Citation Key

for more information see: http://open.umich.edu/wiki/CitationPolicy

Use + Share + Adapt

{ Content the copyright holder, author, or law permits you to use, share and adapt. }

Public Domain – Government: Works that are produced by the U.S. Government. (USC 17 § 105)

Public Domain – Expired: Works that are no longer protected due to an expired copyright term.

Public Domain – Self Dedicated: Works that a copyright holder has dedicated to the public domain.

Creative Commons – Zero Waiver

Creative Commons – Attribution License

Creative Commons – Attribution Share Alike License

Creative Commons – Attribution Noncommercial License

Creative Commons – Attribution Noncommercial Share Alike License

GNU – Free Documentation License

Make Your Own Assessment

{ Content Open.Michigan believes can be used, shared, and adapted because it is ineligible for copyright. }

Public Domain – Ineligible: Works that are ineligible for copyright protection in the U.S. (USC 17 § 102(b)) *laws in your jurisdiction may differ

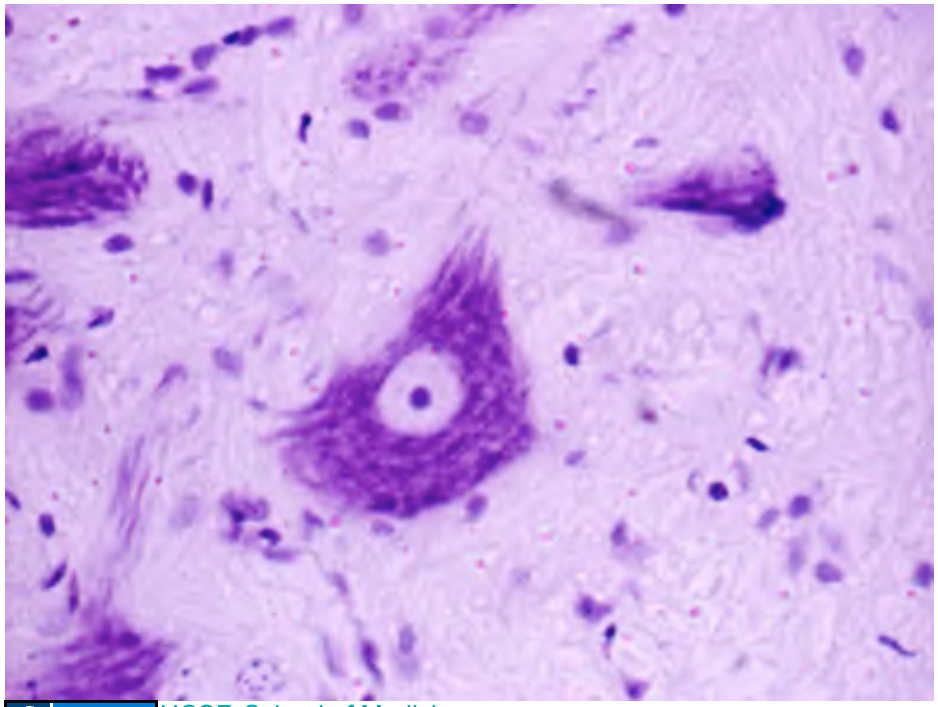
{ Content Open.Michigan has used under a Fair Use determination. }

Fair Use: Use of works that is determined to be Fair consistent with the U.S. Copyright Act. (USC 17 § 107) *laws in your jurisdiction may differ

Our determination **DOES NOT** mean that all uses of this 3rd-party content are Fair Uses and we **DO NOT** guarantee that your use of the content is Fair.

To use this content you should **do your own independent analysis** to determine whether or not your use will be Fair.

Spinal Cord and Spinal Nerves



PD-INCL UCSF, School of Medicine

M1 CNS Head and Neck
March 3, 2009

Lecture Outline

- Spinal Cord Function
- Development
- Gross Anatomy
  - Regions Cervical, Thoracic, Lumbar, Sacral
  - Meninges
- Spinal Nerves
- Gray Matter
- White Matter
- Reflexes
- Blood Supply

Important Terms

- Dermatome
- Motor Unit
- Receptive Field
- Column
- Fasciculus
- Lower Motor Neuron
- Rootlets (Dorsal and Ventral)
- Roots (Dorsal and Ventral)
- Somatic
- Visceral
- Lamina of Rexed
- White Rami Communicantes
- Gray Rami Communicantes
- Afferent
- Efferent
- Dorsal Horn
- Ventral Horn
- Dorsal Root Ganglia
- Sympathetic Ganglia

Spinal Cord Essential Functions

- Receives sensory input
  - Somatic and Visceral
- Contains motor neurons
- Direct (local) connections of motor and sensory information: Reflexes
- Carries motor information from brain to muscles
  - Somatic and Visceral

REMINDER

• Afferent Arrives

- Information arriving to the CNS in general, a nucleus within the CNS or a neuron

• Efferent Exits

- Information leaving the CNS in general a, a nucleus within the CNS or neuron

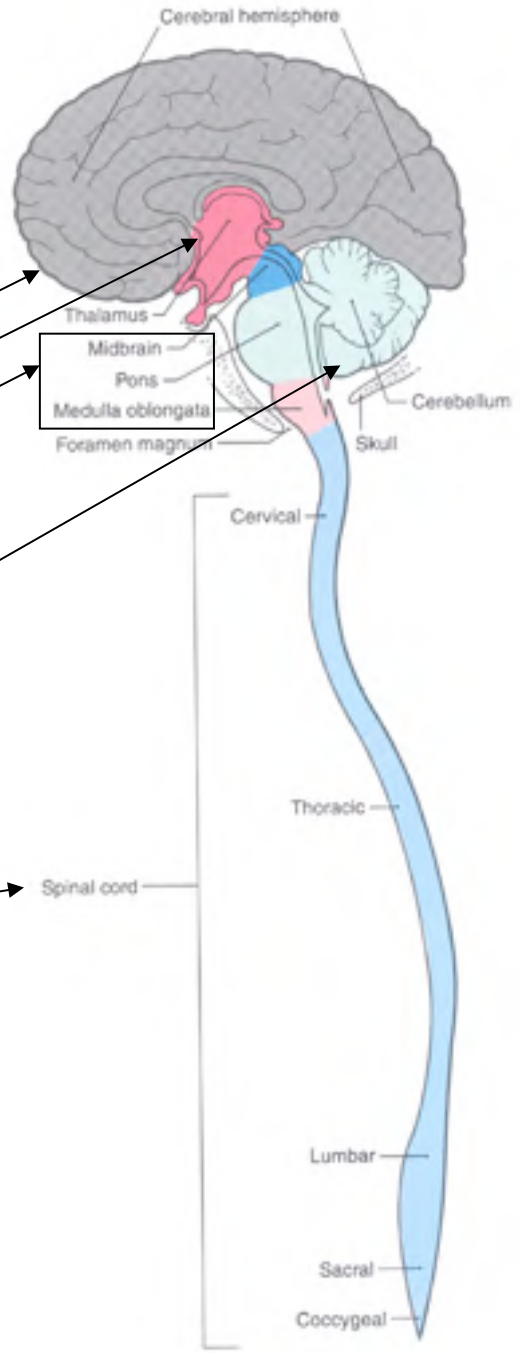
The Nervous System consists of:

1. Central Nervous System (CNS)
2. Peripheral Nervous System (PNS)

CENTRAL NERVOUS SYSTEM (CNS)

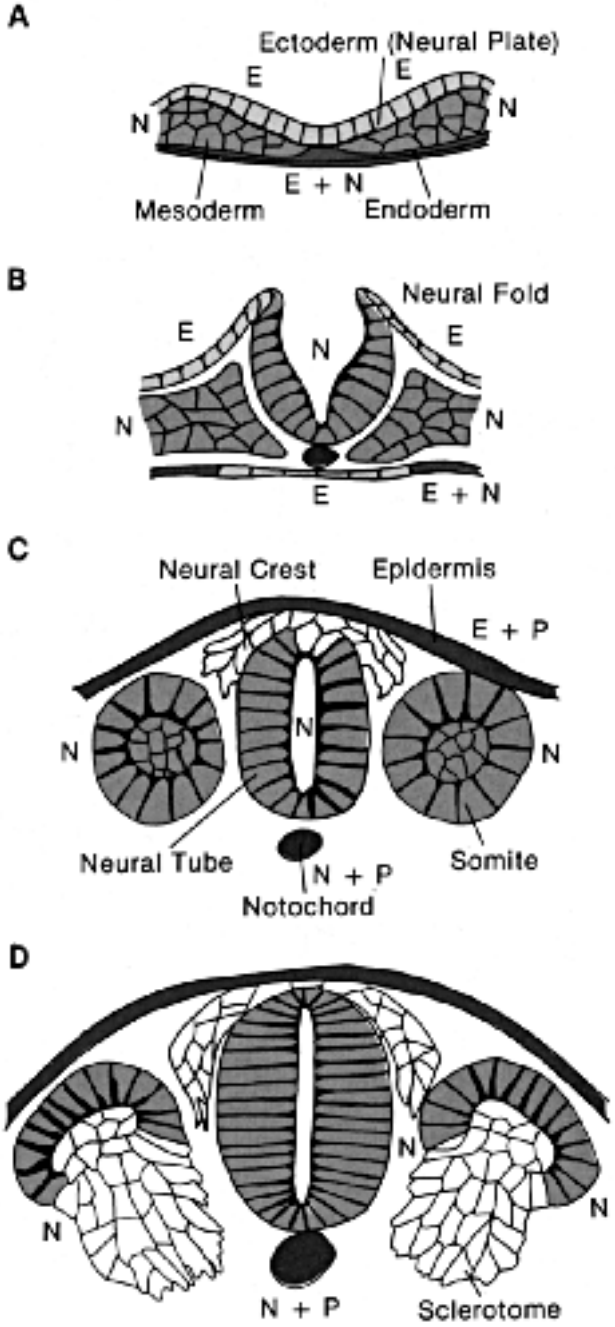
BRAIN:
- Forebrain
  - Telencephalon
  - Diencephalon
- Brain Stem
  - Midbrain
  - Pons
  - Medulla
- Cerebellum

SPINAL CORD (5 regions):
- Cervical
- Thoracic
- Lumbar
- Sacral
- Coccygeal



 Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

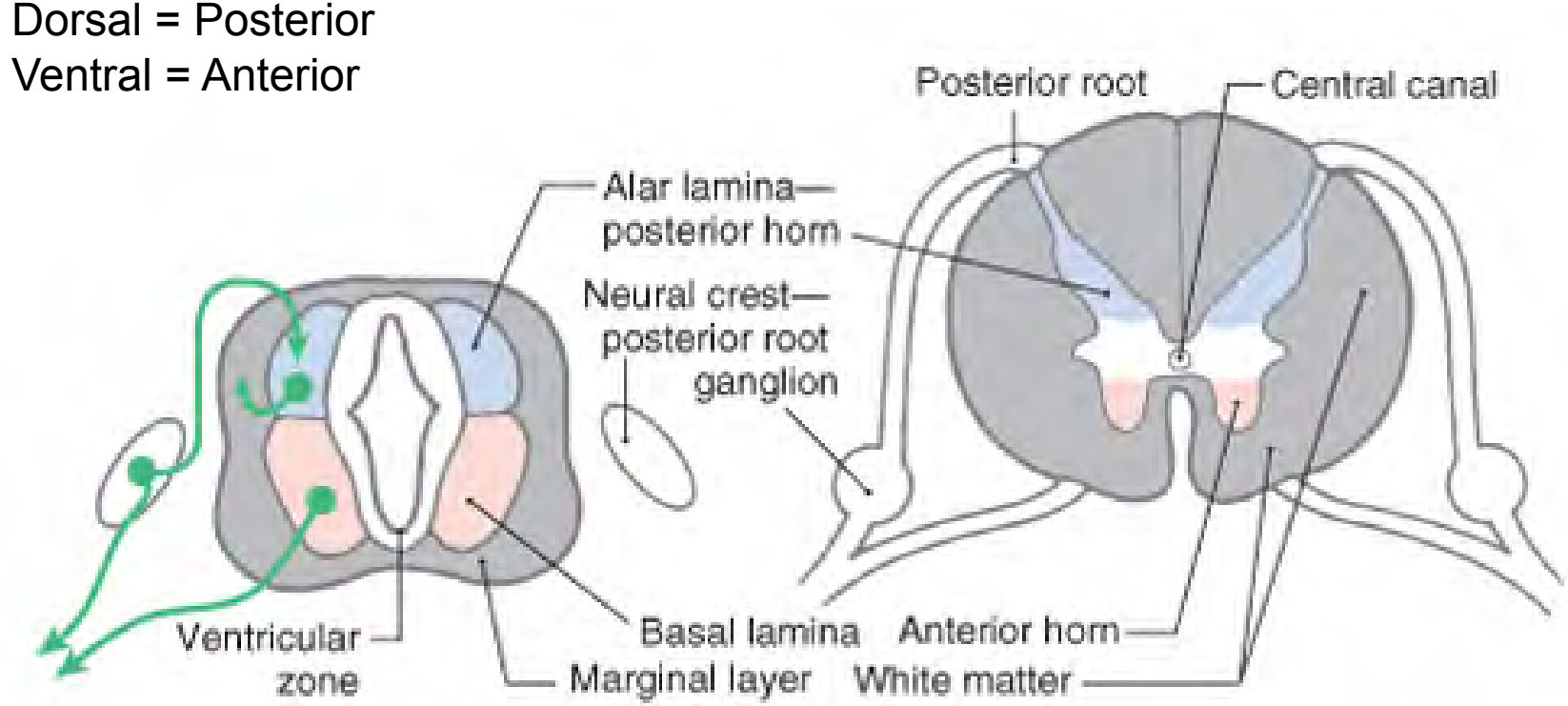
Spinal Cord Development



G.M. Shepard, Neurobiology, 3rd Edition Fig. 9.3

Spinal Cord Development

Dorsal = Posterior
Ventral = Anterior



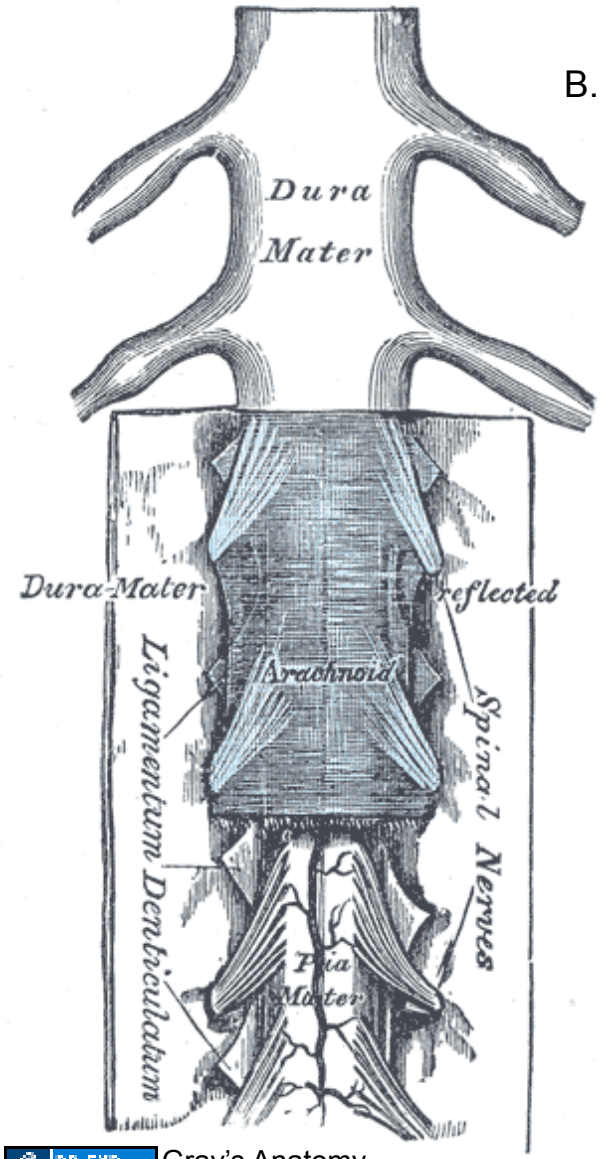
PD-INCL Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 9-1

Spinal Cord

A. OUTER LAYER = White Matter ; (tracts of axons & their myelin)

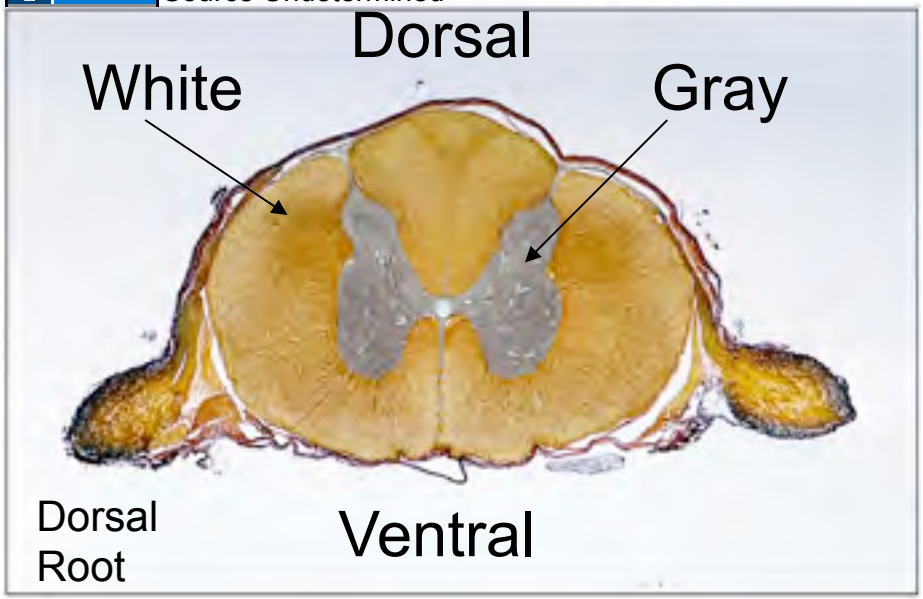
1. Ascending Sensory (Afferent) Tracts
2. Descending Motor (Efferent) Tracts

B. Inner Layer - Gray Matter, rich in neuronal cell bodies and dendrites



PD-EXP Gray's Anatomy

PD-INCL Source Undetermined



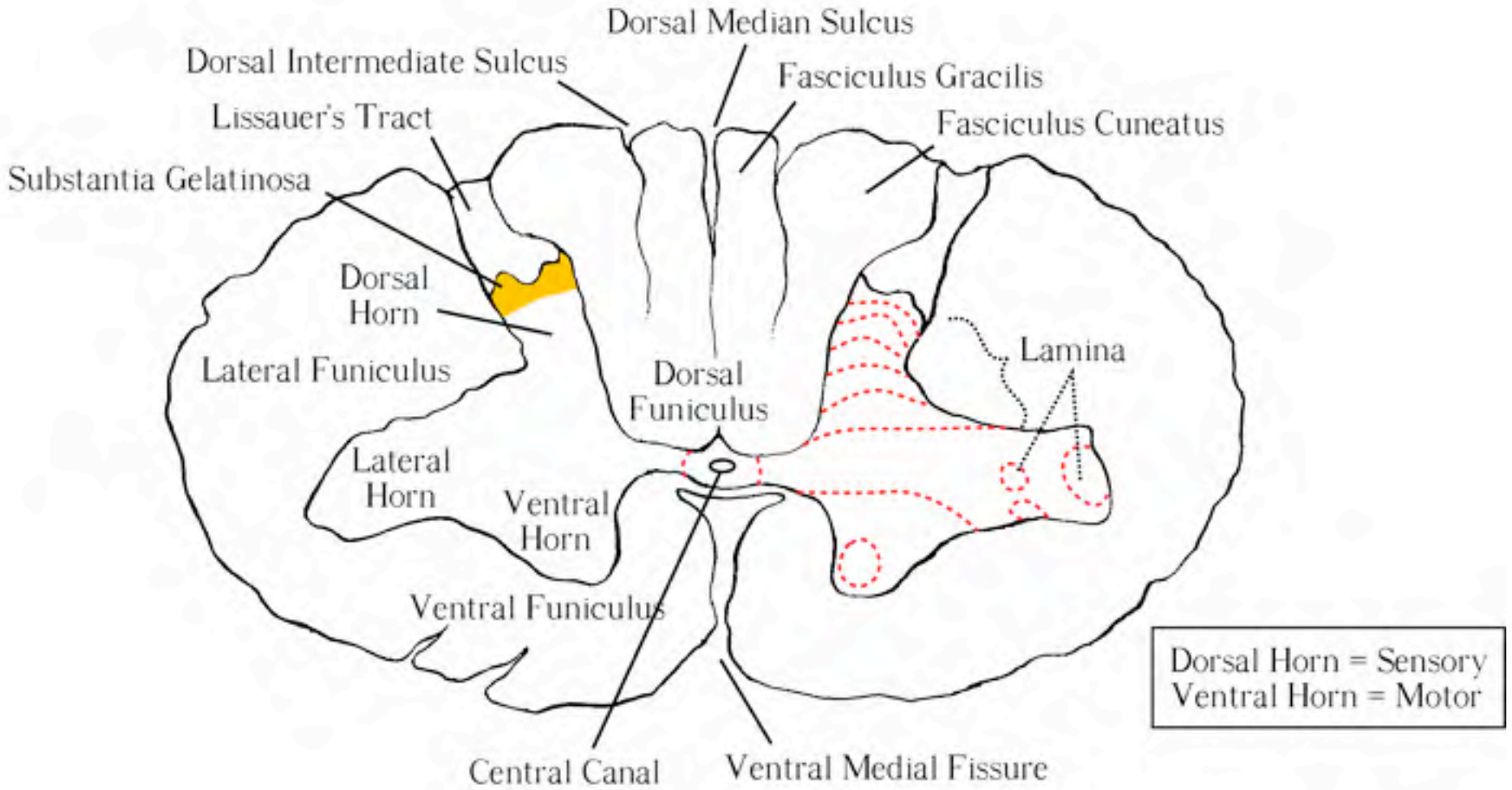
(b)

Spinal Cord Anatomy

A. Funiculi - dorsal, lateral & ventral

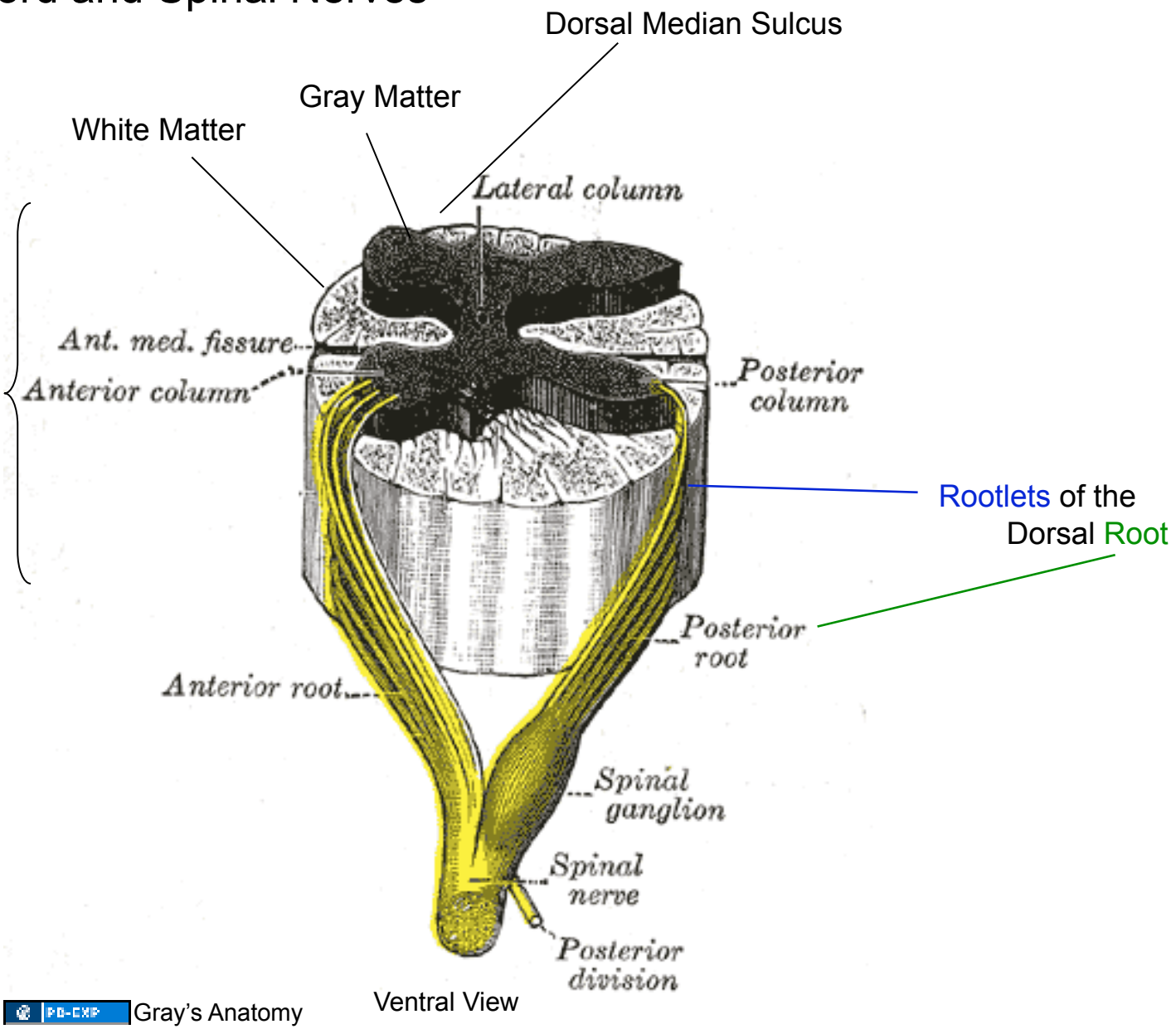
B. Horns - dorsal, lateral and ventral

C. Laminae



 Source Undetermined, See also Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed

The Spinal Cord and Spinal Nerves



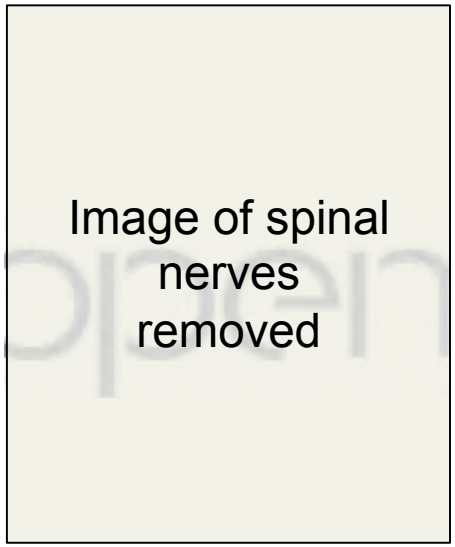
SPINAL NERVES:

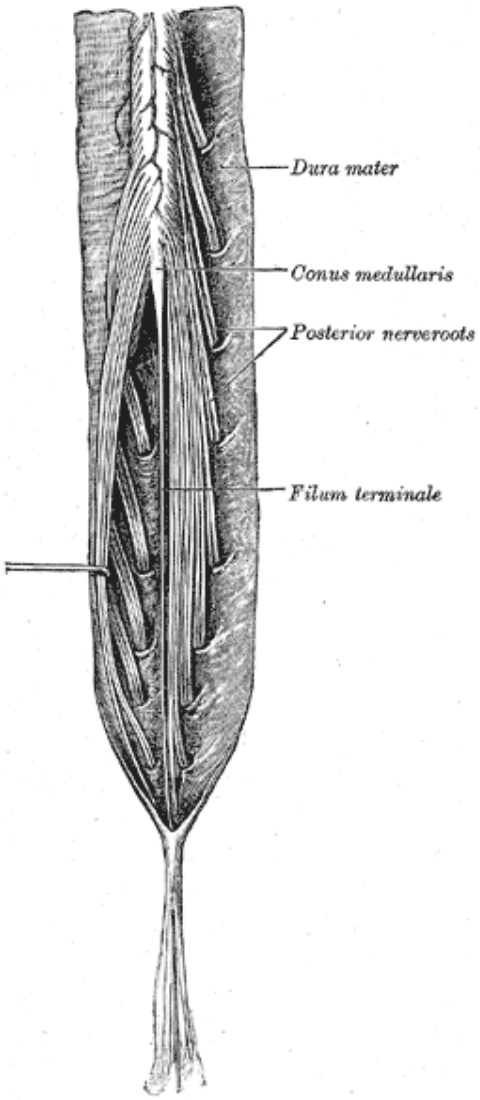
31 pairs (left and right) innervate the neck, trunk and limbs from 5 regions of the spinal cord:

8 pairs of cervical nerves
innervate the neck and arms

12 pairs of thoracic nerves
innervate the thorax

5 pairs of lumbar nerves and
5 pairs of sacral nerves and
1 pair of coccygeal nerves
collectively innervate the abdomen, pelvis,and legs





PD-EXP Gray's Anatomy

Spinal nerves pass through the vertebral column (intervertebral foramen)

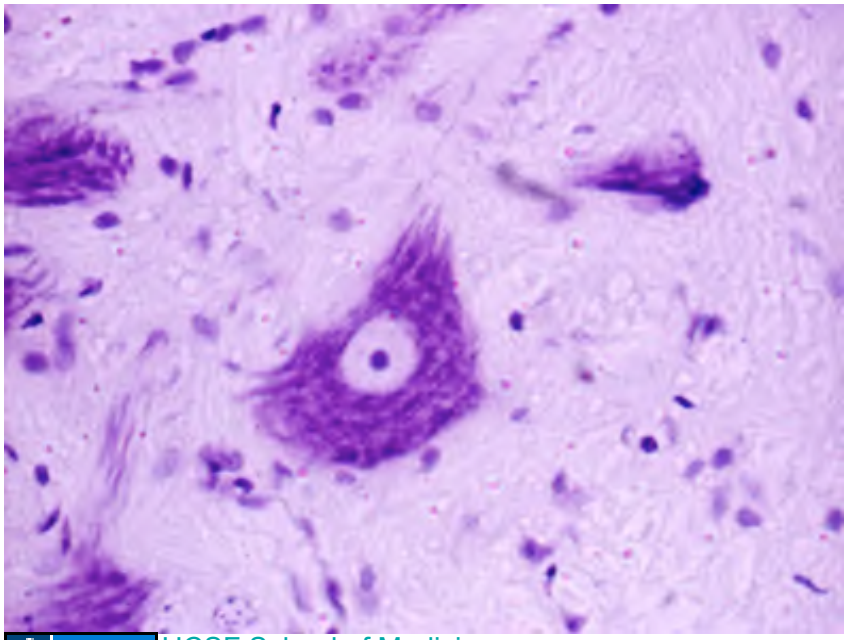
The first (C1) emerges between the first vertebrae and the base of the skull.

C8 emerges from intervertebral foramen between C7 and T1.

Other spinal nerves emerge from intervertebral foramen below the vertebrae of the same number.

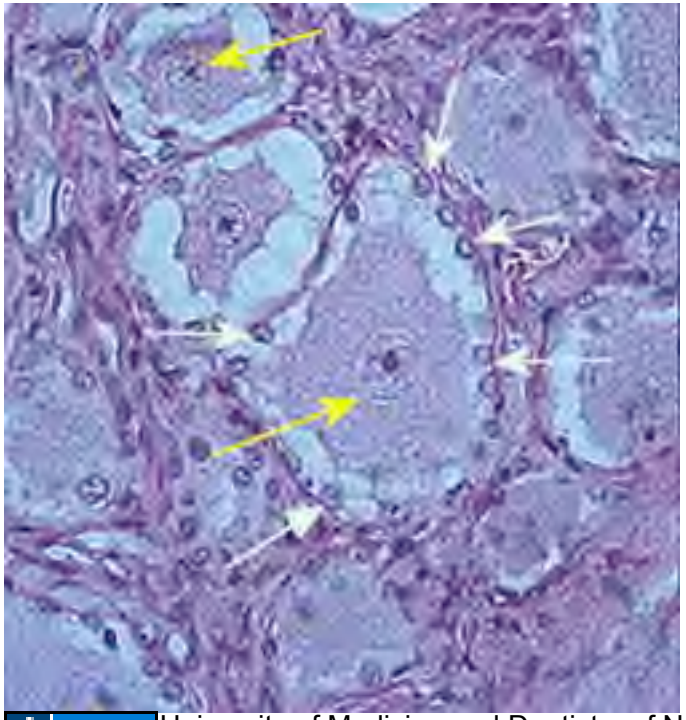
The vertebral column grows longer than the spinal cord; therefore, these vertebrae become located several segments below the entrance/exit of the spinal nerve from the spinal cord.

Motor Neuron
Spinal Cord Ventral Horn



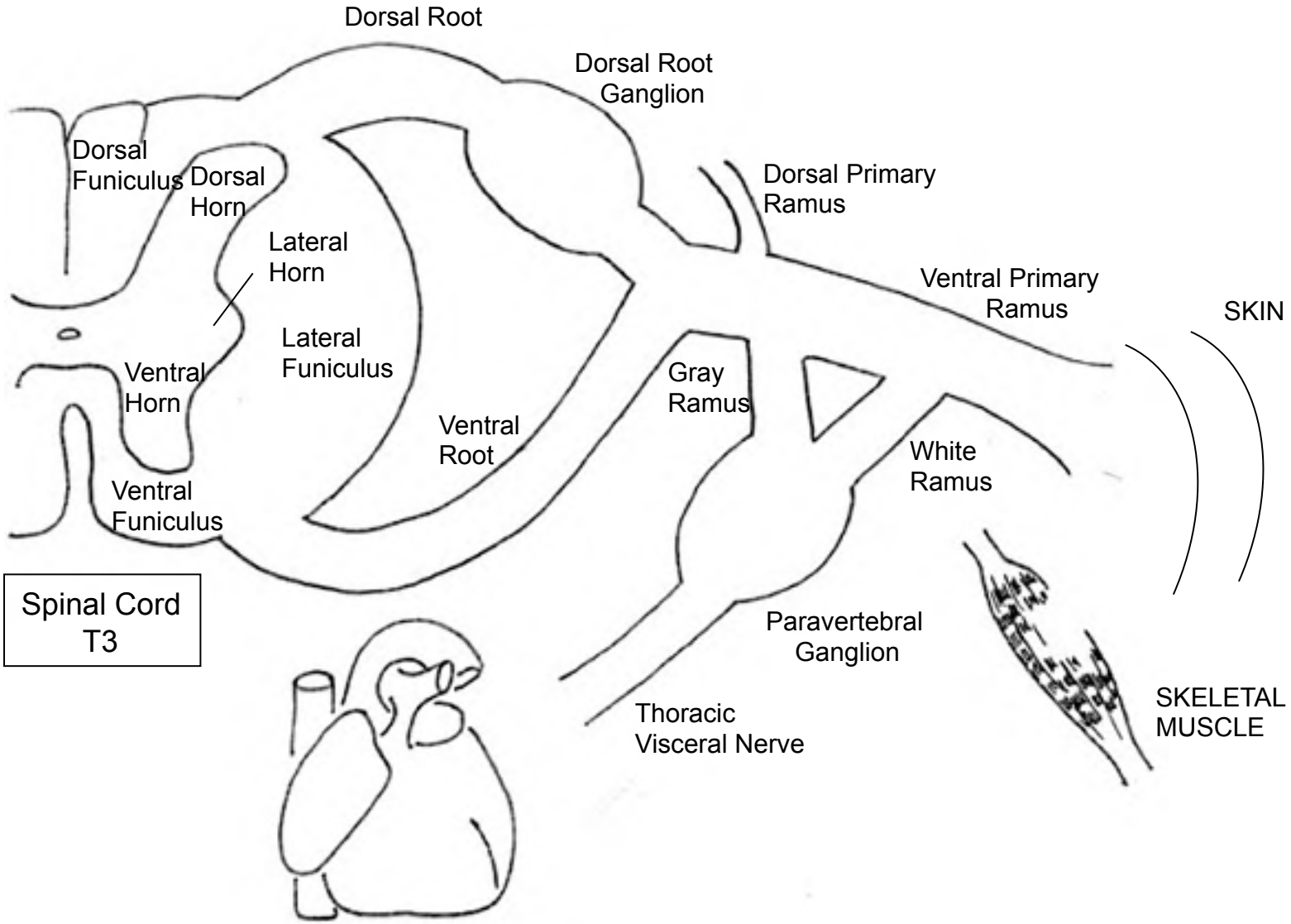
PD-INEL UCSF School of Medicine

Sensory Neuron
Dorsal Root Ganglion

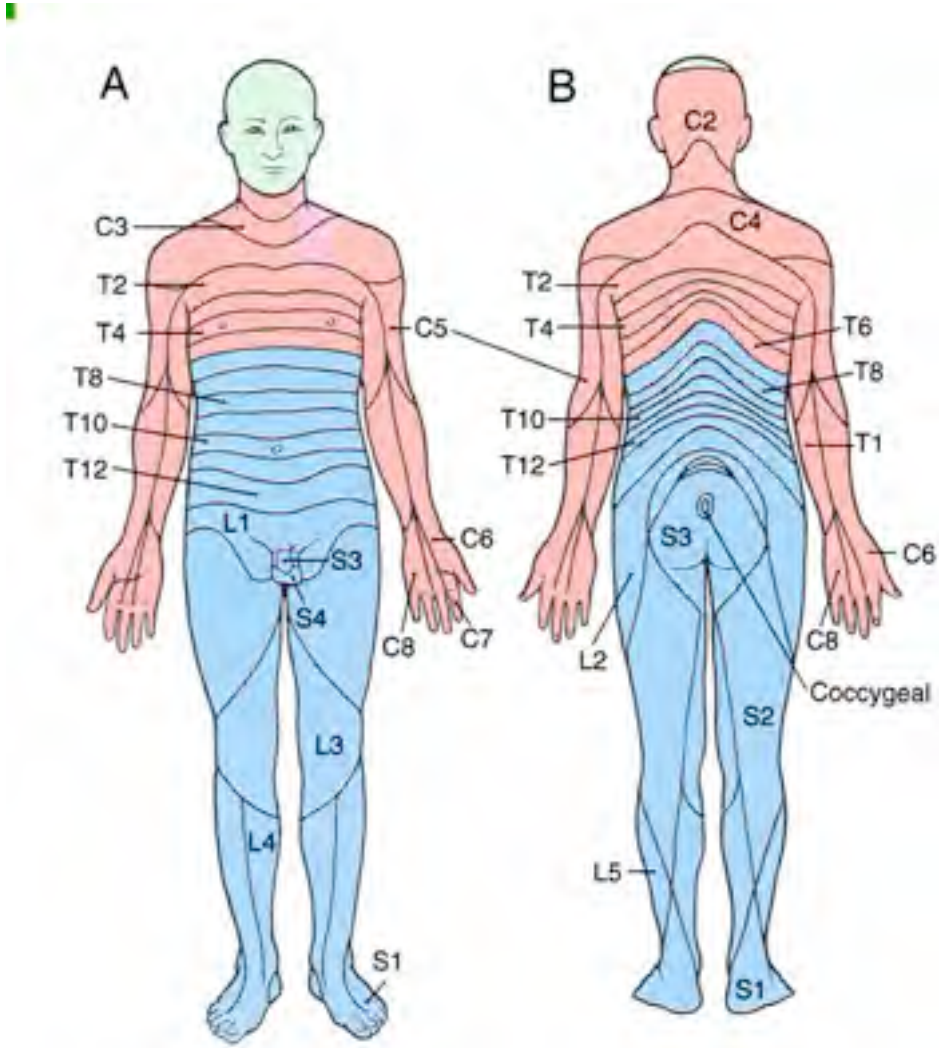


PD-INEL University of Medicine and Dentistry of New Jersey

Spinal Cord and Spinal Nerve



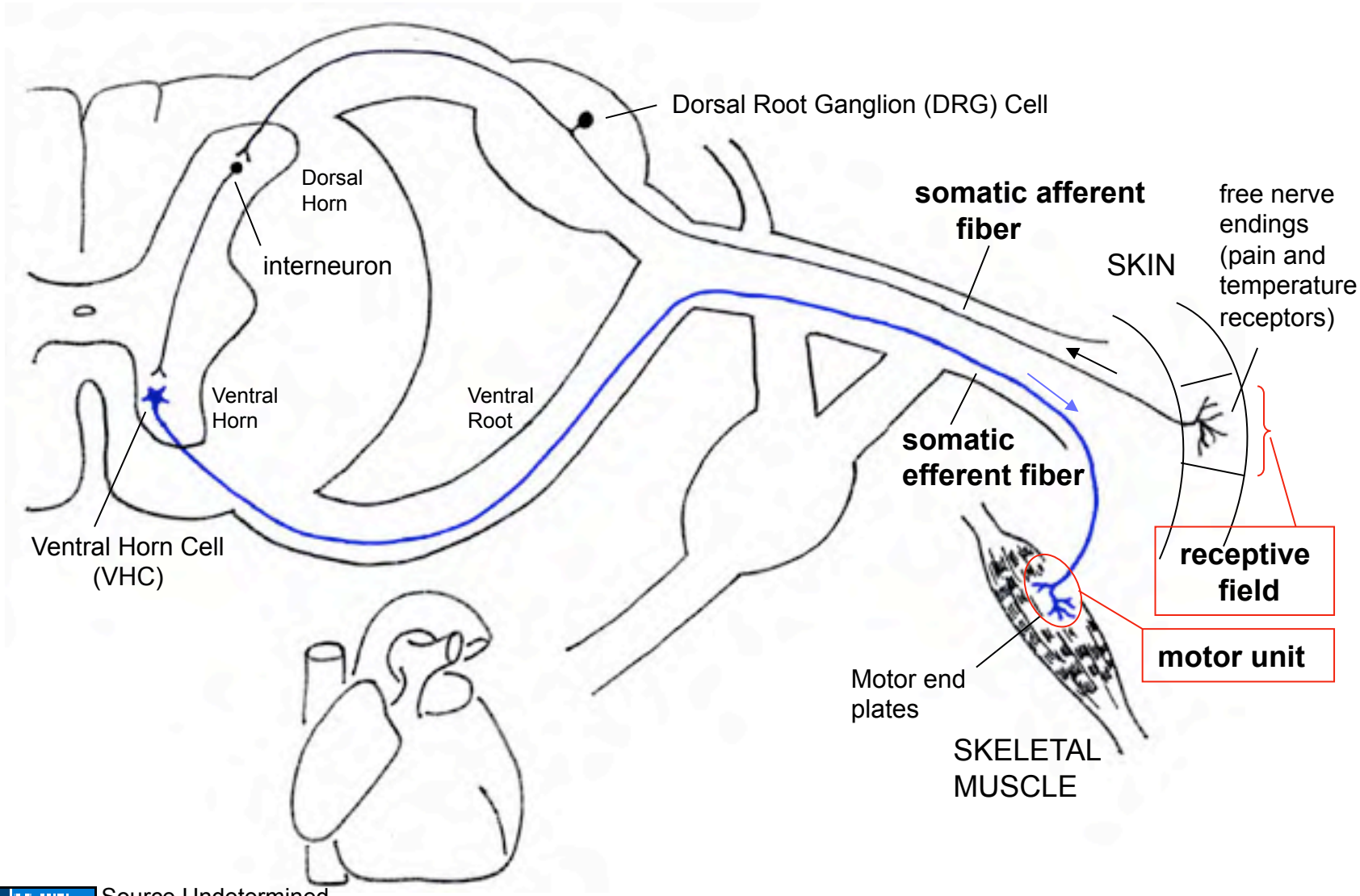
A “dermatome” = an area of skin innervated by one segment of the spinal cord (in other words, by one pair of spinal nerves).



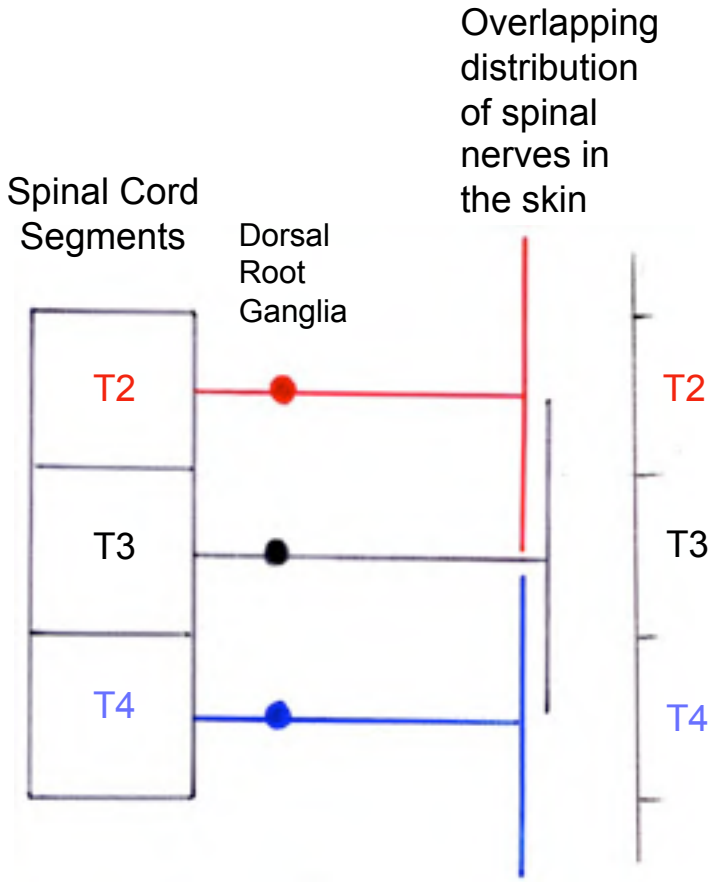
PD-INCL Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 18-4

Receptive Fields and Motor Units

Receptive Field = area of skin innervated by one DRG neuron
Motor Unit = total number of skeletal muscle fibers innervated by one motor neuron

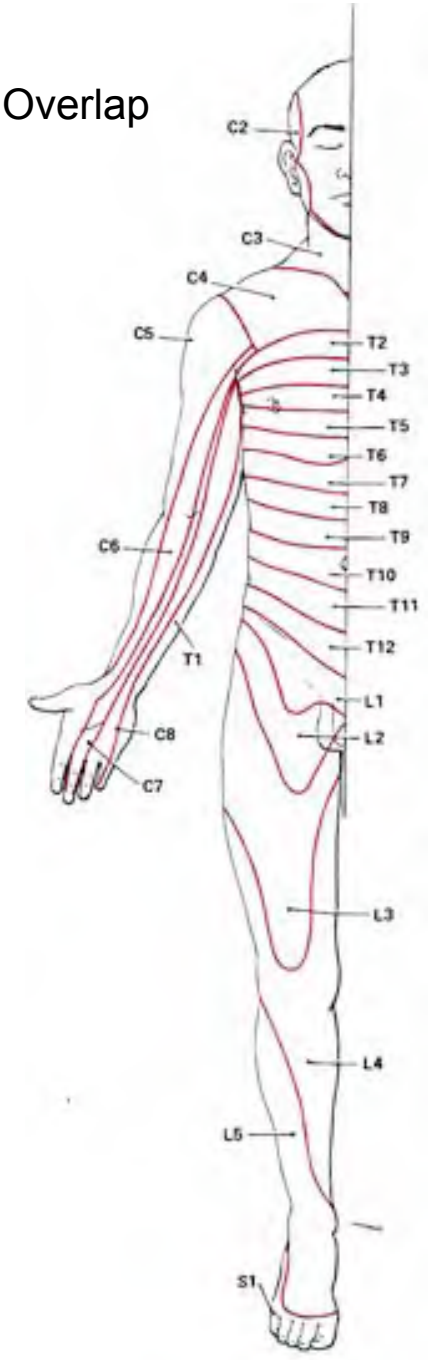


Dermatomes of Adjacent Spinal Cord Segments Overlap



PD-INCL Source Undetermined

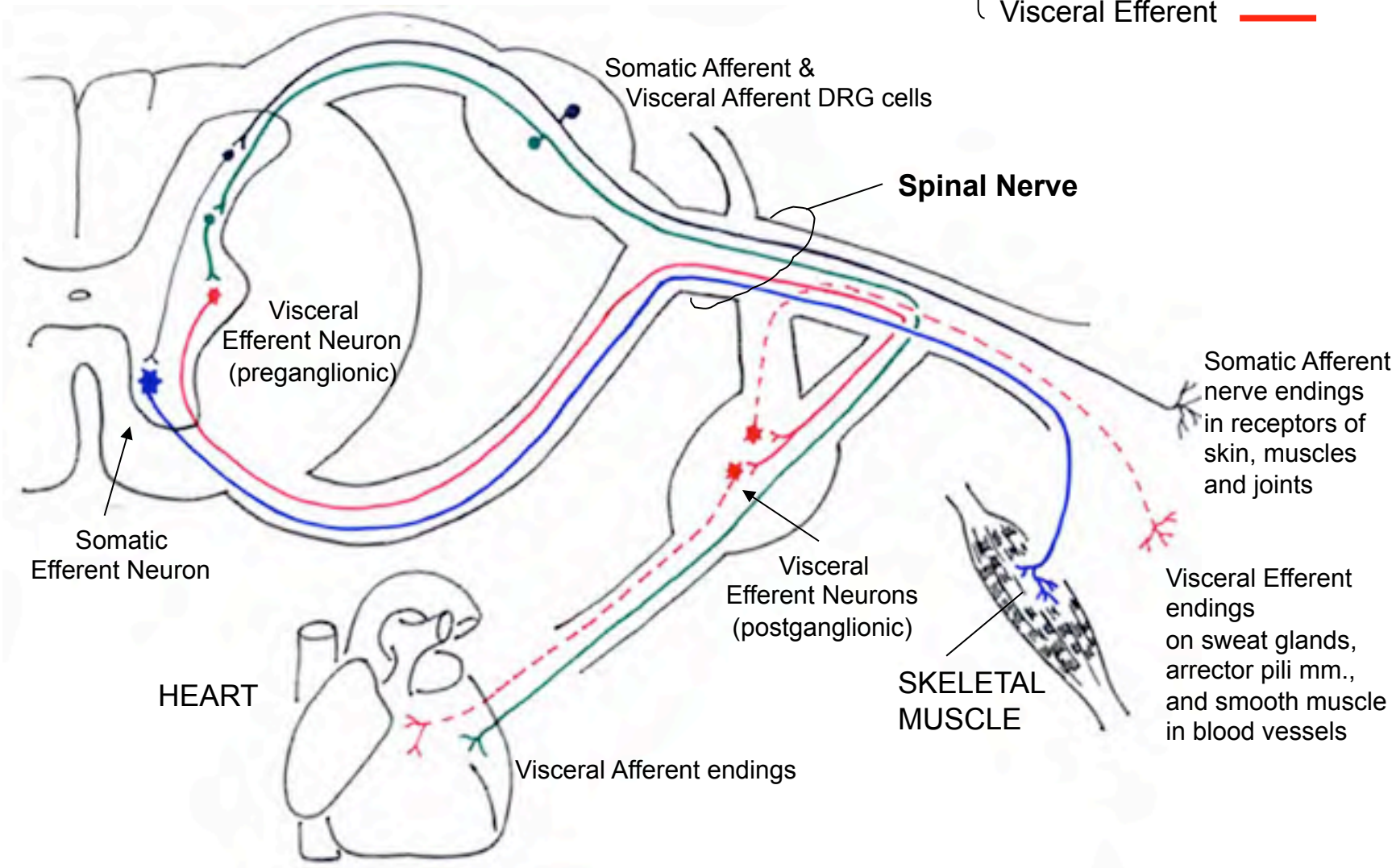
the dermatome map



PD-INCL Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed, Fig. 6-1

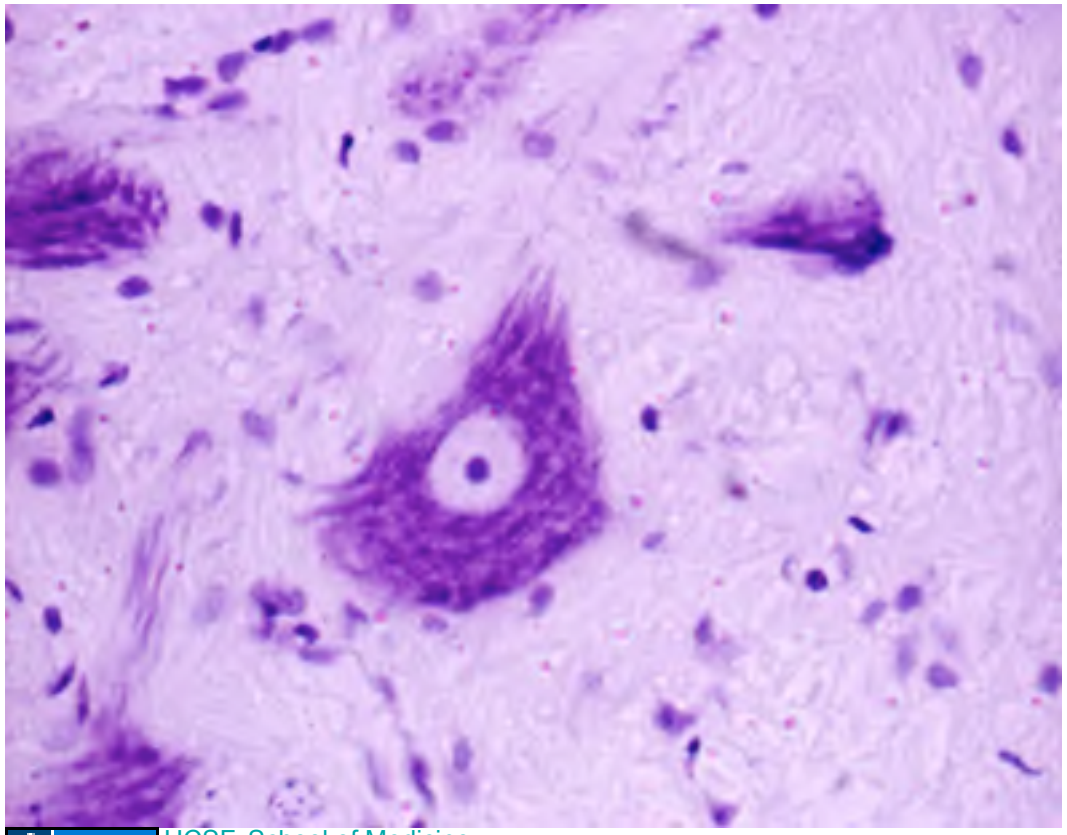
Four Functional Components of the Spinal Nerve:

2 { Somatic (body wall) / Visceral (viscera) } X 2 { Afferent (sensory) / Efferent (motor) } = 4 { Somatic Afferent / Somatic Efferent / Visceral Afferent / Visceral Efferent }



Gray Matter

Motor Neuron
Spinal Cord Ventral Horn



PD-INCL UCSF, School of Medicine

3 Types of Motor neurons

Alpha Motor Neurons (somatic)

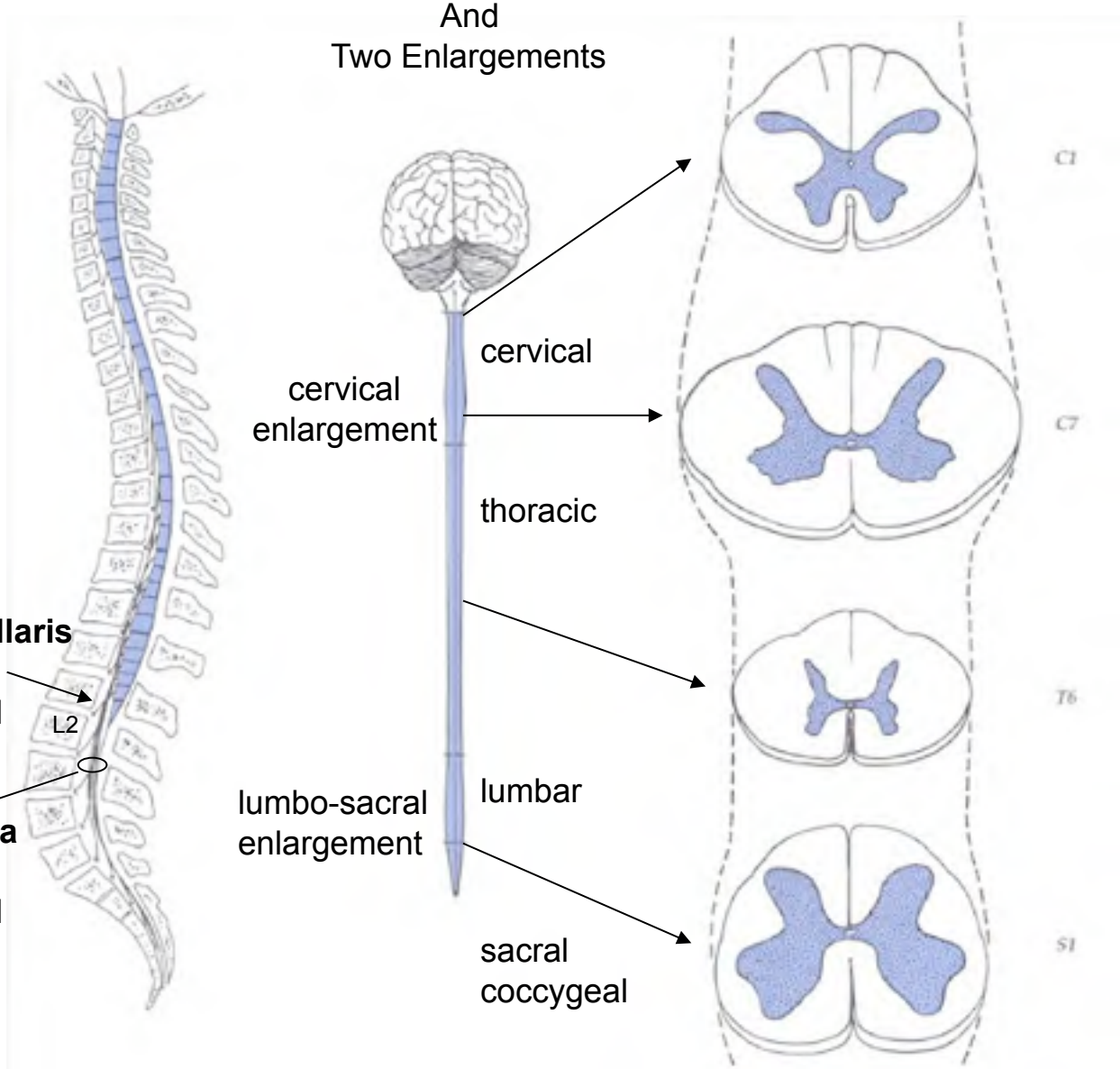
Innervate skeletal muscle

Gamma Motor Neurons

Innervate intrafusal muscle fibers

Preganglionic Sympathetic Neurons (visceral)

Five Spinal Cord Regions
And
Two Enlargements

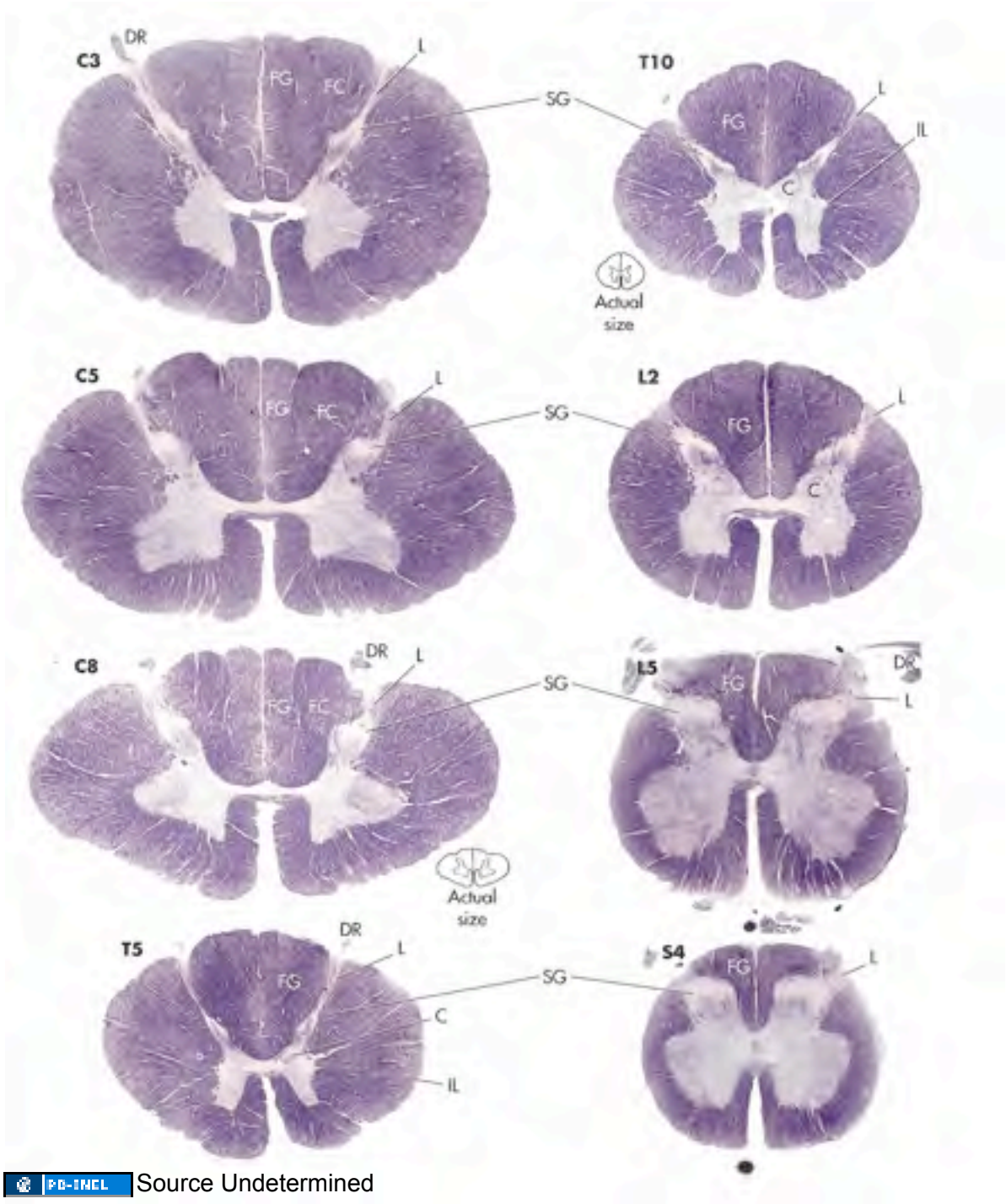


Conus Medullaris
at L1-L2
vertebral level
in the adult

Cauda Equina
from L2
into the sacral
canal

The absolute amount of white matter decreases from cervical to coccygeal segments.

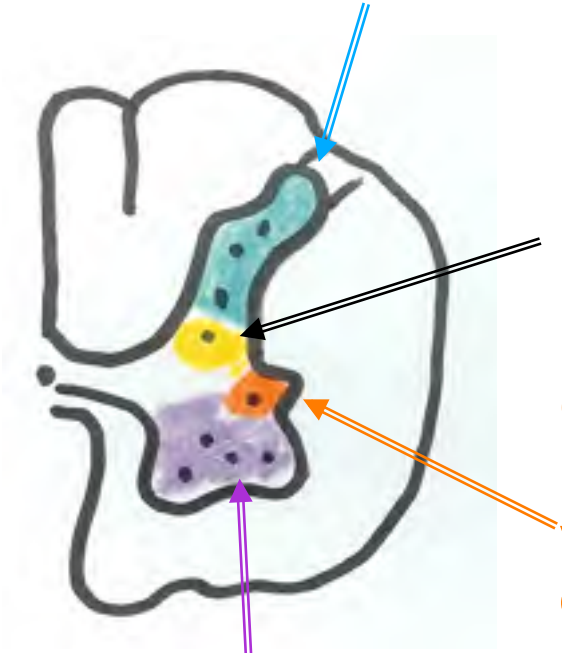
The amount of gray matter is greater in the enlargements than the upper cervical and thoracic regions.



PD-INCL Source Undetermined

General Organization of the Spinal Cord

GSA (general sensory afferent) – receive somatic sensory input

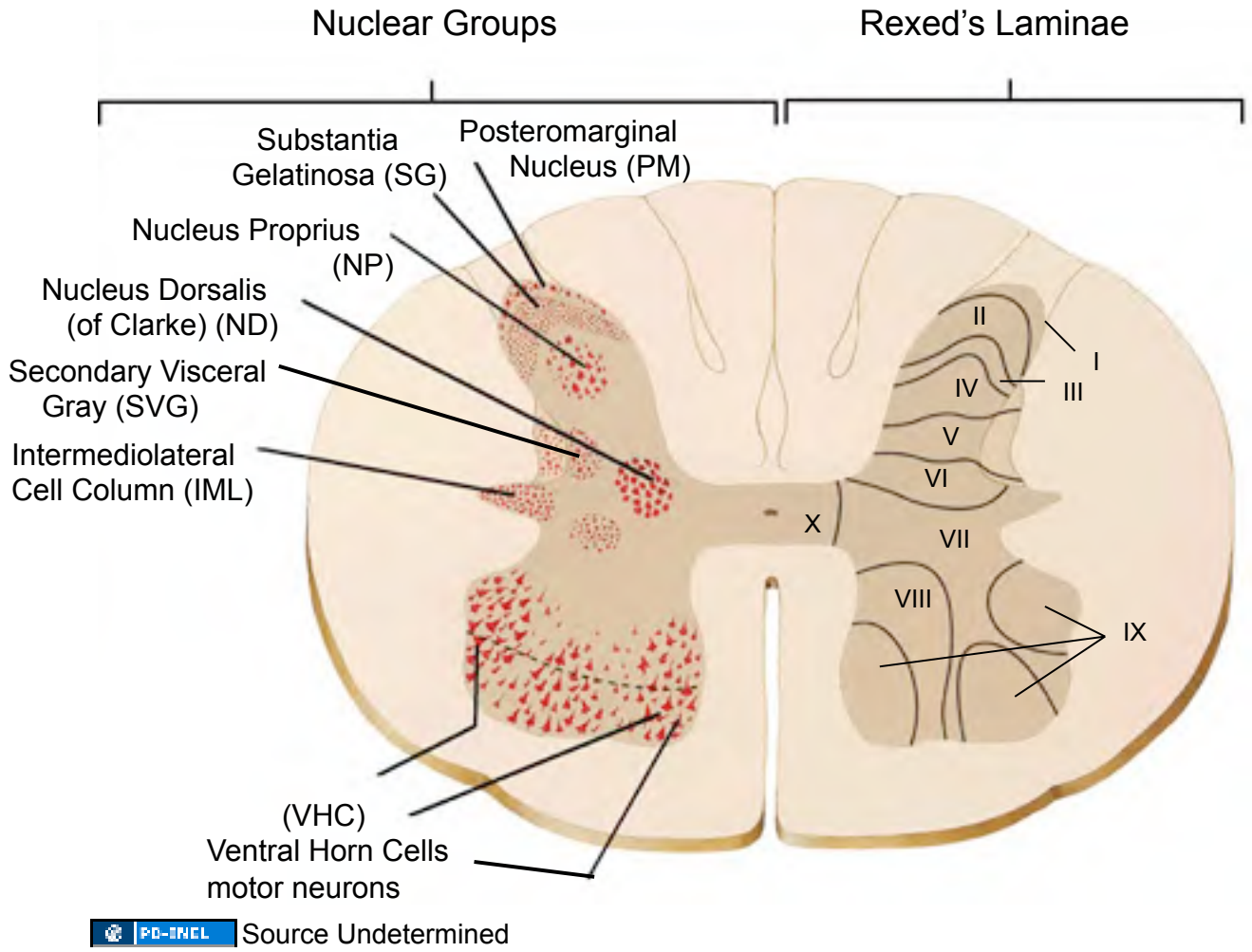


GVA (general visceral afferent)– receive visceral sensory input (restricted distribution)

GVE (general visceral efferent) (autonomics) – motor to viscera; secretomotor to organs and motor smooth muscle. (restricted distribution)

GSE (general somatic efferent) – motor to somatic (striated) muscles

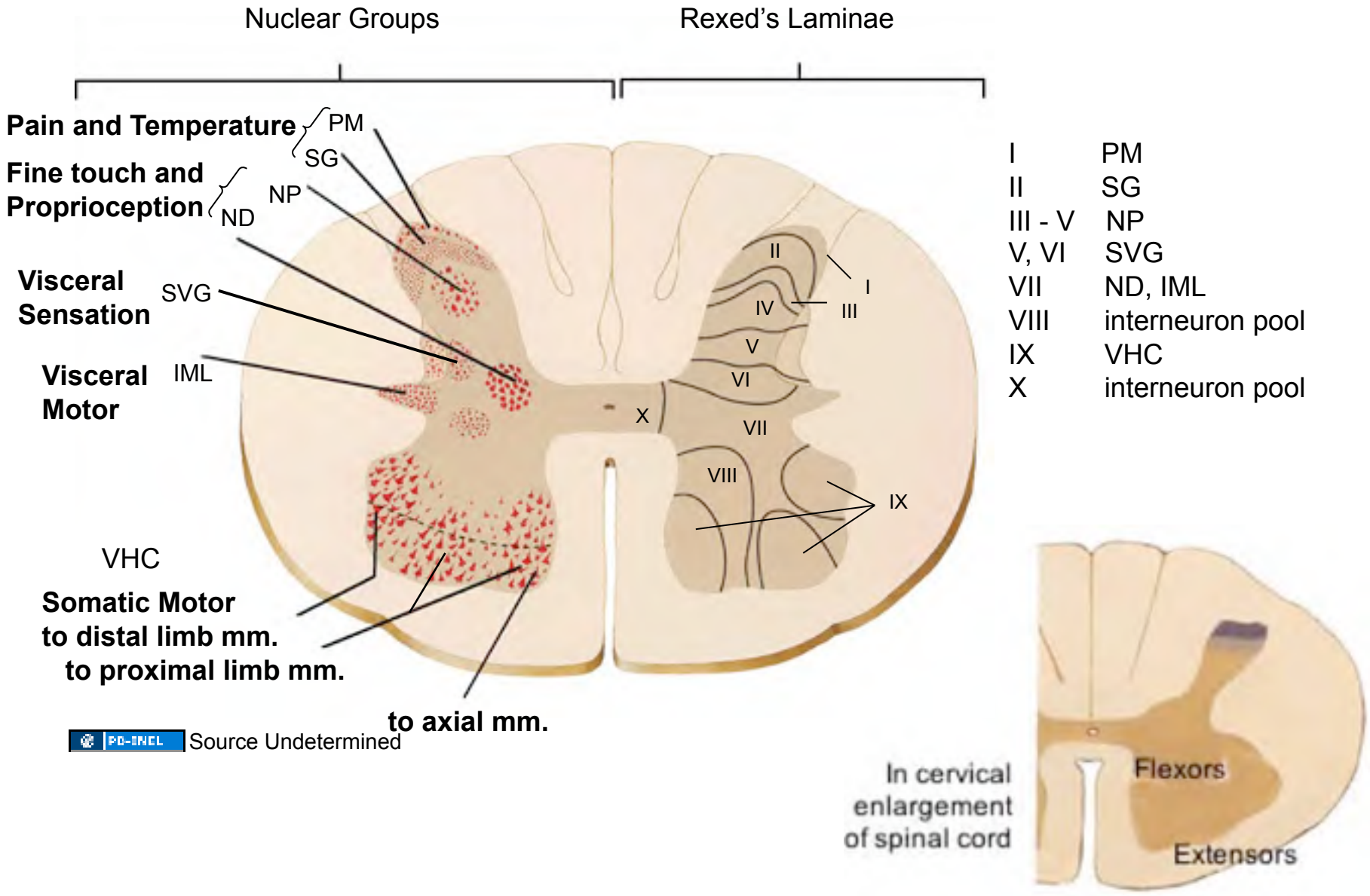
The Spinal Cord Gray Matter



I	PM
II	SG
III - V	NP
V, VI	SVG
VII	ND, IML
VIII	interneuron pool
IX	VHC
X	interneuron pool

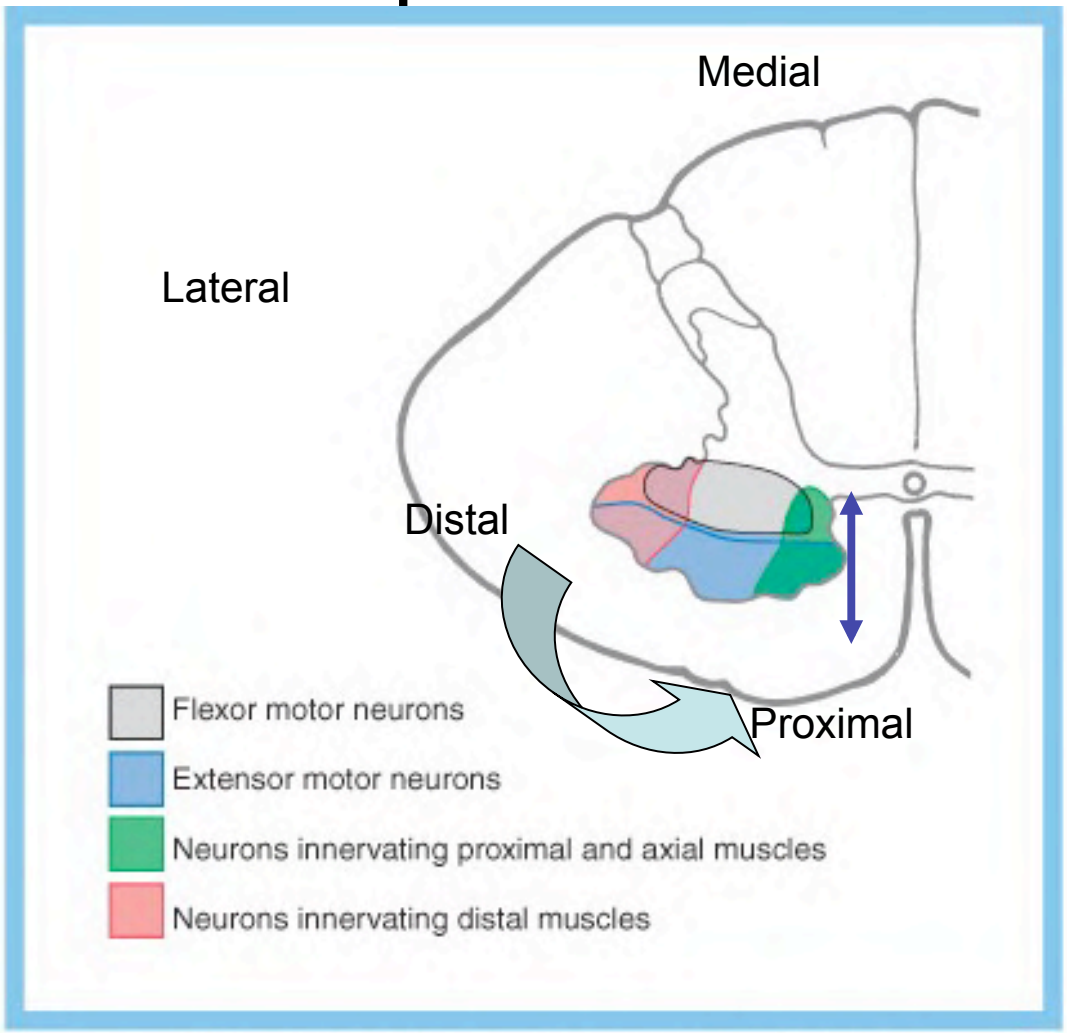
PD-ANEL Source Undetermined

The Spinal Cord Gray Matter



PD-ANEL Source Undetermined

Somatotopic Organization of the Spinal Cord



Dorsal

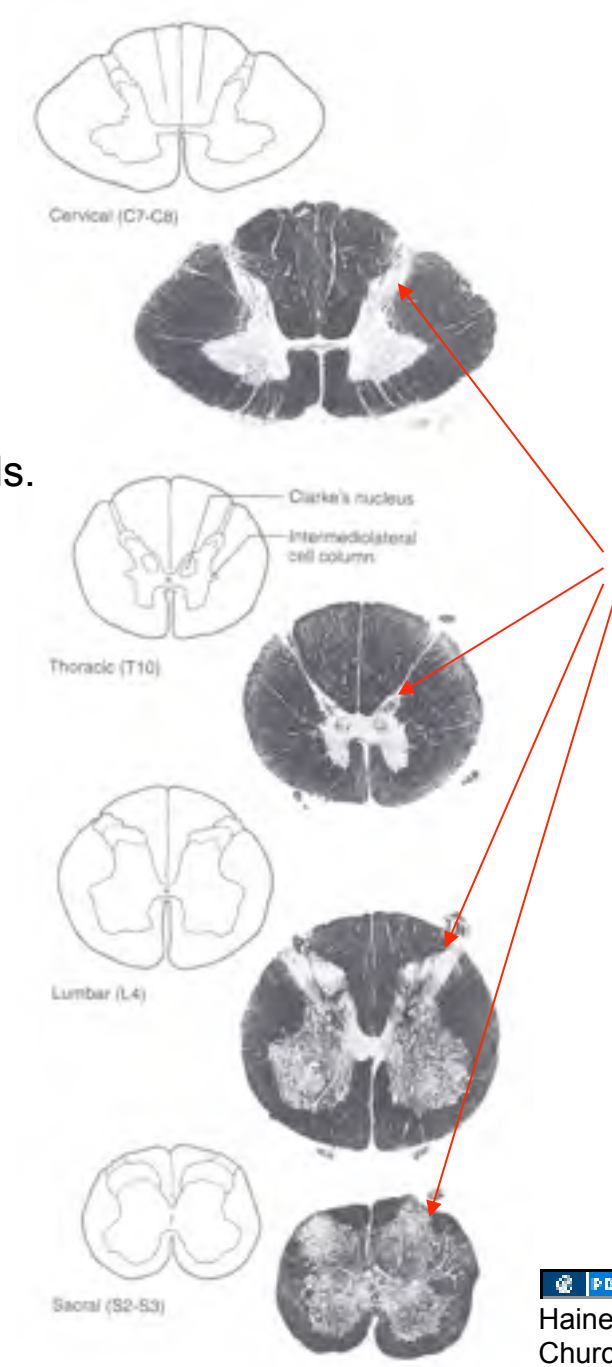
Ventral

Spinal Cord

Longitudinal Organization of the gray matter

Nuclei (laminae) of the gray matter are actually longitudinal columns of cells.

Each column is a structurally and functionally defined population of neurons.



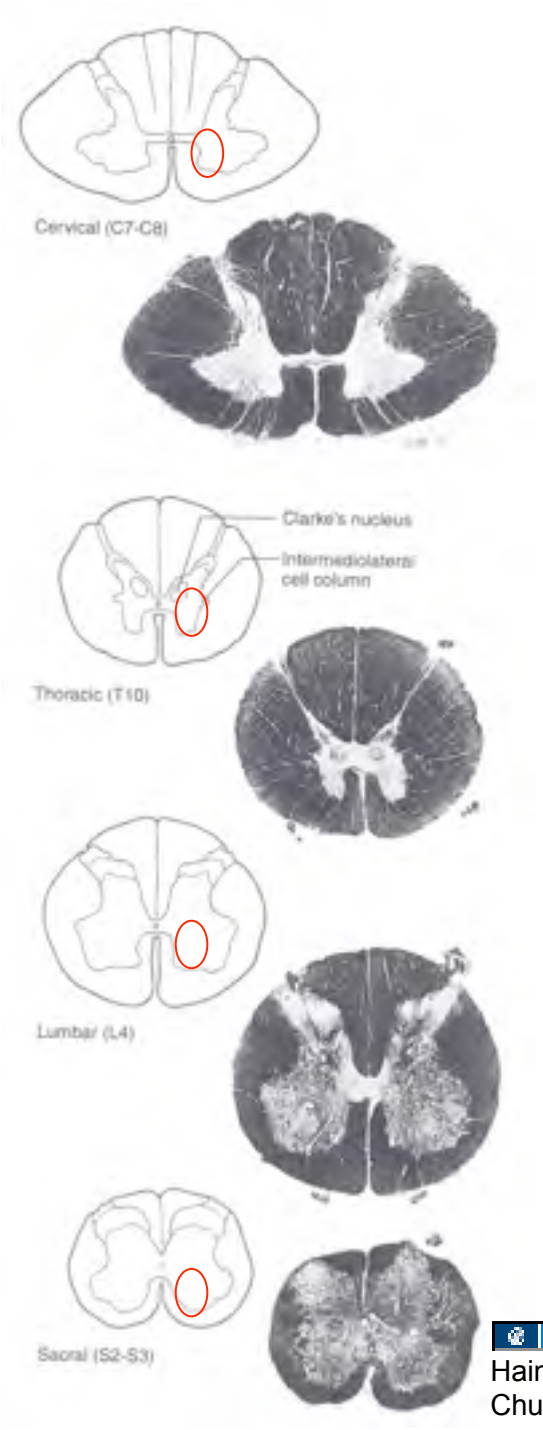
For example, the **substantia gelatinosa** (receiving pain and temperature input) extends throughout the length of the cord.

PD-INCL

Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

Spinal Cord

Longitudinal Organization of the gray matter



A second example is the column of ventral horn cells that innervate axial muscles at all levels of the vertebral column.

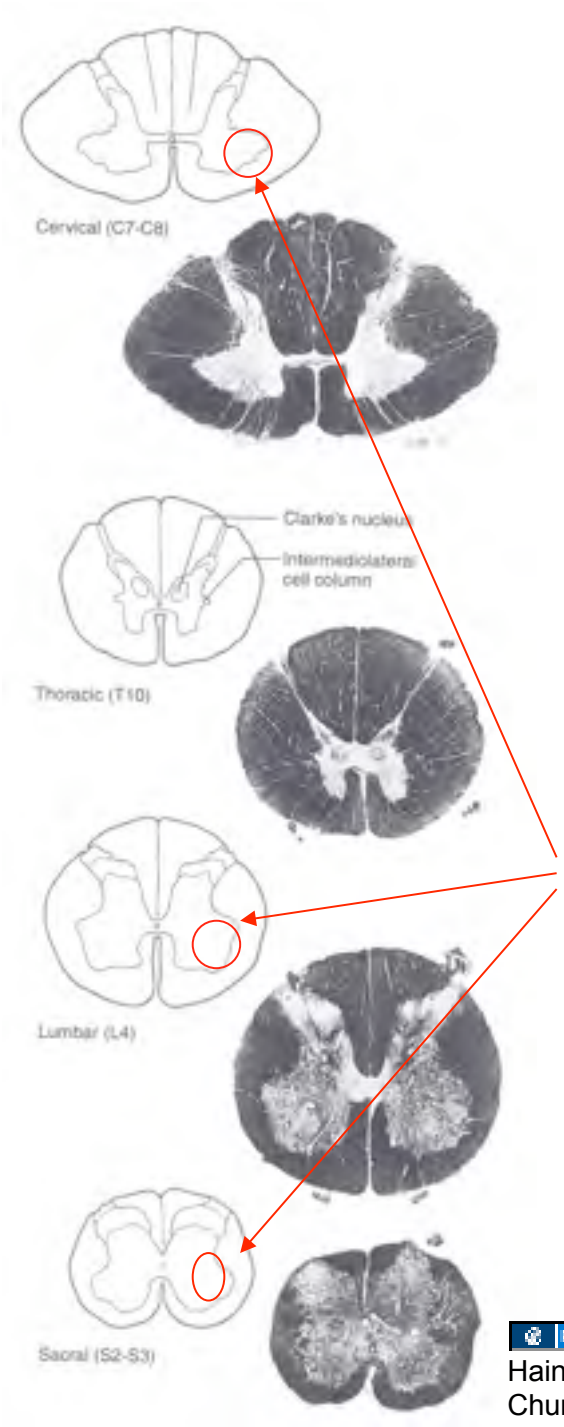
This cell column forms the medial part of the ventral horn.

PD-INCL

Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

Spinal Cord

Longitudinal Organization
of the gray matter

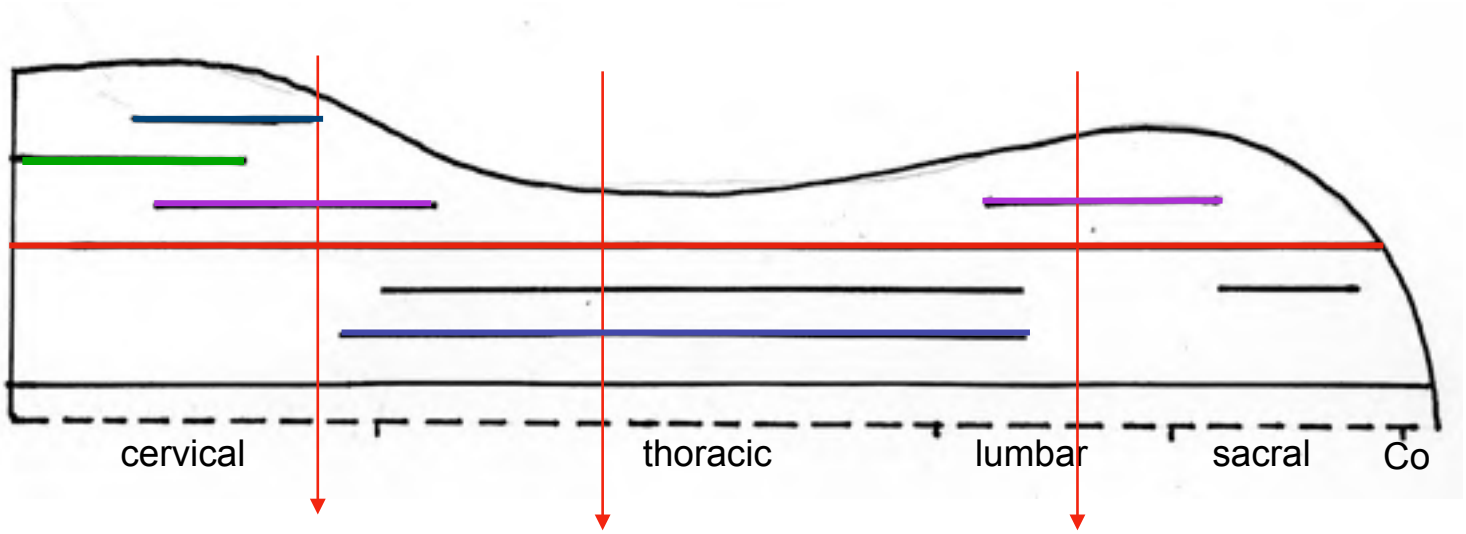


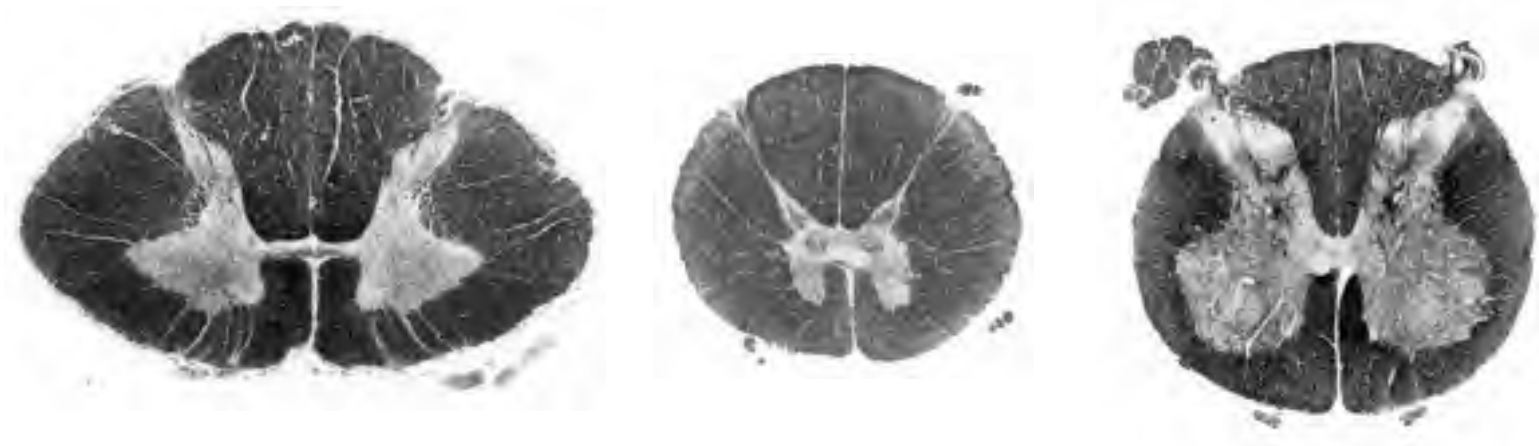
In the enlargements, neurons innervating the limb muscles form a lateral cell column in the ventral horn.

This is a discontinuous column of cells. These added cells in the enlargements make the ventral horn much larger than the ventral horn of the thoracic cord.

Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

Phrenic Nucleus
Accessory Nucleus
VHC - lateral columns
VHC - medial column
IML & SVG - visceral
Nucleus dorsalis
Substantia Gelatinosa





C7 T4 L4

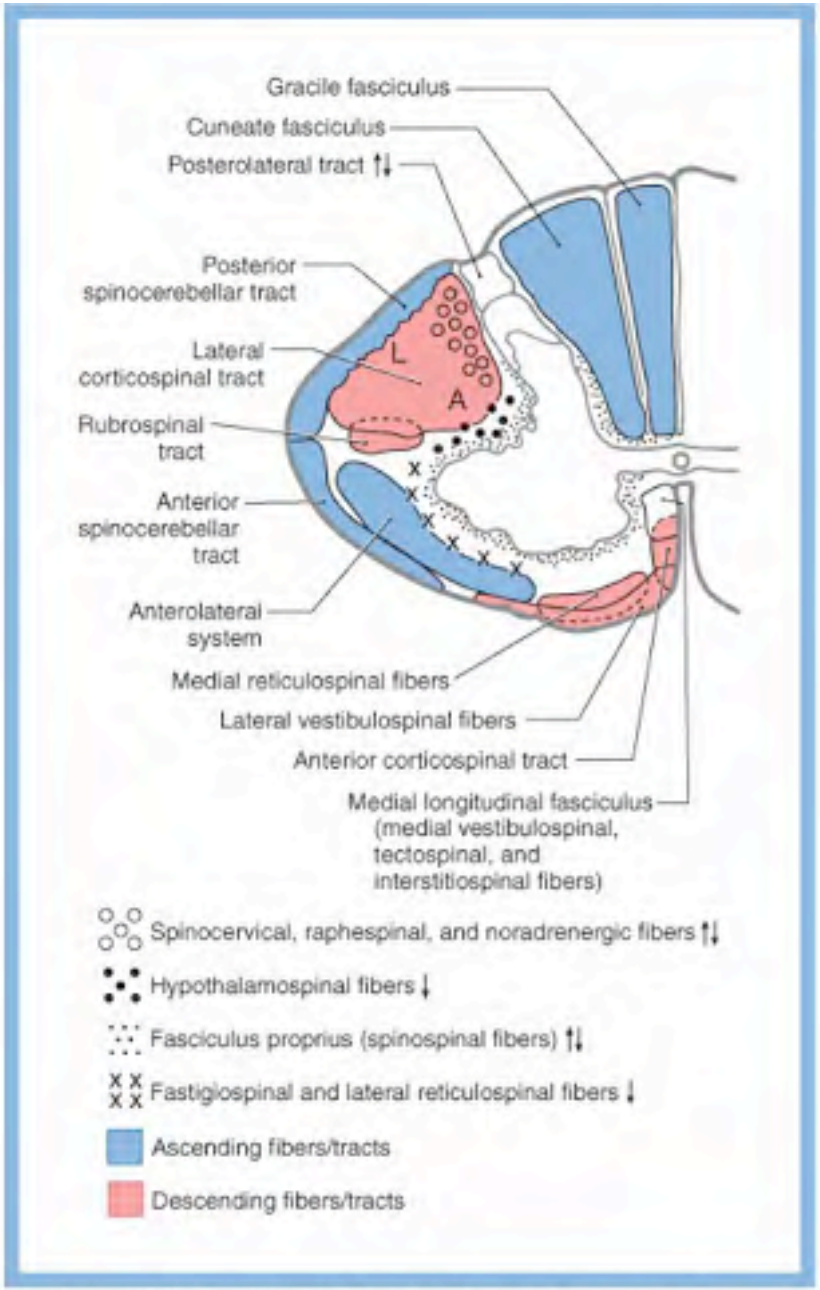
 Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

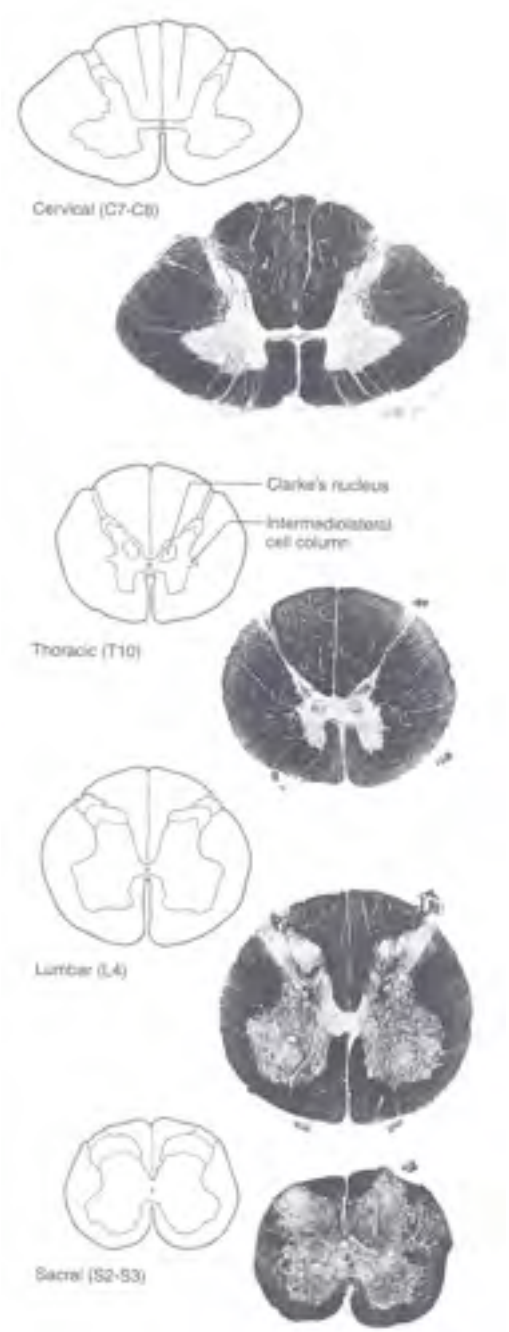
Nucleus or Column	Spinal Level	Function
Dorsal Horn		
Posteromarginal nucleus Substantia gelatinosa Principal sensory nucleus (Nucleus proprius)	All levels	All three nuclei receive primary sensory information. The first two appear to modulate this information, whereas the principal sensory nucleus is associated more with transmission to higher centers and with reflex connections.
Dorsal nucleus of Clarke (nucleus dorsalis)	C8-L3	Nucleus of origin of the dorsal spinocerebellar tract
Ventral Horn		
Spinal accessory nucleus	C1-C5	Lower motor neurons of trapezius and sternocleidomastoid muscles
Phrenic nucleus	C3-C5	Lower motor neurons of the diaphragm
Intermediolateral nucleus	T1-L3 S2-S4	Nucleus of origin of sympathetic preganglionic fibers Nucleus of origin of sacral parasympathetic preganglionic fibers
Medial motor column	All levels	Lower motor neurons that innervate the trunk
Lateral motor column	C5-T1 L1 -S3	Lower motor neurons that innervate the limbs

INTERMISSION

- 10 minute visceral afferent/efferent break

White Matter





The White Matter of the Spinal Cord is composed of:

- ascending tracts (fibers relaying sensory information from the spinal nerves to the brain)
- descending tracts (fibers from the brain that terminate in each segment to influence motor function and sensory transmission)
- fiber bundles with both ascending and descending fibers, carrying information for intersegmental coordination

White matter decreases from the cervical to the sacral segments of the cord.

All tracts have a topographic organization.

Not all tracts are present at all levels of the cord

PD-INCL Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

REFLEXES

This is one of the types of "local processing" that occurs in the spinal cord without influence from higher centers.

A Polysynaptic Spinal Reflex Arc

Receptor - in skin, muscle, joint or viscera

Afferent (sensory) fiber - process of a pseudounipolar cell in the dorsal root ganglion

Interneuron in Spinal Cord - (distinguishes polysynaptic from monosynaptic reflex)

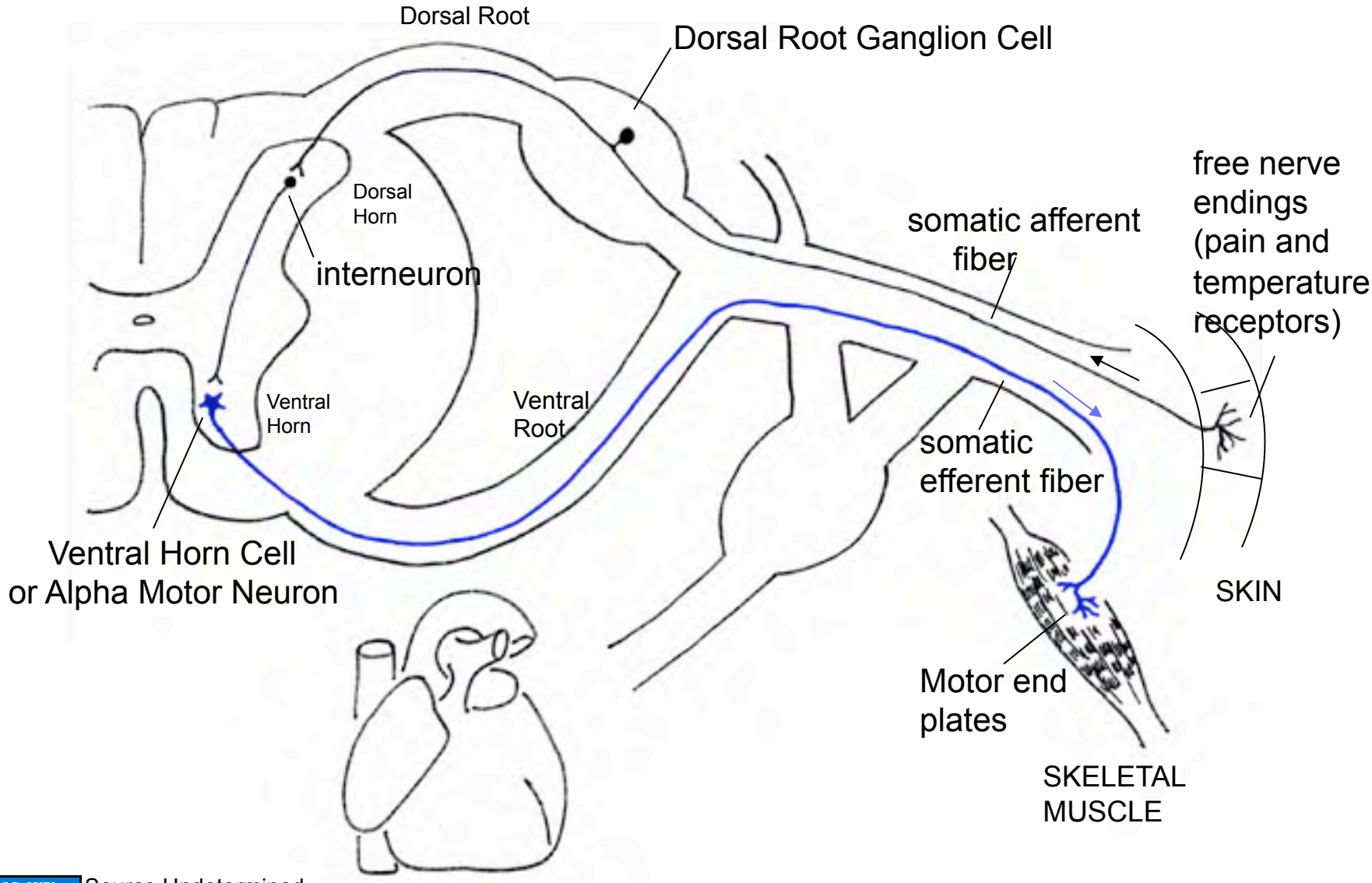
Efferent (motor) fiber - axon of cell in the ventral or lateral horn

Effector - muscle (striated or smooth) or gland

Afferent Arrives

Efferent Exits

Spinal Reflex Arc

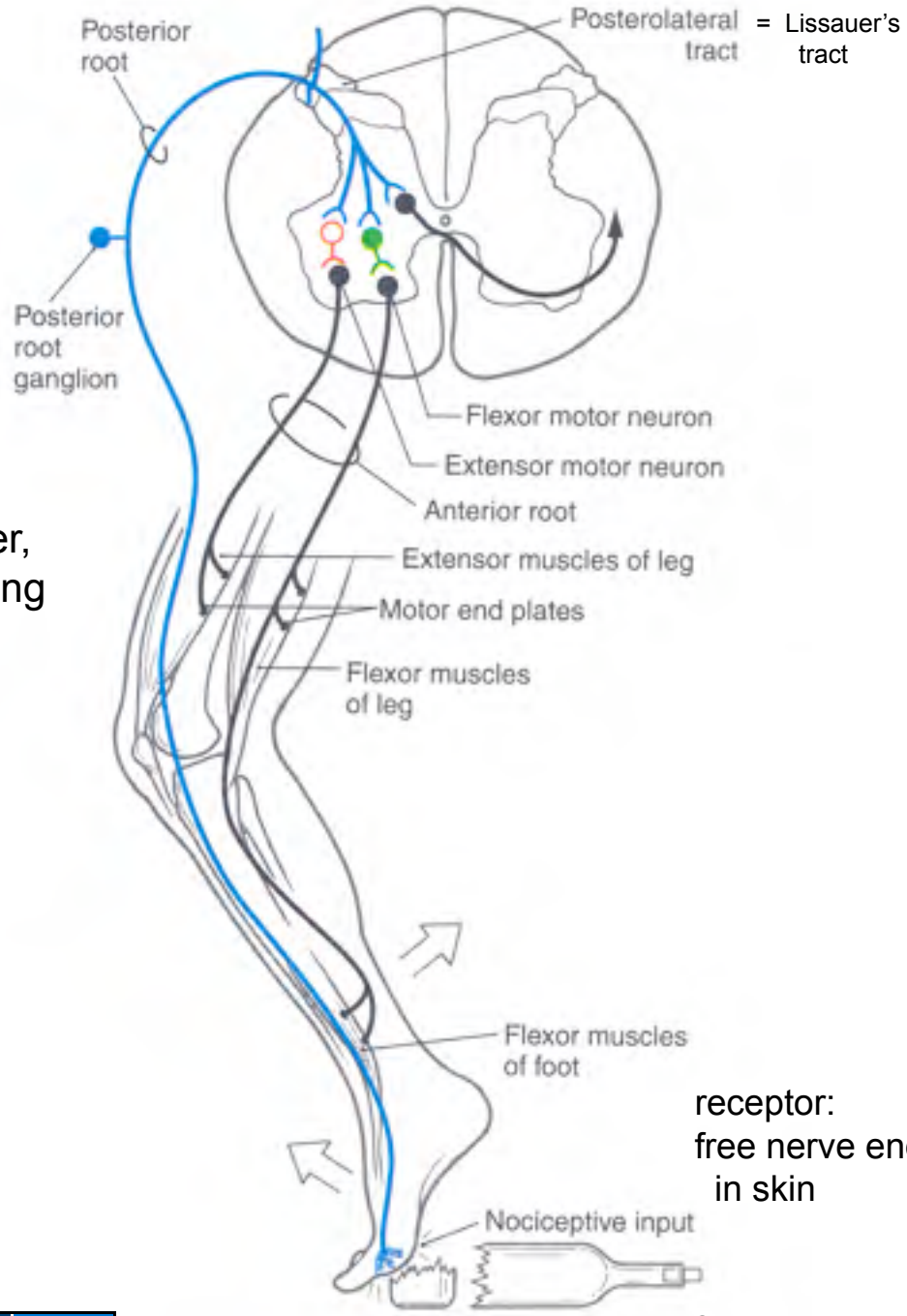


The Flexor Reflex

- contraction of flexor muscles in response to pain
  and
- inhibition of antagonists

Pain fibers (afferents) are small diameter, lightly myelinated, slowly-conducting fibers
Polysynaptic

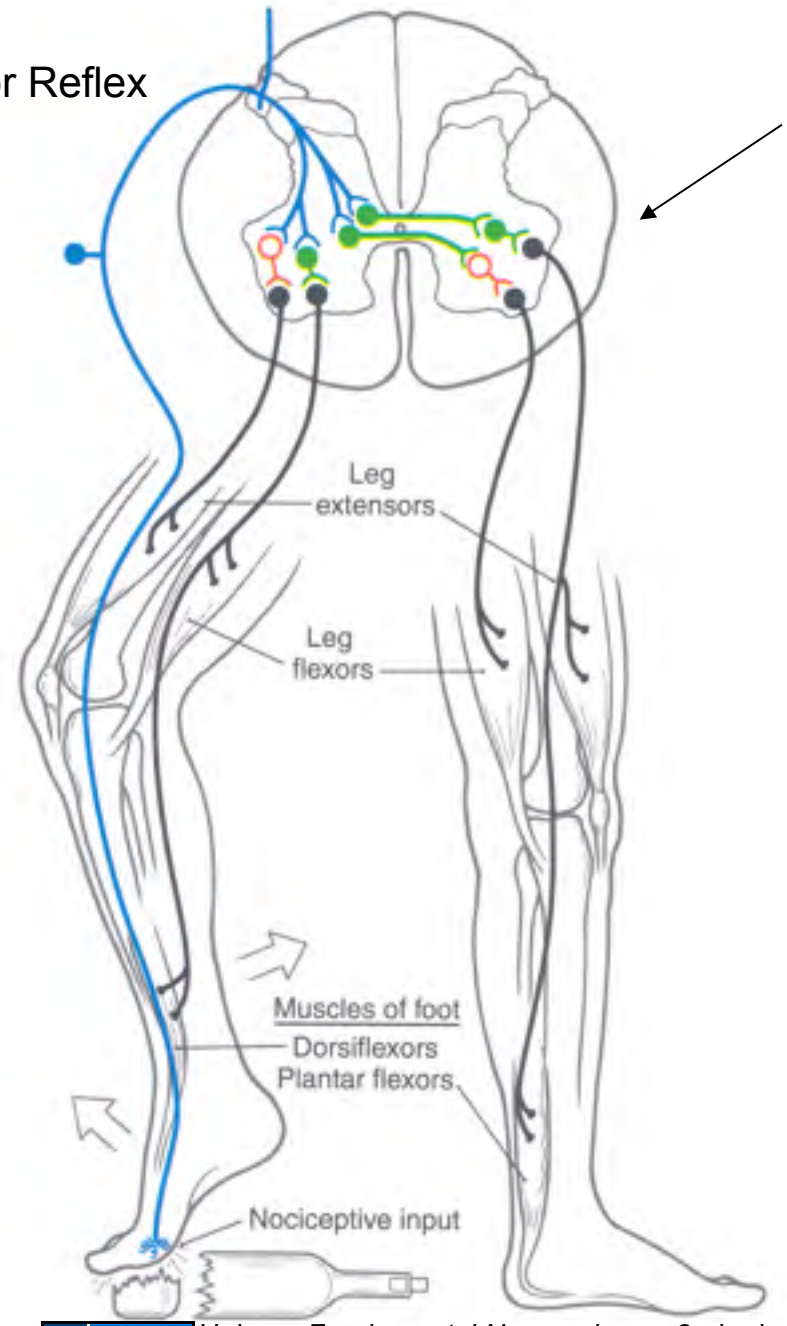
Branching axons of the afferents spread activation to flexor VHCs in adjacent spinal segments
Result is recruitment of all flexors of the limb (and inhibition of the extensors)



receptor:
free nerve endings in skin

PD-INCL Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

Flexor Reflex



The Crossed Extension Reflex

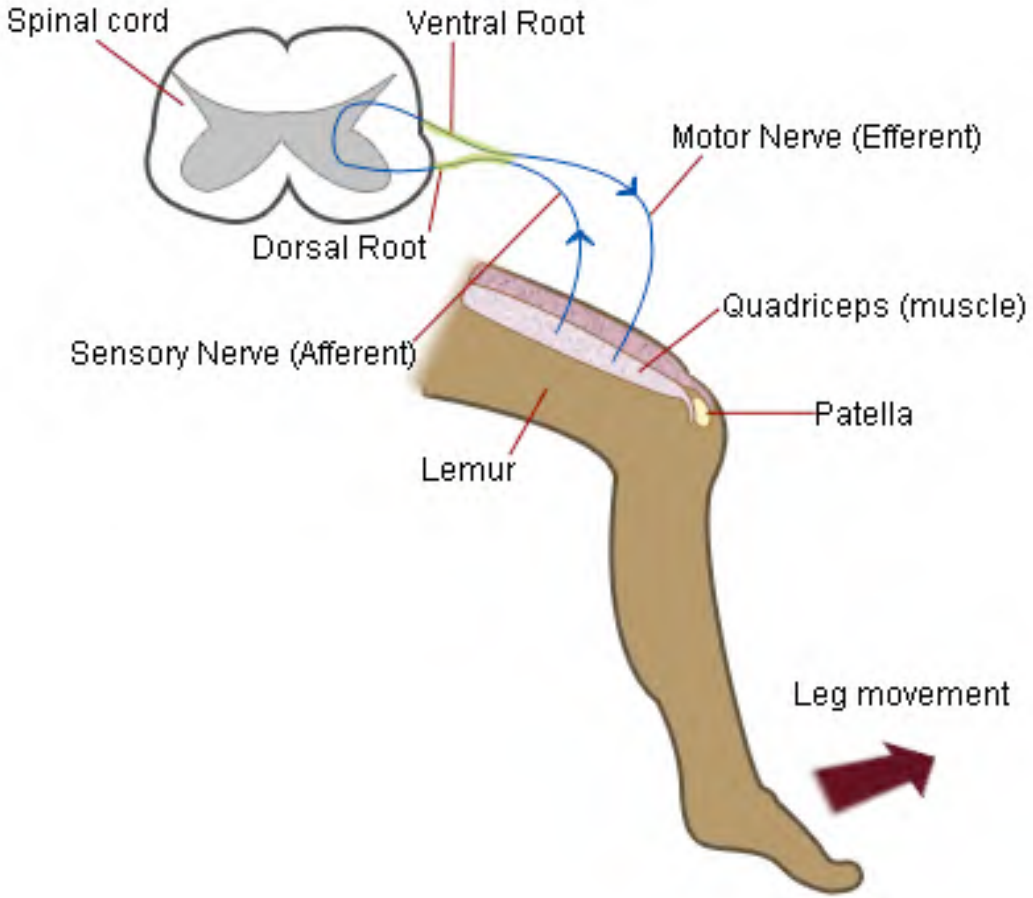
Elicited by the afferents of the Flexor Reflex

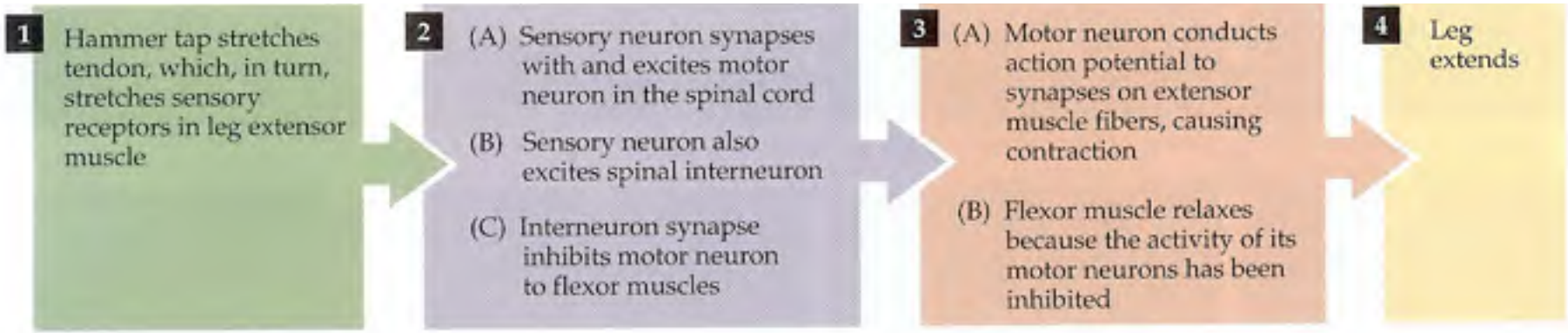
Interneurons send axons to the contralateral ventral horn

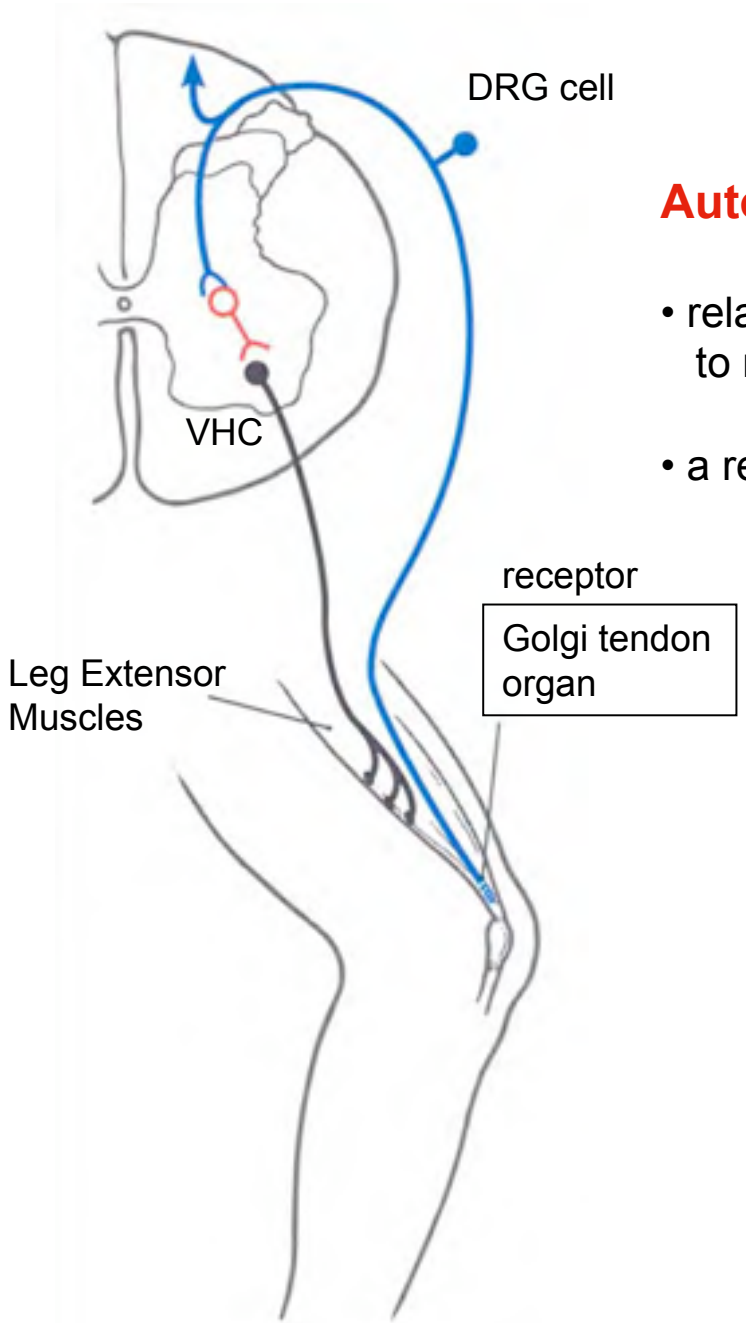
Activate:
excitatory interneurons to Ventral Horn Cells that innervate extensors

inhibitory interneurons to VHCs that innervate flexors

PD-INCL Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002







Autogenic Inhibition

- relaxation of a muscle in response to relatively high tension on the tendon
- a relatively rapid and a discrete response

PD-INCL Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002

The Muscle Spindle

Muscle spindle afferents respond to stretch on the membrane

Muscle

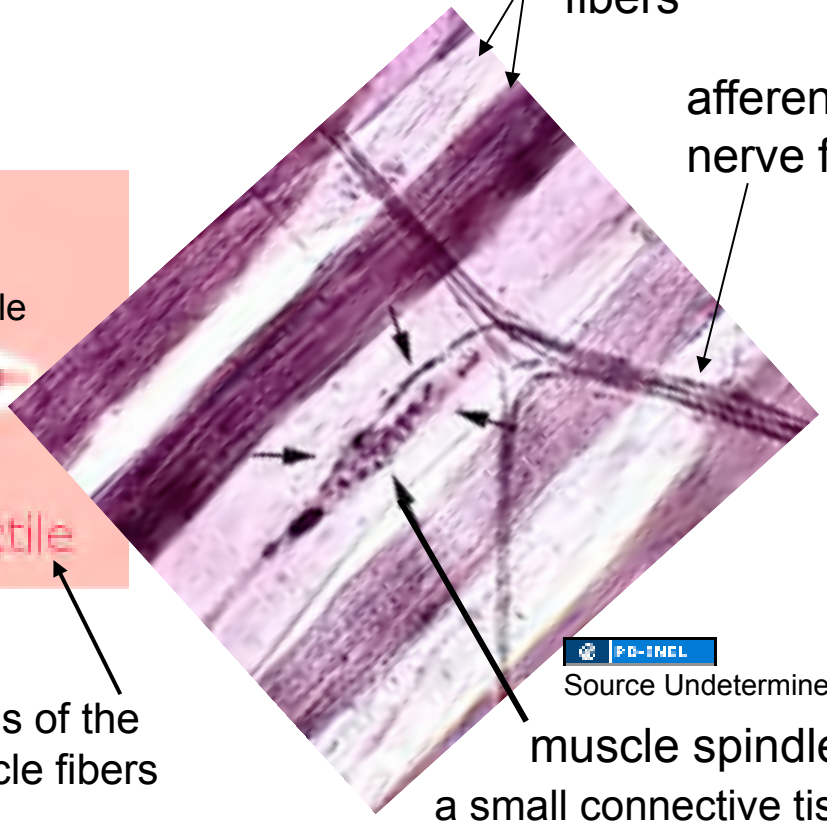
Sbmehta (Wikipedia)

Gamma motor neuron axon controls contraction of the intrafusal fiber

contractile ends of the intrafusal muscle fibers

extrafusal muscle fibers

afferent nerve fibers

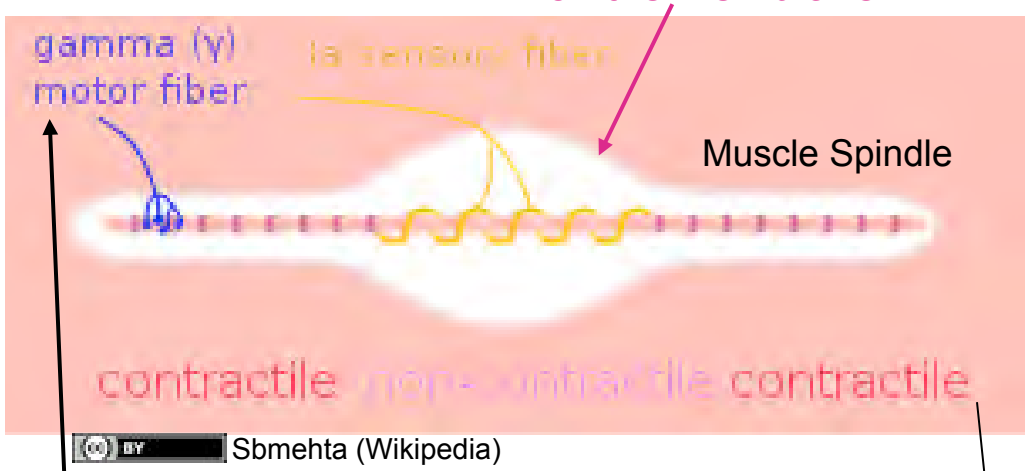


Source Undetermined

muscle spindle

a small connective tissue capsule containing "intrafusal" muscle fibers

The Brain Controls the Muscle Spindle's Responsiveness



Sbmehta (Wikipedia)

Gamma motor neuron axon controls contraction of the intrafusal fiber

contractile ends of the intrafusal muscle fibers

The muscle spindle is stretched by lengthening of the muscle.

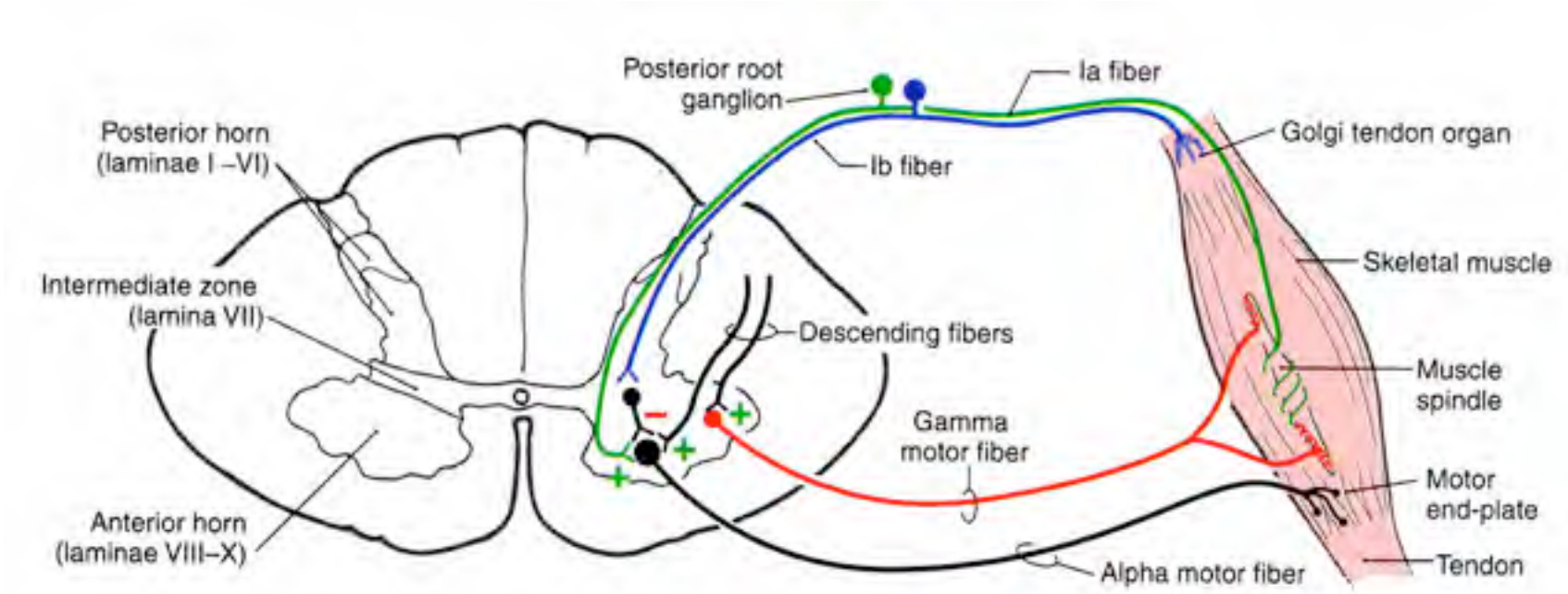
The firing of the afferent fibers in response depends upon the tension on the central part of the intrafusal fibers.

Contraction of the intrafusal fibers (via gamma motor neuron firing) sets the tension on the central region of the intrafusal fiber.

This control is governed by input to the gamma motor neurons from the brain.

Alpha Motor Neurons Integrate Input from the Brain
with Input from the Muscles, Tendons and Joints

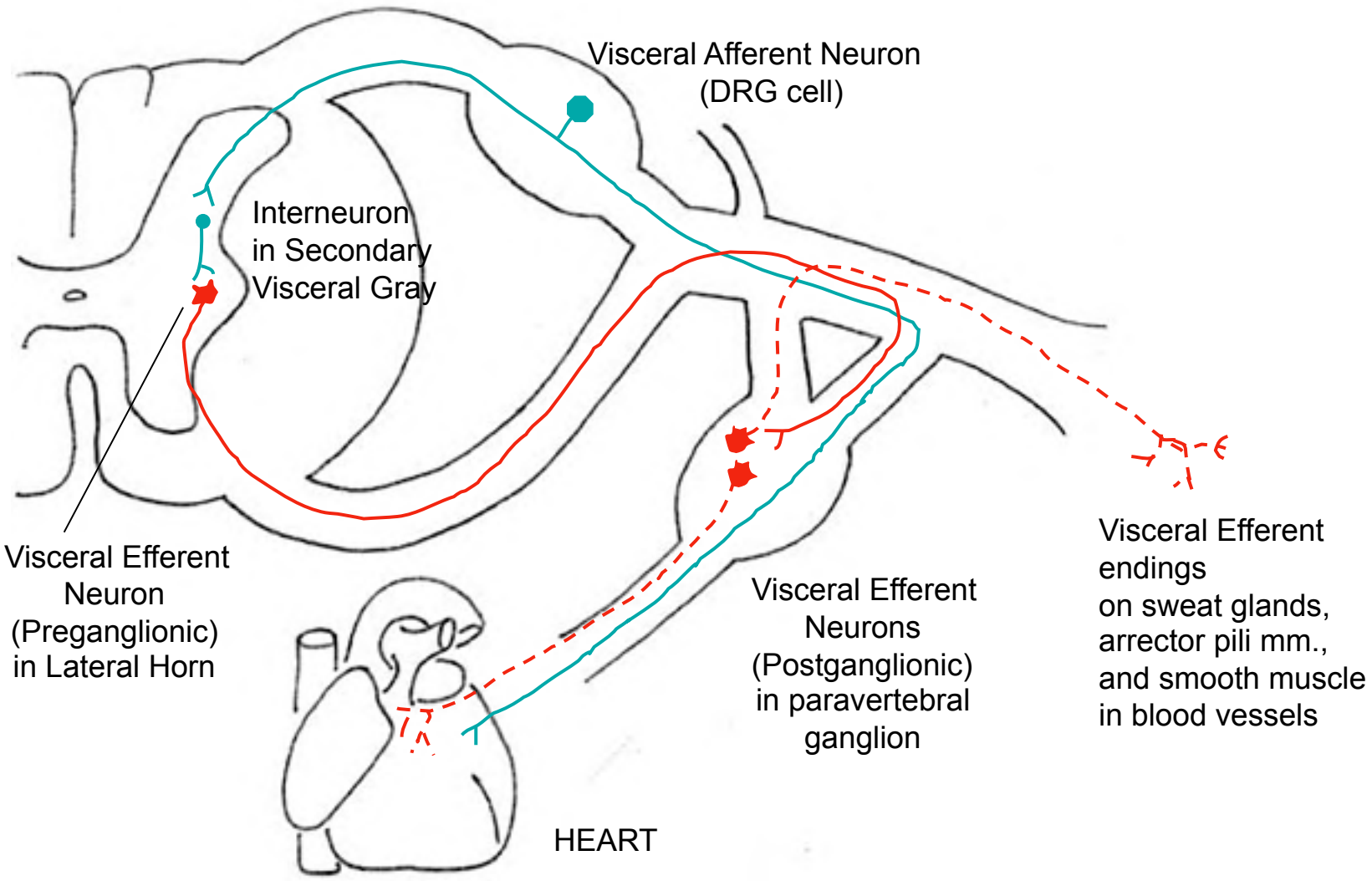
Gamma Motor Neurons are controlled by the Brain



PD-ANEL Source Undetermined

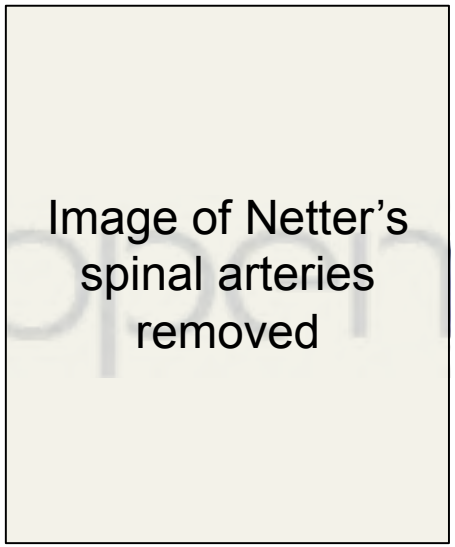
"Alpha-gamma coactivation" from the brain ("descending fibers") keeps the muscle spindle sensitive to changes in length and the rate of change.

Visceral Spinal Reflex Arc



Blood Supply to the Spinal Cord

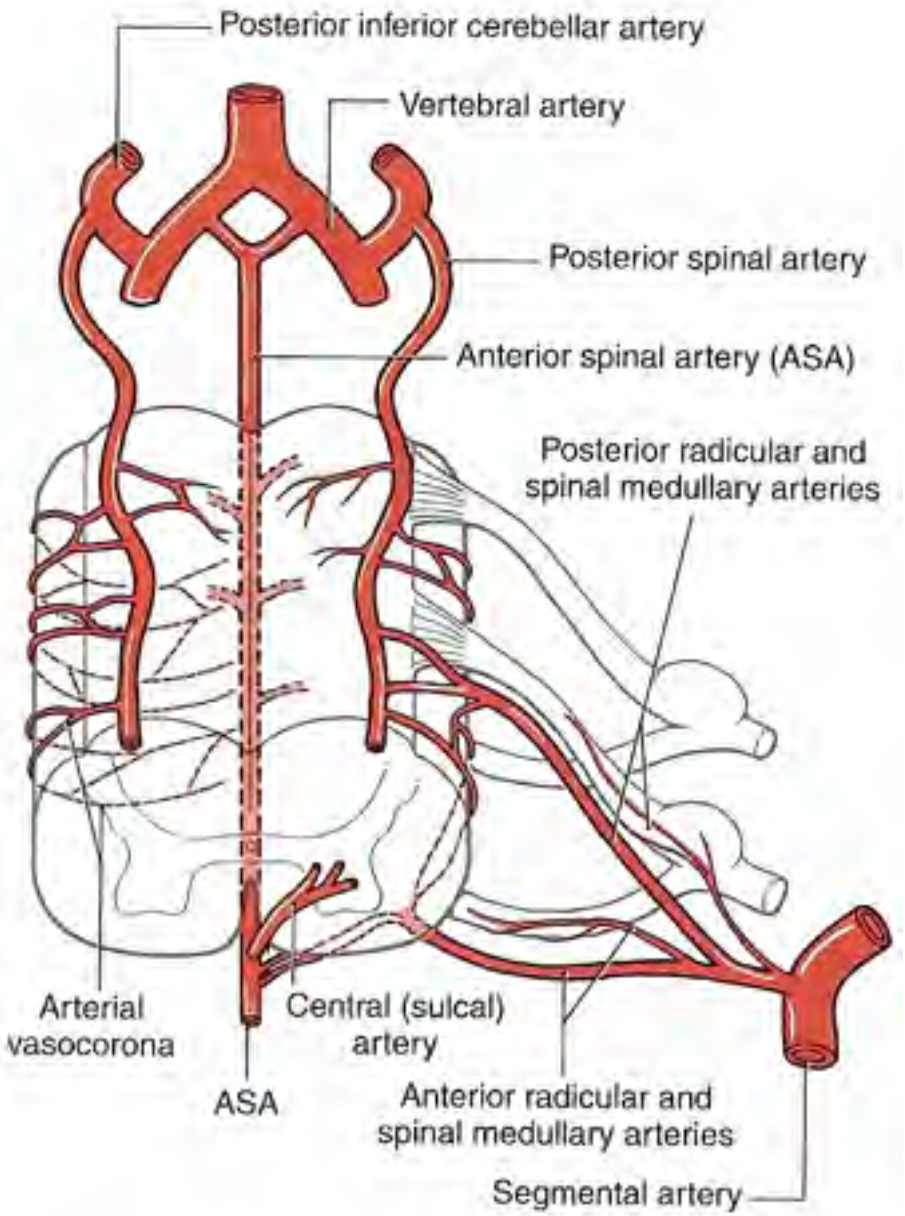
Ventral Spinal
and
Ventral Radicular
Arteries

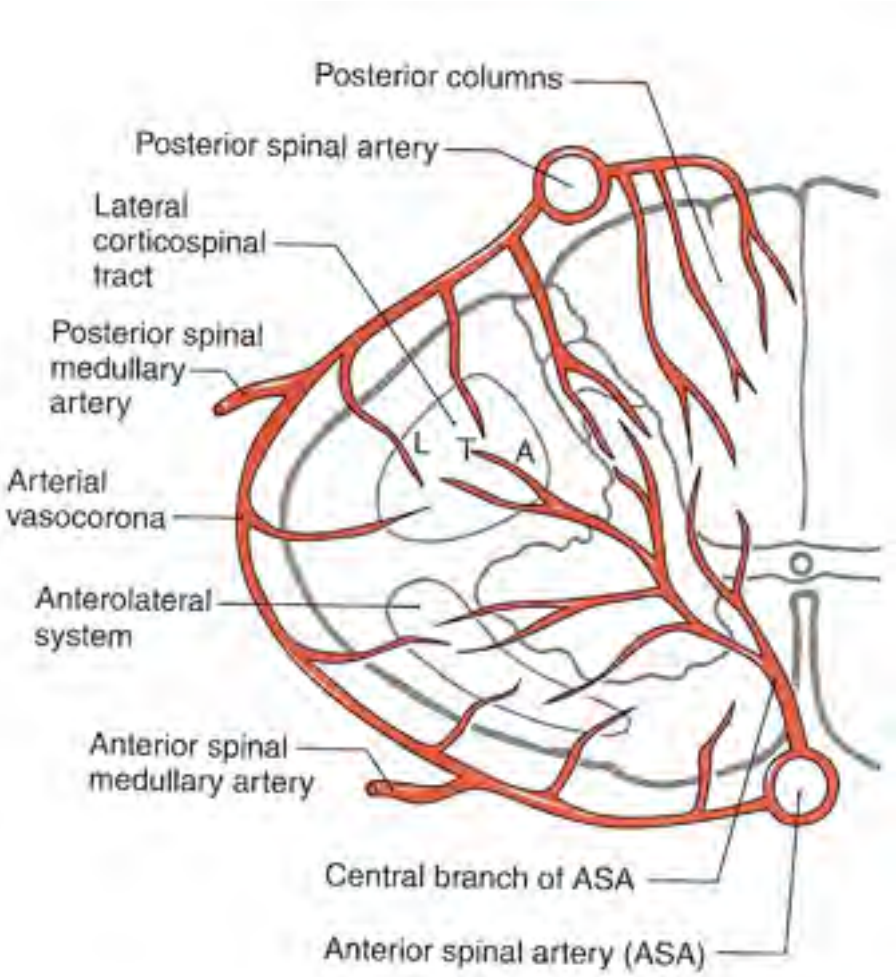


Dorsal Spinal
and
Dorsal Radicular
Arteries

Ventral and Dorsal spinal branches off the vertebral arteries descend the spinal cord and are supplemented by spinal radicular branches of the segmental arteries.

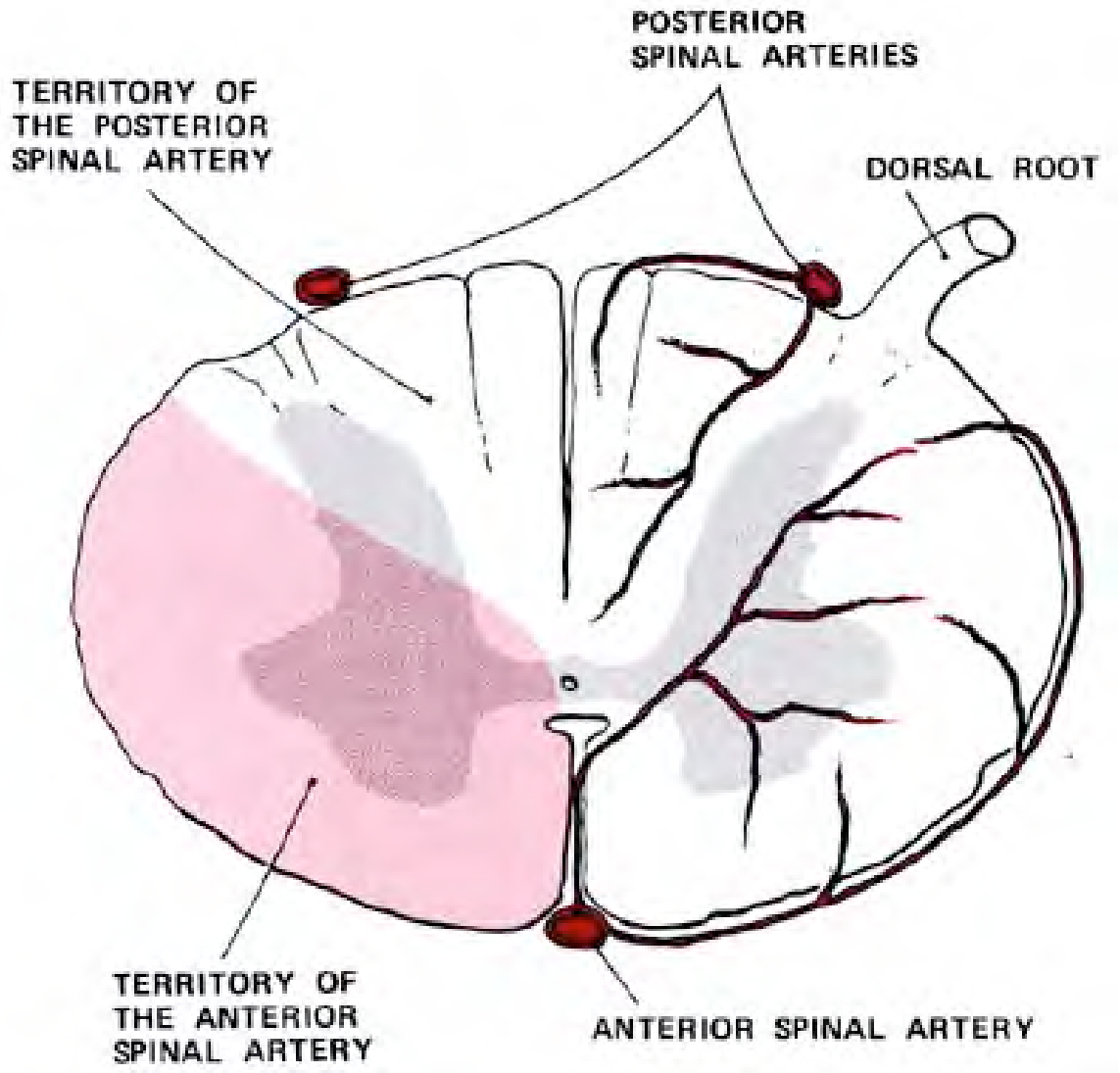
BLOOD SUPPLY OF SPINAL CORD





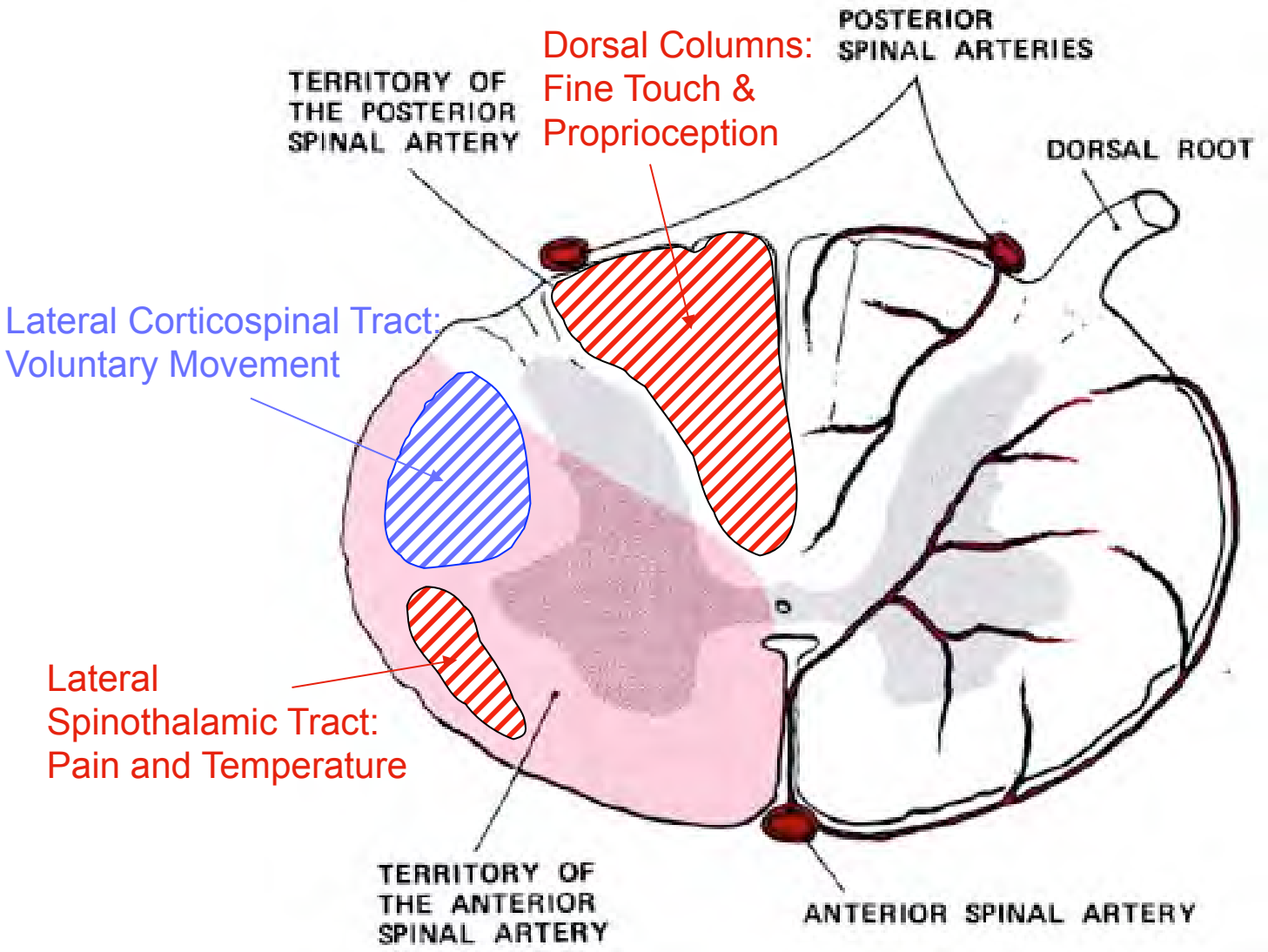
PD-INCL Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 8-25

Blood Supply to the Spinal Cord



 Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed, Fig. 27

Blood Supply to the Spinal Cord



 Modified From Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed, Fig. 6-1

Additional Source Information

for more information see: http://open.umich.edu/wiki/CitationPolicy

Slide 3: UCSF, School of Medicine http://missinglink.ucsf.edu/lm/IDS_101_histo_resource/cell_structure.htm
Slide 8: Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002)
Slide 9: G.M. Shepard, Neurobiology, 3rd Edition Fig. 9.3
Slide 10: Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 9-1
Slide 11: Gray's Anatomy; Source Undetermined
Slide 12: Source Undetermined, See also Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed
Slide 13: Gray's Anatomy
Slide 15: Gray's Anatomy
Slide 16: UCSF School of Medicine, http://missinglink.ucsf.edu/lm/IDS_101_histo_resource/cell_structure.htm; University of Medicine and Dentistry of New Jersey
Slide 17: Source Undetermined
Slide 18: Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 18-4
Slide 19: Source Undetermined
Slide 20: Source Undetermined; Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed, Fig. 6-1
Slide 21: Source Undetermined
Slide 23: UCSF, School of Medicine, http://missinglink.ucsf.edu/lm/IDS_101_histo_resource/cell_structure.htm
Slide 24: Source Undetermined
Slide 26: Source Undetermined
Slide 27: Source Undetermined
Slide 28: Source Undetermined
Slide 29: Elsevier. Haines, *Fundamental Neuroscience for Basic and Clinical Applications 3e*.
Slide 30: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 31: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 32: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 33: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 37: Elsevier. Haines, *Fundamental Neuroscience for Basic and Clinical Applications 3e*.
Slide 38: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 41: Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 9-6
Slide 42: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 43: Haines, *Fundamental Neuroscience*, 2nd ed.,Churchill-Livingstone, 2002
Slide 44: Source Undetermined; Christina T3, Wikipedia, CC:BY:SA, http://creativecommons.org/licenses/by-sa/3.0/
Slide 45: Haines, *Fundamental Neuroscience*, 2nd ed., Churchill-Livingstone, 2002)

Slide 46: CC:BY: Sbmehta (Wikipedia) http://creativecommons.org/licenses/by/2.5/; Source Undetermined
Slide 47: CC:BY: Sbmehta (Wikipedia) http://creativecommons.org/licenses/by/2.5/
Slide 48: Source Undetermined
Slide 49: Source Undetermined
Slide 51: Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Fig. 8-25
Slide 52: Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed, Fig. 6-1
Slide 53: Modified From Manter and Gatz's Essentials of Clinical Neuroanatomy and Neurophysiology, 8th ed, Fig. 6-1