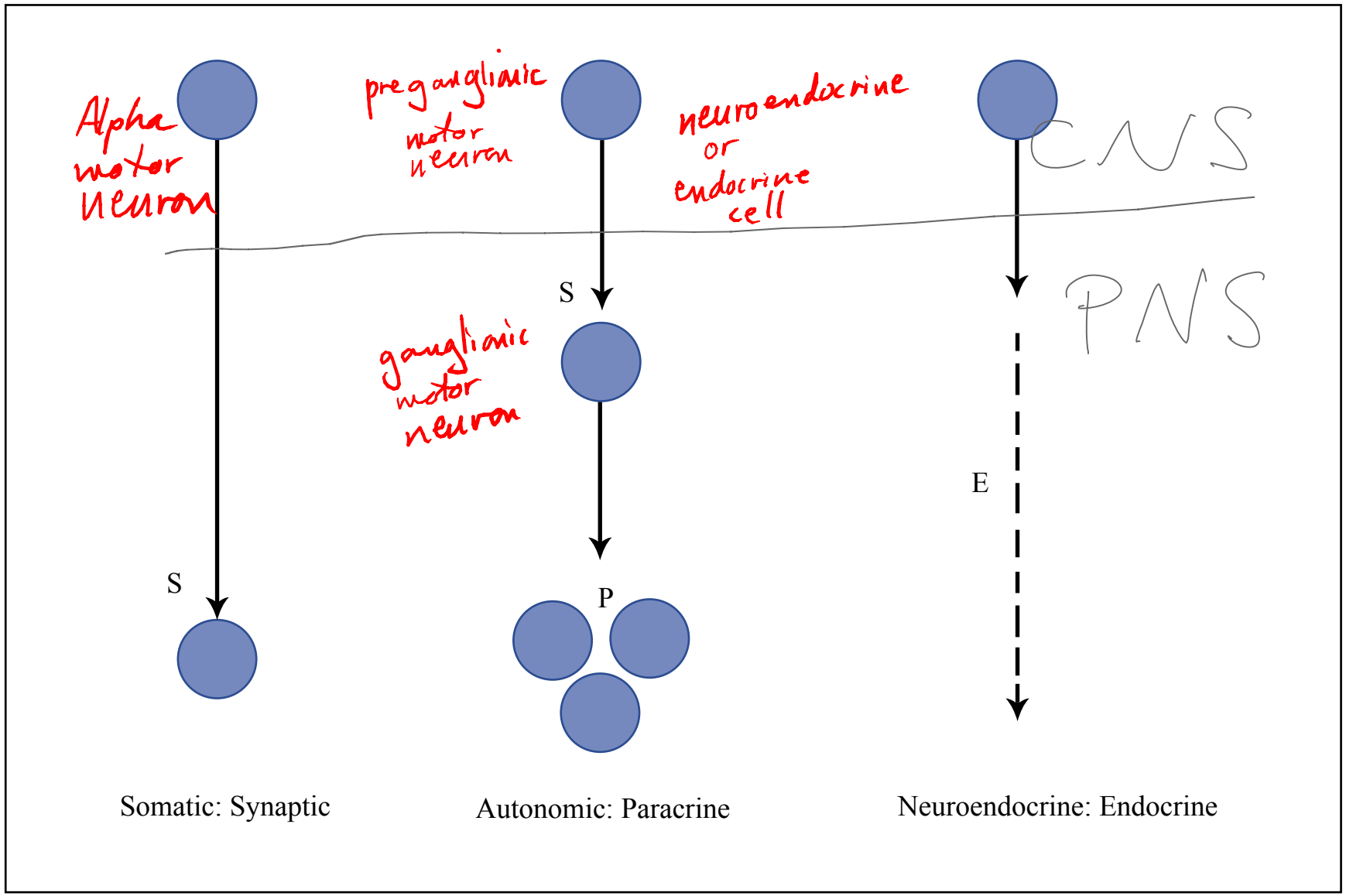
Questions, chapter 9

15) Striated muscles have synaptic innervation, whereas smooth muscles and glands have paracrine innervation. Explain the difference.

Where are the neurons located that give rise to the axons that innervate the glands and smooth muscle?

Step back a moment:

Arrangement of motor neurons in the three major divisions of the motor system



Arrangements within the Autonomic Nervous System: Paracrine innervation

(P. Brodal & others)

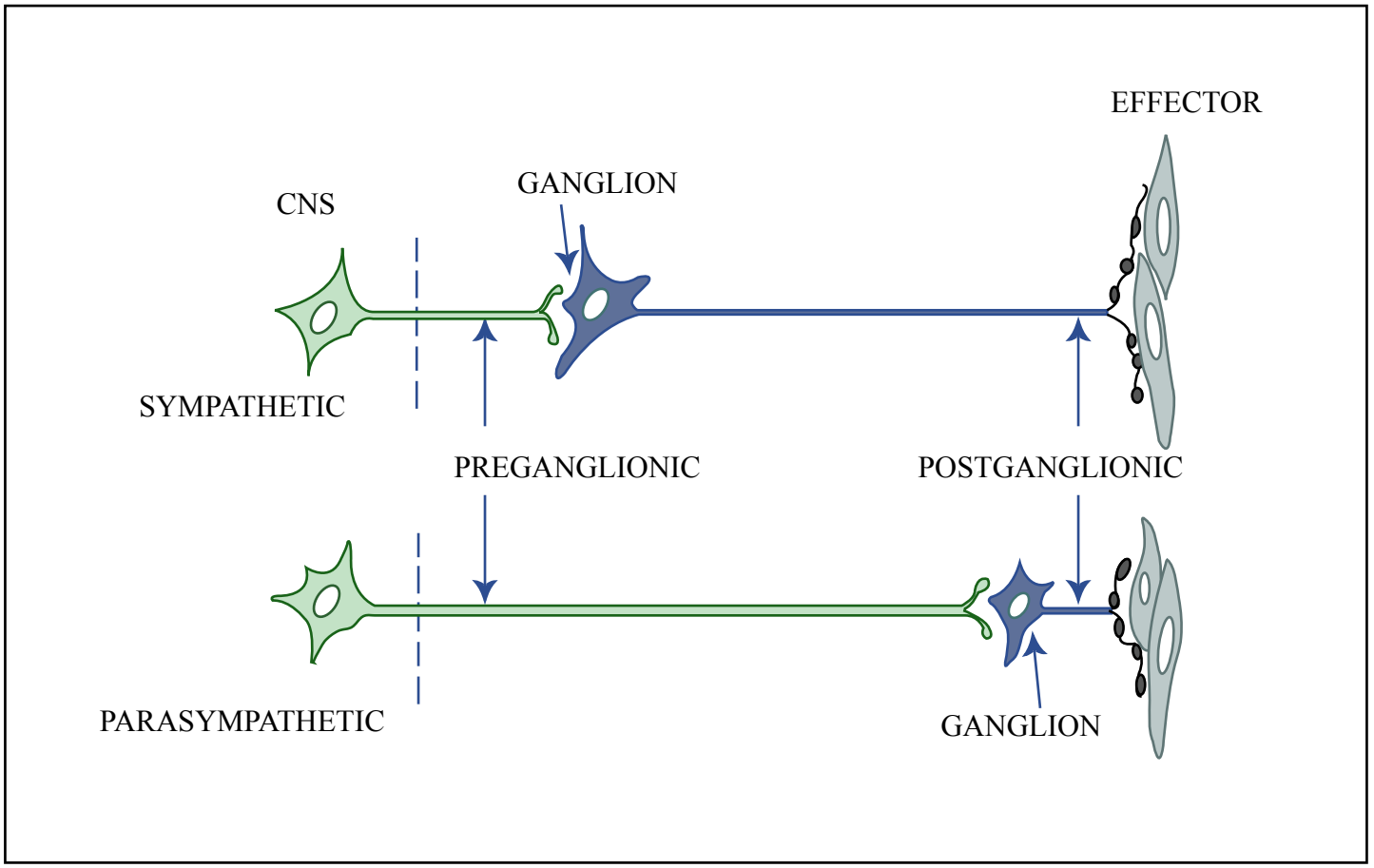
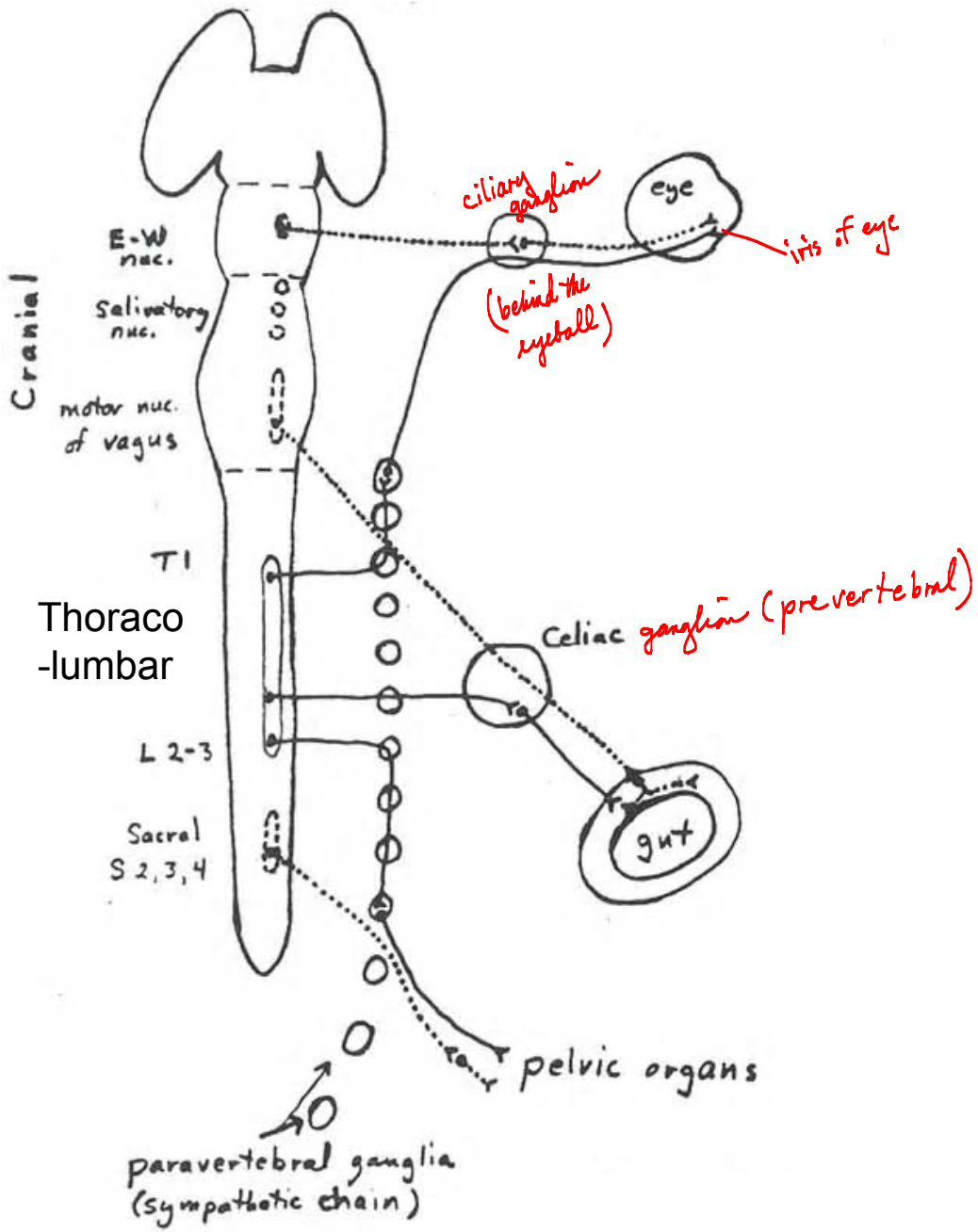


Image by MIT OpenCourseWare.

End session 8

Autonomic pathways:

a selective schematic view



Schneider, G. E. *Brain Structure and its Origins: In the Development and in Evolution of Behavior and the Mind*. MIT Press, 2014. ISBN:9780262026734.

9.14 Brain Structure and Its Origins

Spring 2014