

Three major types of body movement,
prior to refinements made possible by neocortex

1) Locomotion

- Avoidance/escape or approach
- Explore/forage/seek: basic for all drives

2) **Orienting of head and body**: important for
accomplishing the goals of the above

3) Grasping

- with mouth
- with limbs (reaching and the control of distal muscles); important for consummation

Orienting of head and body:

Important for accomplishing the goals of approach and escape/avoidance

- Somatosensory, visual, auditory triggers
 - Early controls: simple reflexive orienting for approach and escape
 - Visual: Early control of turning ^{and escape} movements **may** have been *via* retinal inputs to subthalamus and from there to brainstem
 - Evolution of topographic maps of the world around the head in the midbrain tectal correlation center
 - Visual, auditory, somatosensory maps are in register
 - Control of precise turning toward objects
- There are distinct tectal outputs for escape movements and for turning towards a novel or desired object *as described earlier*

Early in evolution

More on Tectum & Pretectum

to be discussed in chapters on visual system

- Pretectum:
 - Large in non-mammals
 - Role in **protective** responses: pupil constriction, escape from rapidly approaching objects, avoidance of barriers during locomotion
 - Connects to the tectum just caudal to it. Roles in orienting & locomotion have been little studied.
 - Its nucleus of the Optic Tract responds to whole-field movements in the horizontal plane, signaling changes in head direction to forebrain.
- Tectum:
 - The “visual grasp reflex” and the map of the retina
 - Underlying auditory, somatosensory maps that match the visual map
 - Tectal stimulation and lesion data: the **dual outputs**
 - **Escape**: uncrossed descending pathway
 - **Orienting**: crossed “tectospinal tract”

discussed later

Three major types of body movement, prior to refinements made possible by neocortex

1) Approach and Avoidance

- Locomotor control, directional
- Explore/forage/seek: basic for all drives

2) Orienting of head and body: important for accomplishing the goals of the above

3) Grasping: with mouth; with limbs

- Important for consummation *e.g., of foraging for food*
- Movements of reaching; control of distal muscles for grasping *with hands*

Questions on chapter 14

- 4) Grasping with the hands in large primates is largely controlled by neocortex. What brainstem structure appeared earlier in evolution and controlled this kind of movement?

nucl. ruber (red nucleus)

- 5) What other kind of grasping is common in animals, including mammals? Describe a pathway from the midbrain that might be involved (a speculation that could guide anatomical experiments). What type of non-midbrain pathway is likely to be involved?

*oral grasping
tectum to trigeminal motor nucleus*

Grasping: with mouth; with limbs

(reaching and the control of distal muscles)

- After approach to an object: 2 types of grasping with midbrain control
 - Tectum-controlled orienting followed by oral grasping
 - Red nucleus and limb control; grasping with hands
 - Inputs to red nuc. from striatum & subthalamus and from cerebellum
 - Later in evolution, inputs from somatosensory and motor neocortex
- These are midbrain levels of control: part of the background of reflexes and fixed action patterns that remain even after neocortical expansion.
 - Forebrain controls evolved and became dominant in many mammals, especially in primates [a later topic]

Red nucleus in phylogeny

- Absent in hagfishes and lampreys (primitive, jawless vertebrates)
- Present in frogs,
 - with input from striatum and cerebellum.
 - Striatal inputs tend to end mainly in pre-rubral field of the ventral thalamus
- Prominent in reptiles, birds and mammals

From Butler & Hodos (1996) p 217-218. "Hagfishes are similar to lampreys in that they do not have a red nucleus. Cartilaginous fishes with elaborated brains have a relatively large red nucleus.... A rubrospinal tract is absent in pythons, but this absence cannot be correlated with the absence of limbs as the tract is present in colubrid snakes." **Hence, the red nucleus may be involved in control of fins.**

Questions on chapter 14

12) What are the two portions of the red nucleus, and how are they different in their major outputs? How are they different in large primates on the one hand and cats or rodents on the other? *next slide shows correlations*

Also, question 11: Describe major inputs to the red nucleus of the midbrain. *slide 33*

Dentate nucleus & red nucleus, comparative anatomy

(Altman & Bayer; from Padel et al, 1981)

mc=magnocellular
pc=parvocellular

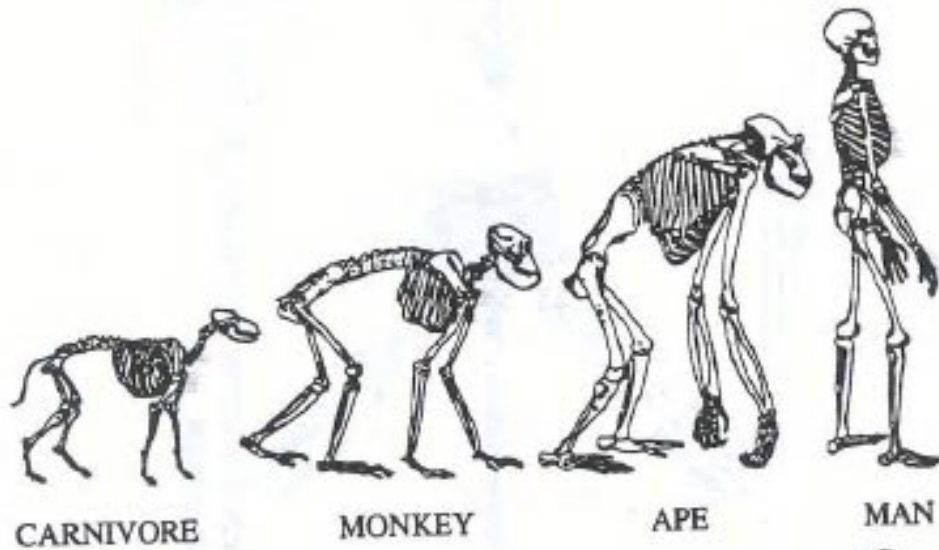


Figure 5-6. Evolutionary change in the cell composition of the red nucleus in relation to a change in the morphology of the cerebellar dentate nucleus. The magnocellular division (the source of descending fibers of the rubrospinal tract) decreases from carnivores through the primate order. Modified after Padel et al. (1981).

Rubrospinal tract comes from mc

Projections to thalamus (VL) and to inferior olive (pre-cerebellar) come mainly from pc

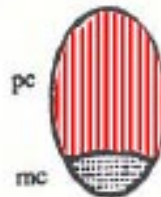
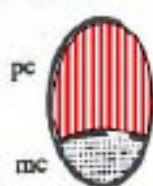
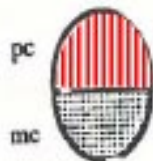
VL projects to motor cortex.

Dentate nuc. of cerebellum
DN



Abbreviations:
DN dentate nucleus
mc magnocellular
pc parvocellular
RN red nucleus

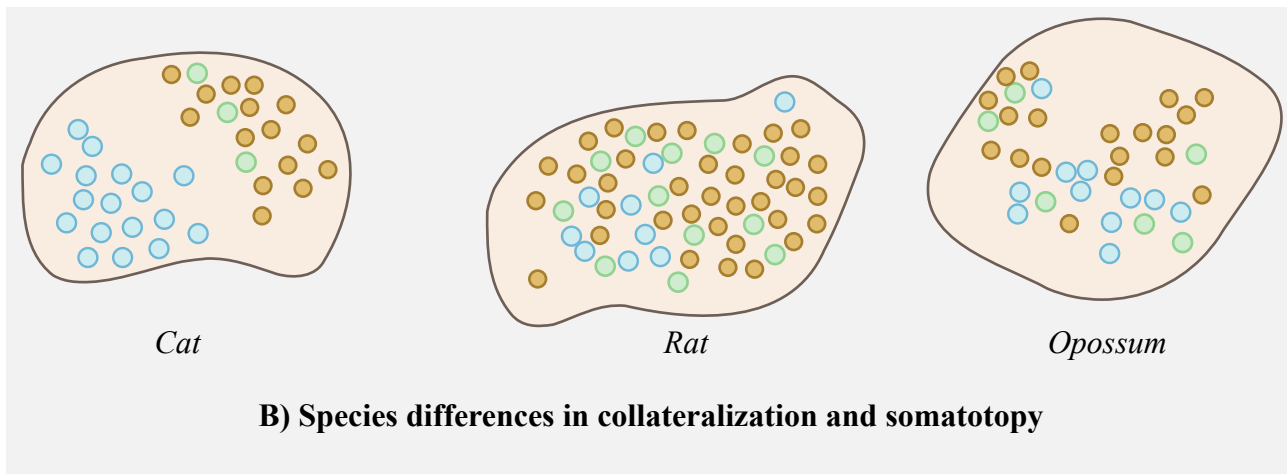
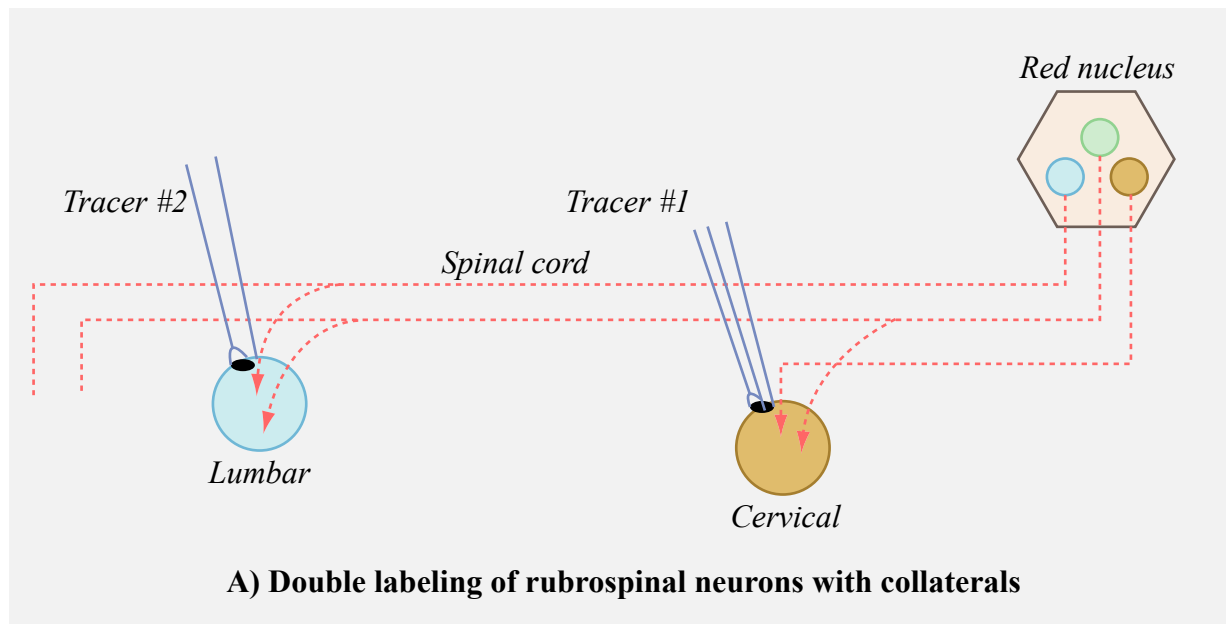
Red nuc.



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

Evolution of mammalian rubrospinal projections:
parcellation increases topographic organization

- *Results of a retrograde tracing study of projections in opossum, rat and cat*



Very incomplete separation of two limbs

Very good separation of forelimb and hindlimb control

Image by MIT OpenCourseWare.

A structural approach to understanding motor control: Begin with the motor neurons

- [REVIEW] Three types of effector contact in three major motor systems
 - 1) Somatic motor neurons: synaptic control
 - 2) Autonomic: pre- and postganglionic motor neurons; paracrine control
 - 3) Neuroendocrine: hormonal control
- Somatic motor neuronal pools: locations

[REVIEW]

Arrangement of motor neurons in the three motor systems

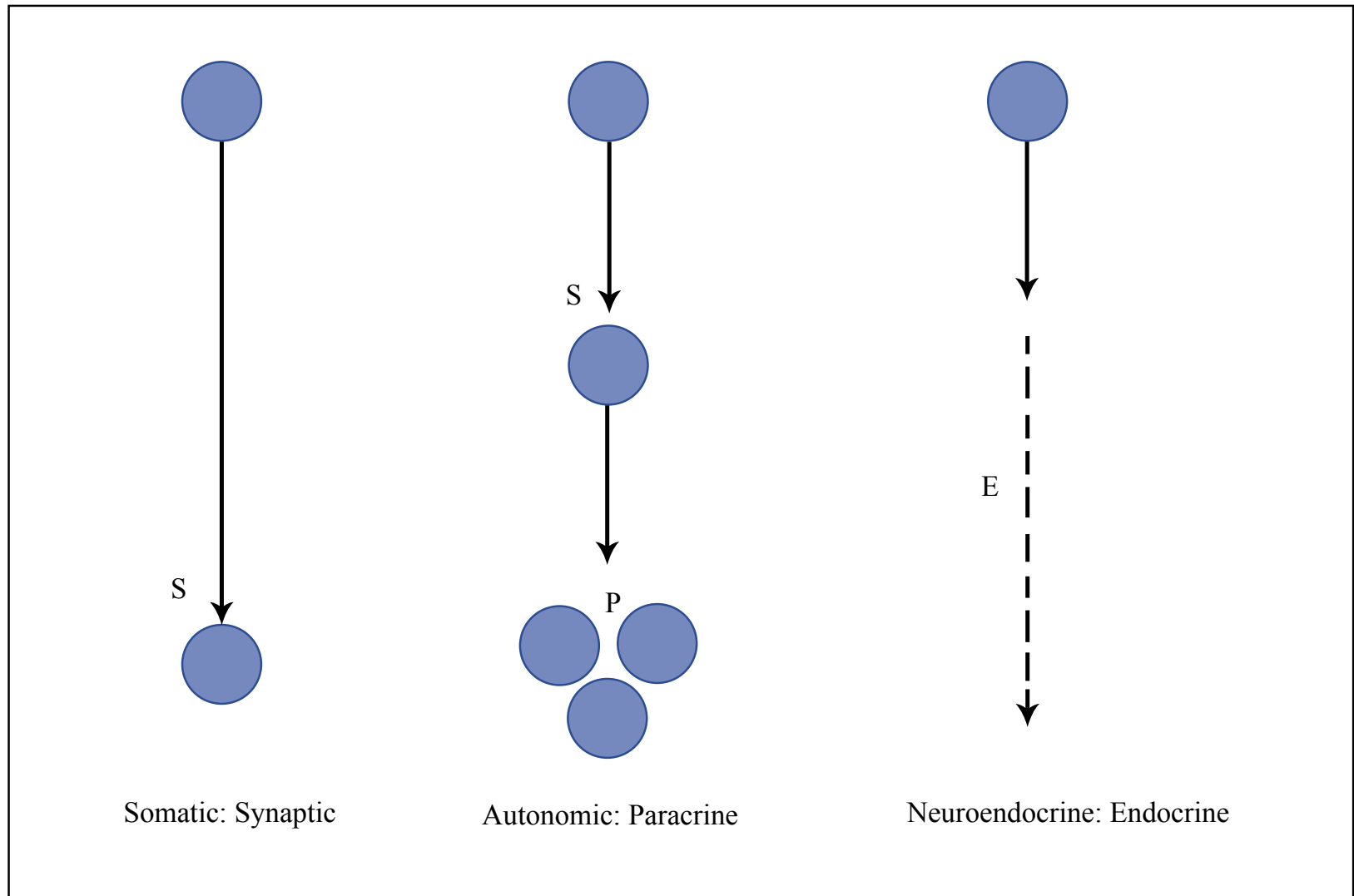


Image by MIT OpenCourseWare.

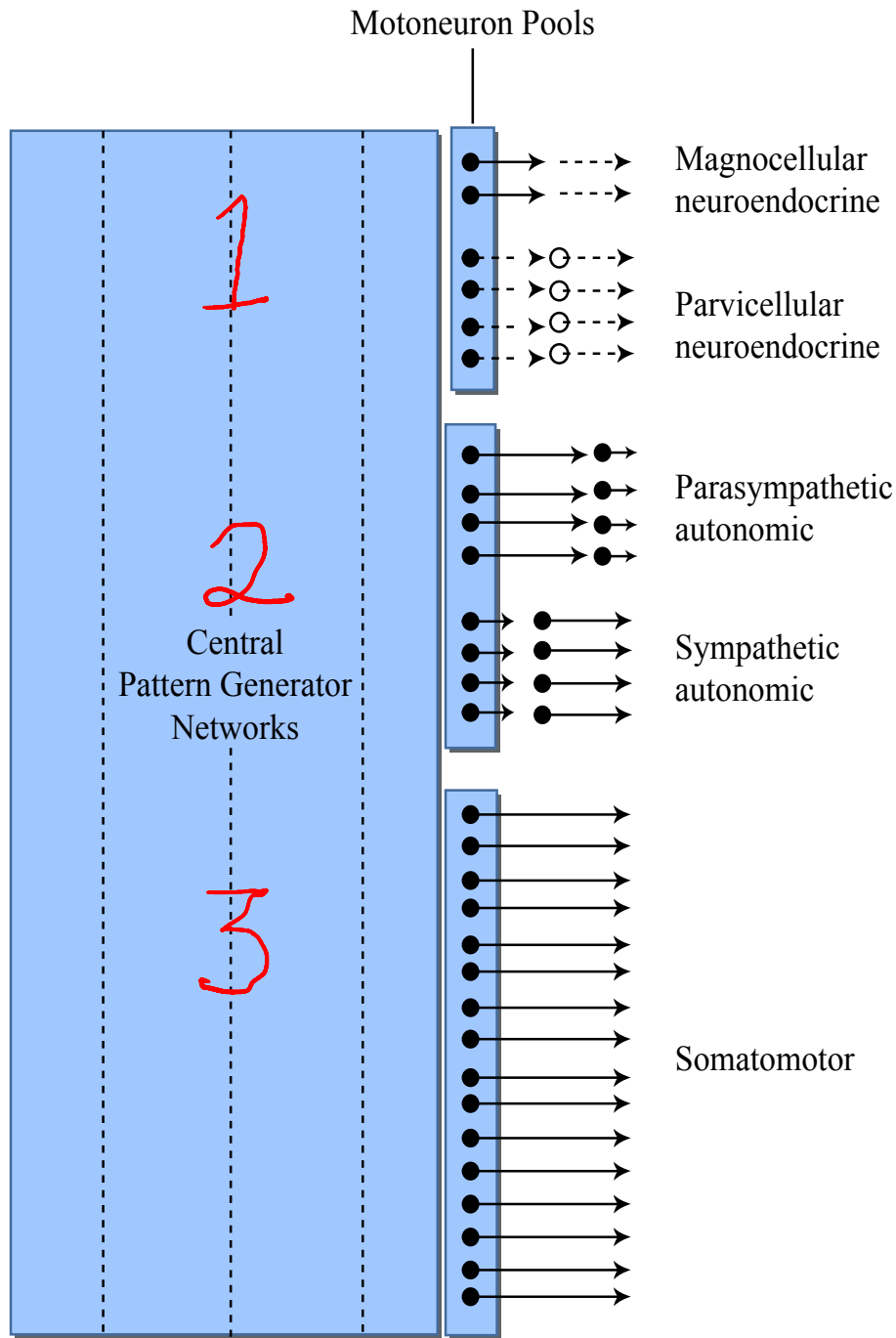


Image by MIT OpenCourseWare.

The three motor systems

Swanson asks, where are the central pattern generator networks that coordinate the three systems?

Although Swanson's question remains unanswered, it may be that there is not very much integration of these three systems that requires pattern generation.

Questions, chapter 14

13) Where are the most rostral somatic motor neurons located?

midbrain, 3rd nerve nucleus,
oculomotor nerve nucleus

The spatial arrangements of motor neurons: illustrated for monkey

- Spinal cord at one of the enlargements
- Radial projections of interneurons
- Descending connections in the cord

- (see figures)

CONTINUED NEXT CLASS

A sketch of the central nervous system and its origins

G. E. Schneider 2014

Part 6: A brief study of motor systems

MIT 9.14 Class 16

Motor systems 2:

Descending pathways and evolution

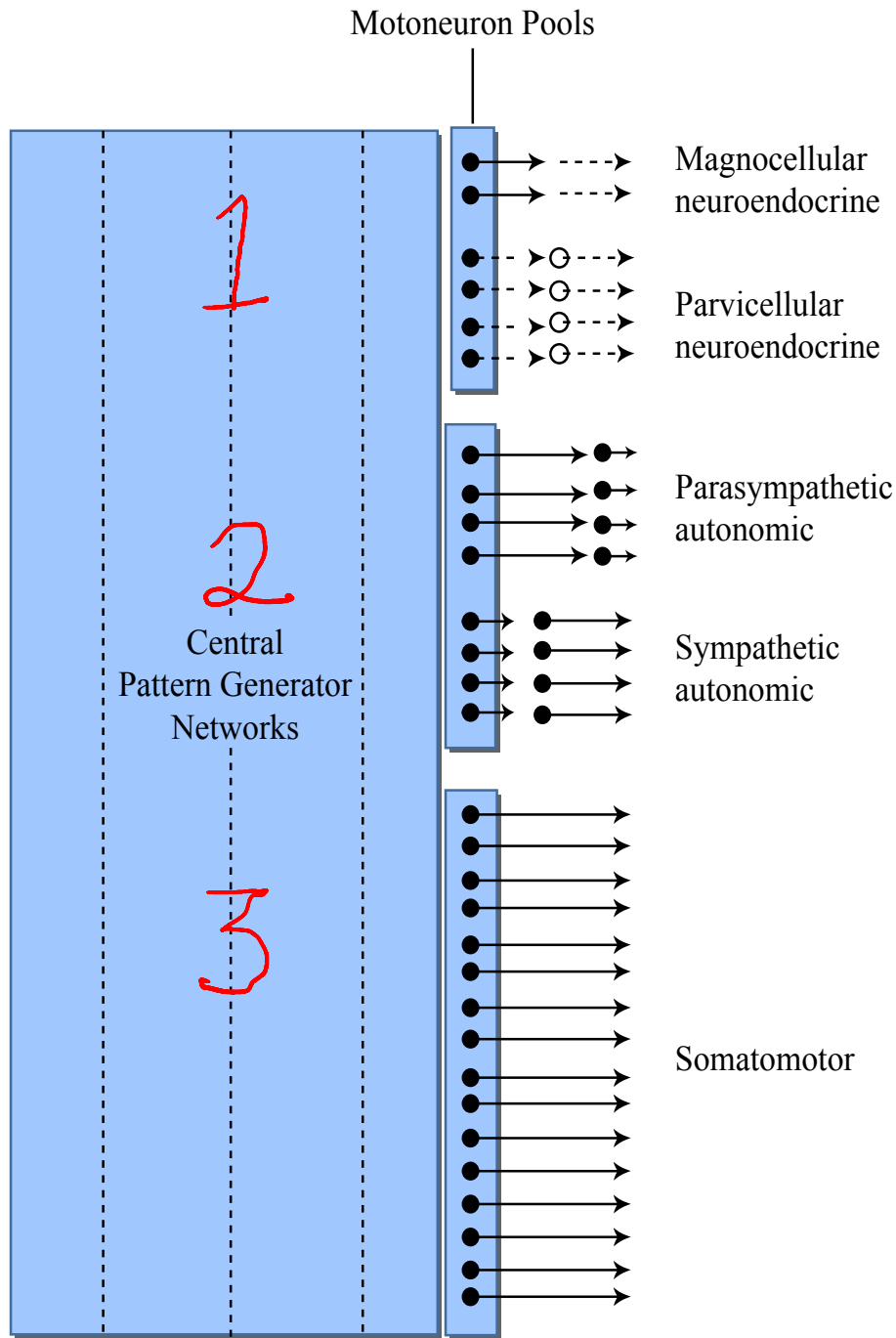


Image by MIT OpenCourseWare.

The three motor systems

Swanson asks, where are the central pattern generator networks that coordinate the three systems?

Although Swanson's question remains unanswered, it may be that there is not very much integration of these three systems that requires pattern generation.

Distribution of somatic motor neurons

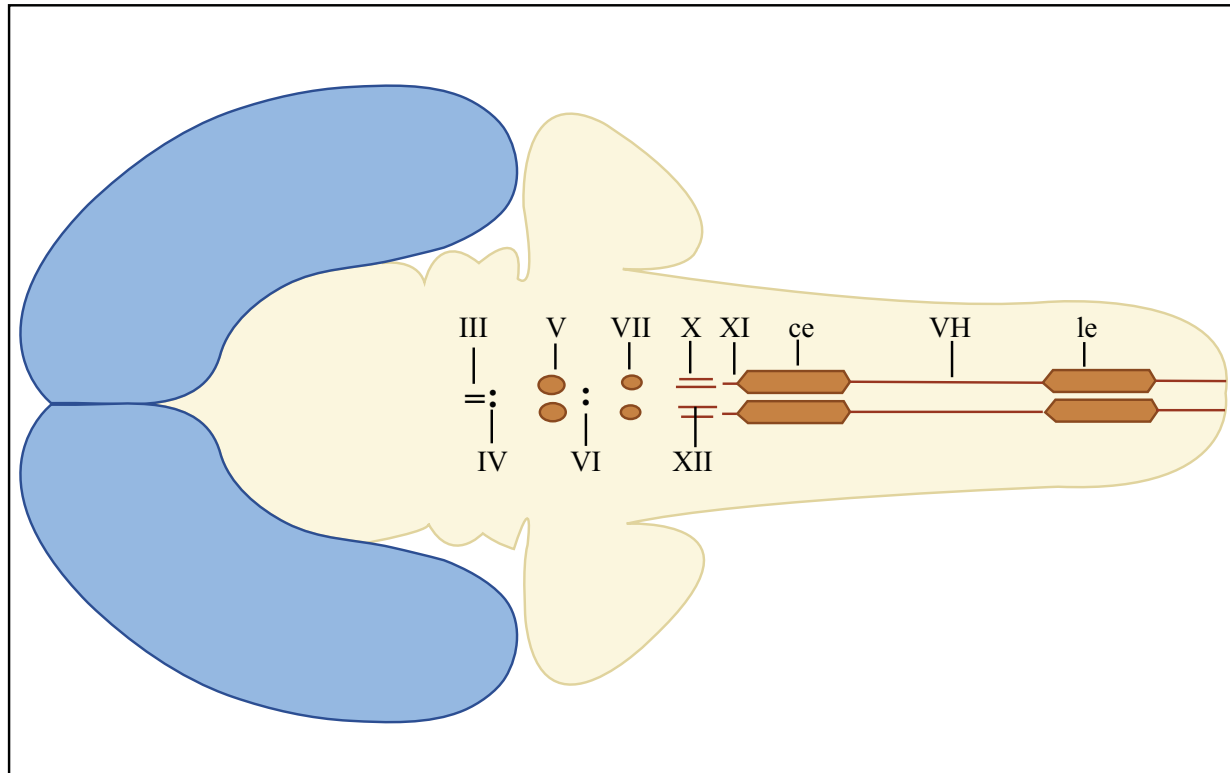


Image by MIT OpenCourseWare.

Where are these neurons located in frontal sections of CNS?

Distribution of somatomotor neuron pools illustrated on a flatmap of rat CNS. Key: **ce**, cervical enlargement; **lc**, lumbar enlargement; **VH**, ventral horn; **III**, oculomotor nuc.; **IV**, trochlear nuc.; **V**, motor nuc. of trigeminal nerve; **VI**, abducens nuc.; **VII**, facial nuc.; **X**, nuc. Ambiguus (of vagus n.); **XI**, nuc of spinal accessory n.; **XII**, hypoglossal nuc.

Questions, chapter 15

- 1) What is the basic spatial layout of motor neurons at one of the spinal cord enlargements?

The spatial arrangements of motor neurons and their connections in the spinal cord

Three topics

- Spinal cord at one of the enlargements
 - Illustrated for human and for monkey
- Radial projections of interneurons
- Descending connections in the cord

Topographic distribution of somatic motor neurons, human spinal cord

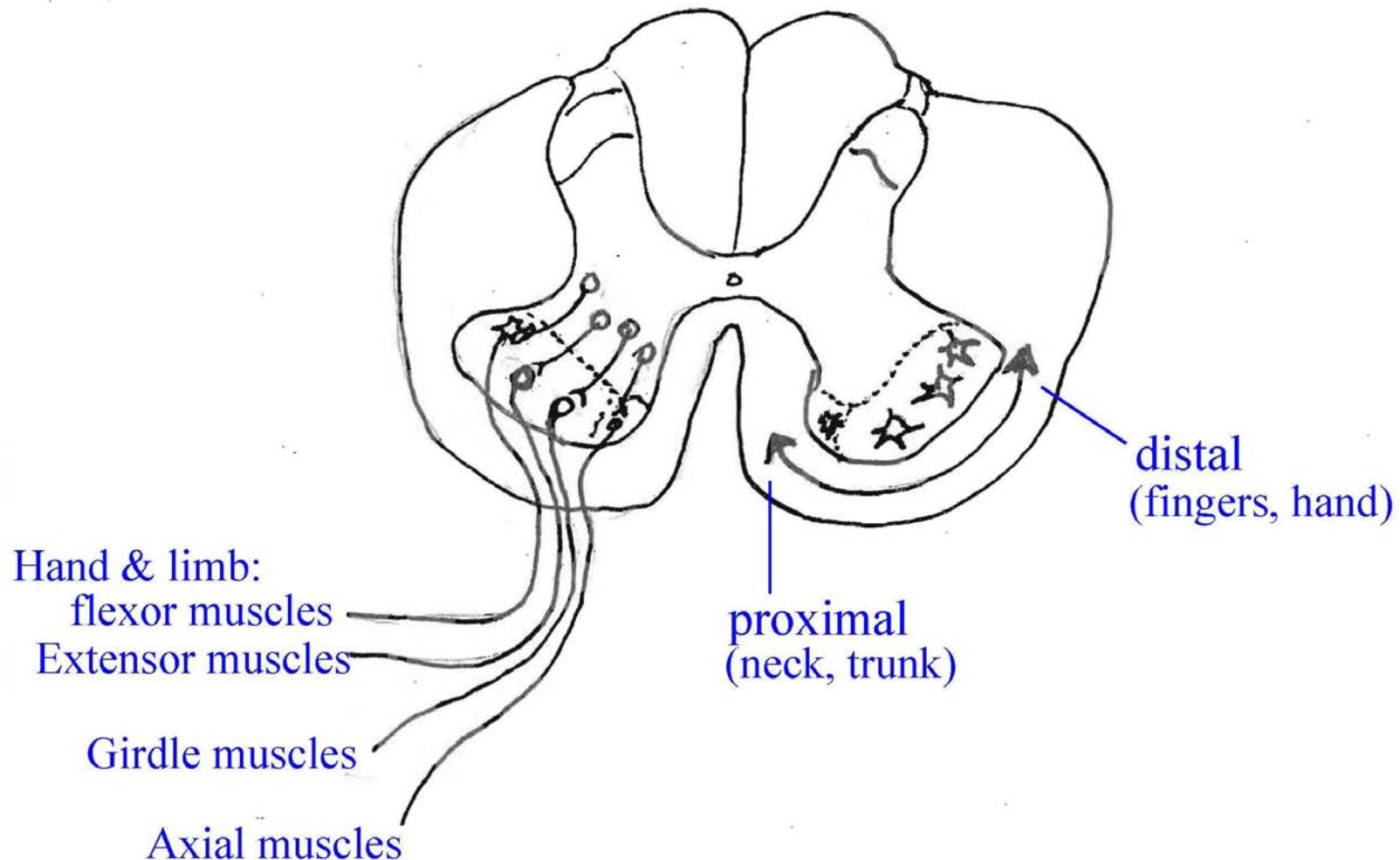
The cartoon is drawn to show that axial muscles are activated by ventromedial motor neurons,

Also, there is a separation of motor neurons innervating flexor and extensor muscles.

Figure removed due to copyright restrictions.

From Swanson (2003) fig 6.3, p. 105

Topographic distribution of somatic motor neurons and the interneurons that connect to them, rhesus monkey spinal cord



Based on Lawrence & Kuypers, 1968

Terminal distribution pattern of descending cortical and subcortical pathways: spinal cord, rhesus monkey (*Lawrence & Kuypers, 1968*)

Figure removed due to copyright restrictions.

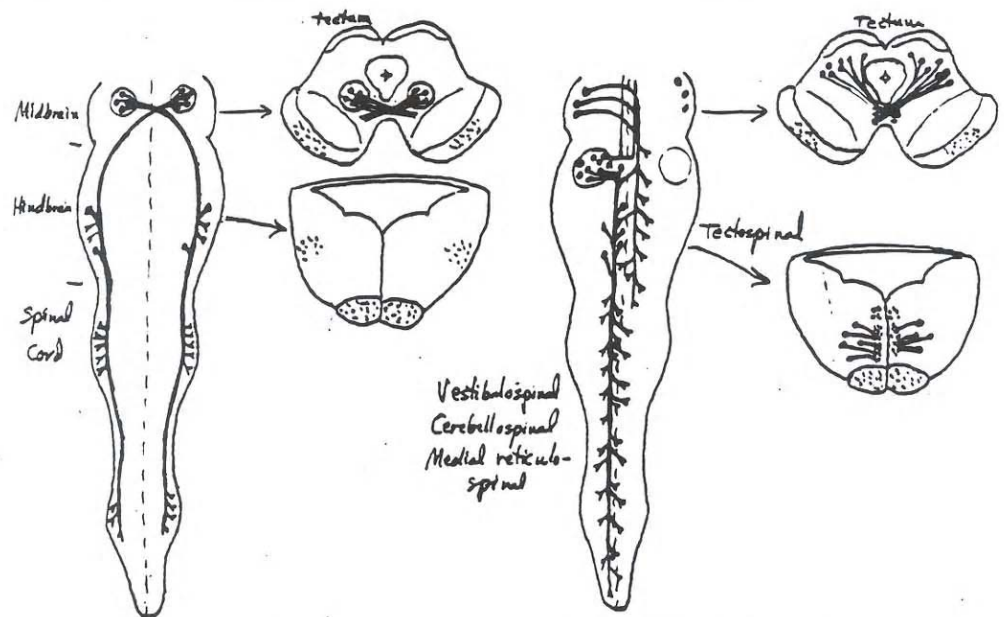
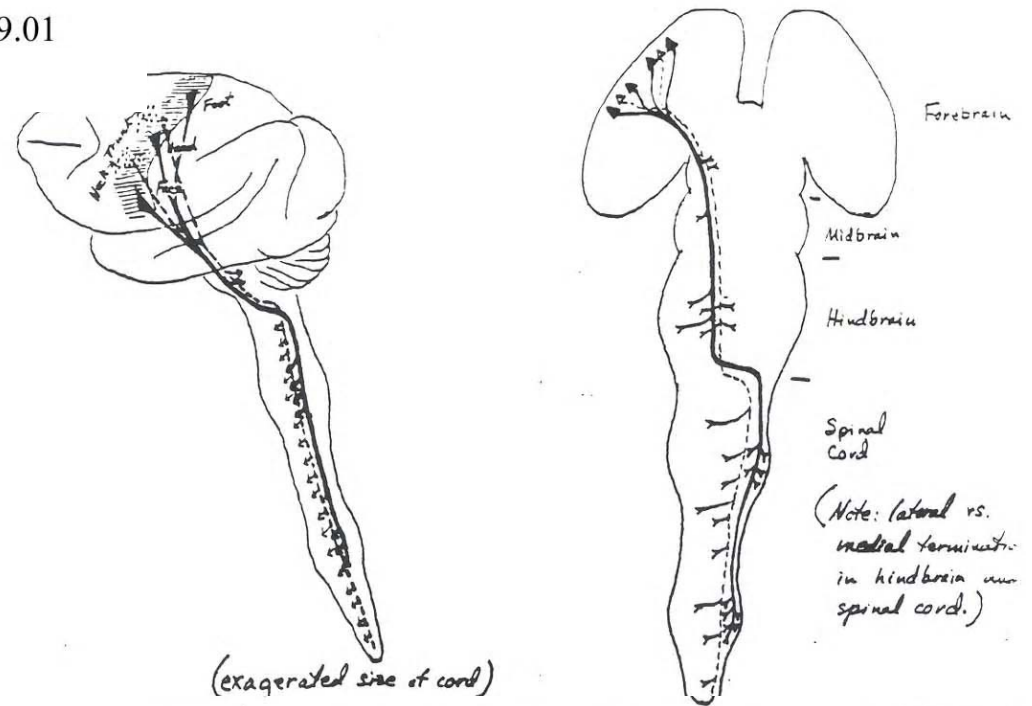
Please see: Lawrence, Donald G., and Henricus GJM Kuypers. "The Functional Organization of the Motor System in the Monkey I. The Effects of Bilateral Pyramidal Lesions." *Brain* 91, no. 1 (1968): 1-14.

9.01

Three Descending Motor Pathways:

Distinguishing the course of axons influencing axial and distal muscle control

[Enlarged on next slides]

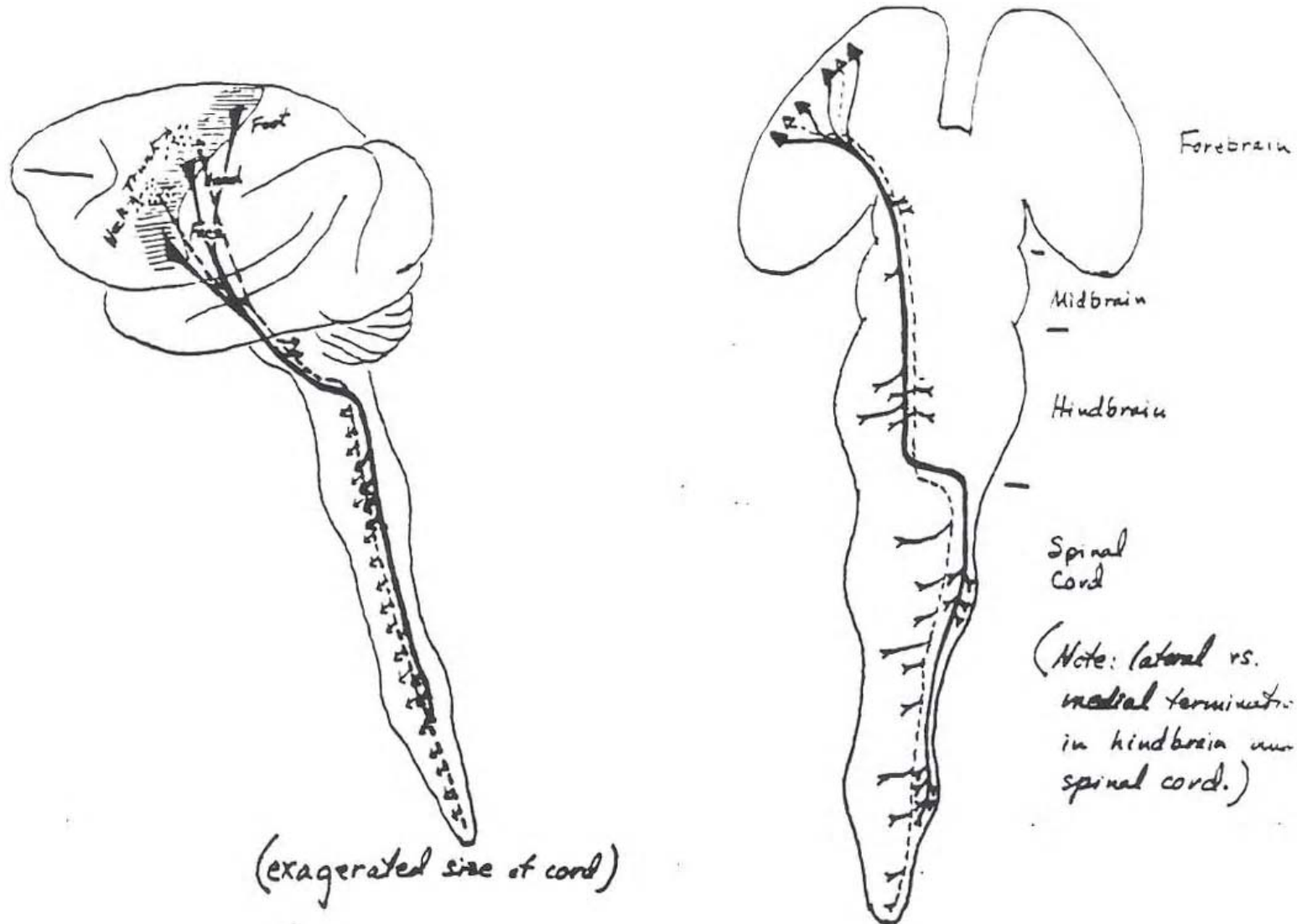


Lateral brainstem pathways

Ventromedial brainstem pathways

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

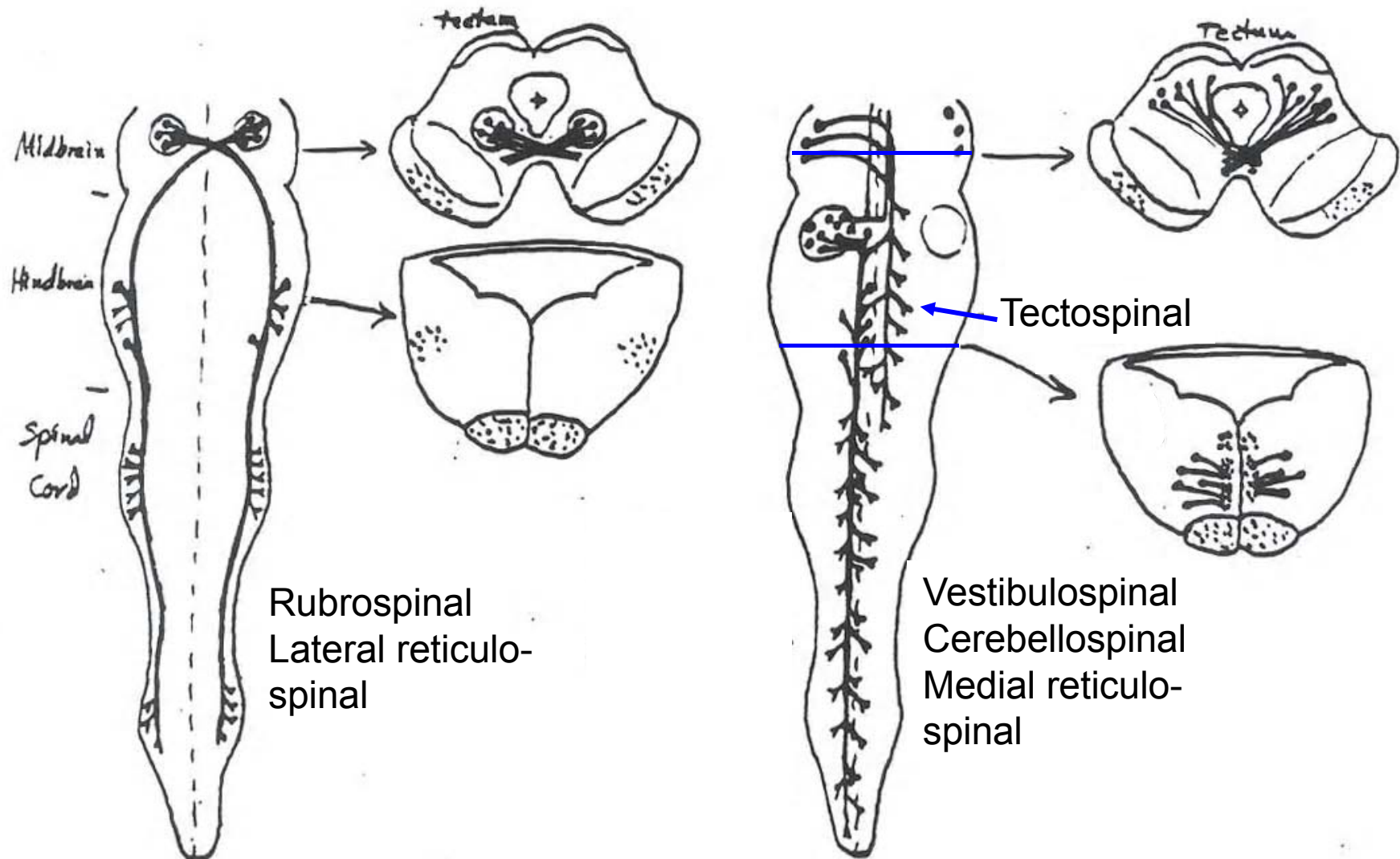
Distinguishing the axons influencing axial vs distal muscles: Corticospinal pathway



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

See the figure in the textbook drawn with different colors for the two groups of axons.

Distinguishing the axons influencing axial vs distal muscles: Lateral and ventromedial brainstem pathways



Lateral brainstem pathways

Ventromedial brainstem pathways

Courtesy of MIT Press. Used with permission.

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

Questions, chapter 15

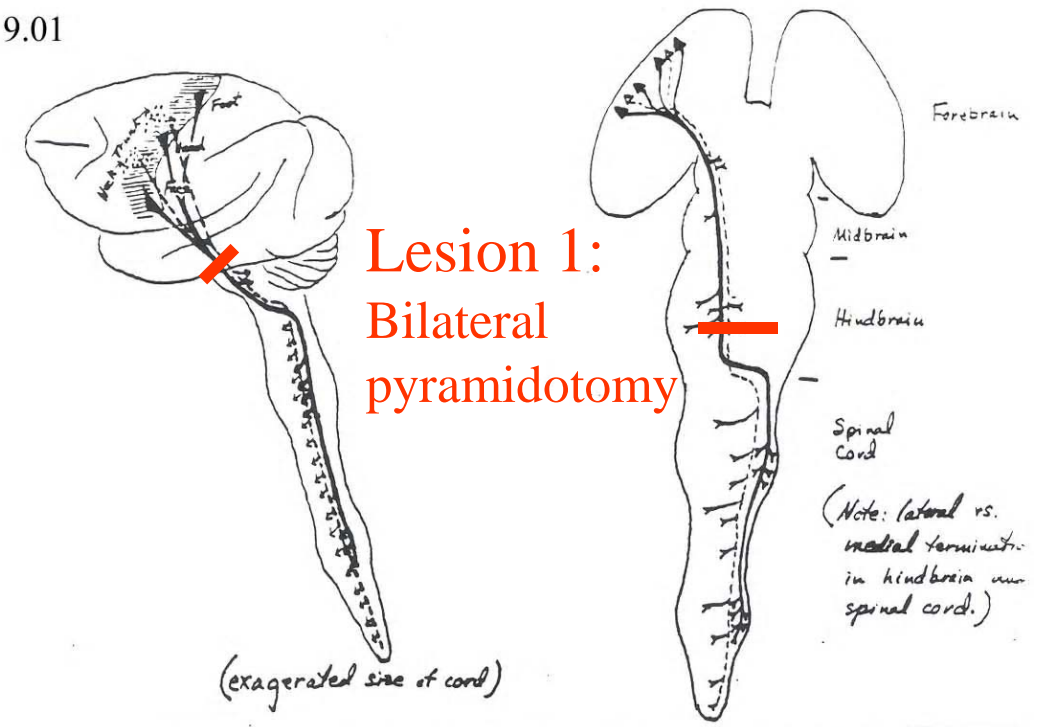
- 2) Describe the three lesions in the Lawrence and Kuypers study of the descending motor system pathways.
- 3) Describe functions of the three major pathways or groups of pathways that were separately destroyed in the study.
- 4) Why would diaschisis effects of lesions of one of the descending pathways in the study be greater in humans than in the monkeys? What are major manifestations of such effects?

Effects of lesions:

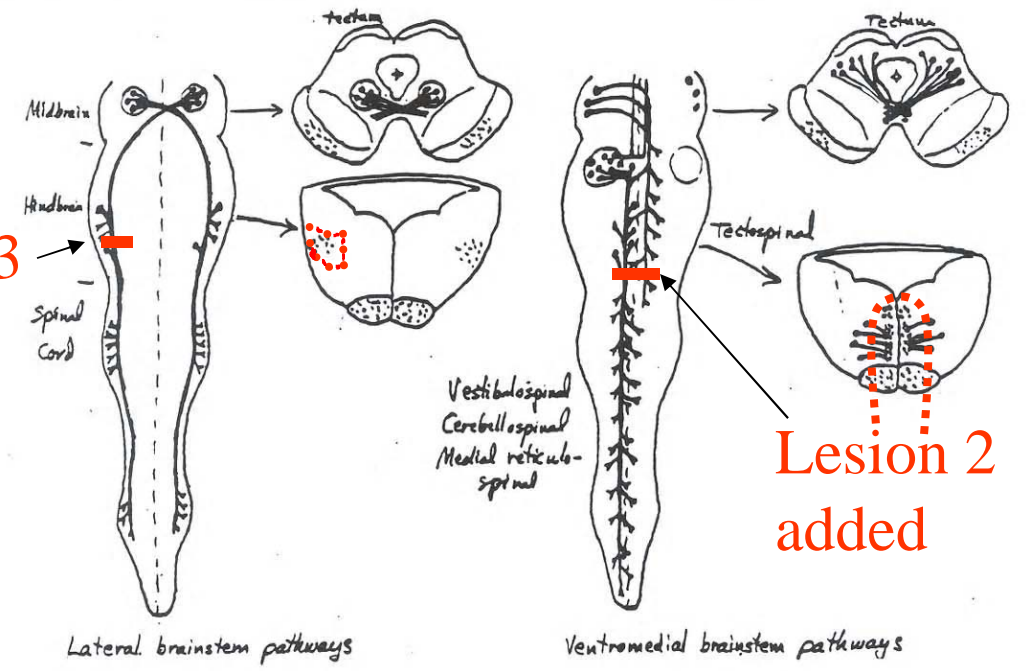
– The logic of Lawrence & Kuypers, 1968 paper
in the journal *Brain*

- Begin with elimination of the corticospinal projections; wait for recovery from diaschisis effects
- Then, ablate either the medial or the lateral pathways descending from the hindbrain and midbrain and observe the remaining functions as well as the functional deficits.

Selective lesions of the descending motor pathways



**OR:
Lesion 3
added**



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

Lawrence & Kuypers, 1968:

- **Lesion #1: pyramidotomy (bilateral)**
 - Loss of speed and strength
 - Loss of control of digits used one at a time

Recall question 4:

Why would diaschisis effects of lesions of one of the descending pathways in the study be greater in humans than in the monkeys? What are major manifestations of such effects? **After recovery of spinal reflexes, the enduring effects are those listed above.**

Questions, chapter 15

- 6) There is no doubt that many dexterous movements are learned and that they depend on corticospinal connections. How are “fixed action patterns” different? **See the textbook on experiments with Syrian hamsters by Katherine Kalil and G. Schneider.**
- 7) How might many learned movements depend on spinal modules more than on direct connections from cortex to motor neurons? **See the textbook on the proposal and evidence from the laboratory of**
- 8) What are Betz cells? How are they related to the discovery by Fritsch and Hitzig (in 1870)? **Betz cells: the giant pyramidal cells in layer 5 of the motor cortex. Motor cortex was first defined and mapped by Fritsch and Hitzig. Betz' publication was in 1874, four years after the report by Fritsch and Hitzig.**

Lawrence & Kuypers, 1968:

- **Lesion #2: destruction of medial brainstem pathways** (added to pyramidotomy) *bilaterally*
 - Defective axial control:
 - Righting: only after 10-40 days
 - Falling: failure to elicit the usual corrective movements
 - Walking: only one monkey could take many steps because of disorientation; he veered from course, bumped into obstacles
 - Better distal control:
 - If monkey was strapped into a chair, it could grasp food objects with the whole hand

Lawrence & Kuypers, 1968:

- **Lesion #3: destruction of lateral brainstem pathways** (added to pyramidotomy)
 - Defective limb control: Hand flexion done only with total arm movements. Inability to grasp objects with the hand.
 - Good axial control
 - Hand used dramatically better in running & climbing (total body movements) *

*Thus, “paralysis” can be very specific if it is not due to loss of motor neurons.

MIT OpenCourseWare
<http://ocw.mit.edu>

9.14 Brain Structure and Its Origins

Spring 2014

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.