9.14  MIT  2005

Class 7 completion
Migration: three types

• Nuclear translocation
• Guidance of cell movement by radial glia cells
• Guidance of cell movement by other substrate factors
A definitive demonstration of nuclear translocation as a mechanism of cell “migration” in the CNS

- Development of the Shepherd’s Crook Cell in Chick Optic Tectum
- Why was this important? Think about the techniques being used, and the nature of the controversy about the mechanism of cell migration in the developing CNS.

Development of the "Shepherd's Crook Cell" of the chick optic tectum.

Midbrain surface

1 2 3 4

Ventricle

growth cone

nucleus

nucleus

the shepherd's crook
• Other mechanisms of cell migration in the CNS will be considered later.
• After – or even during -- neuronal migration in the spinal cord, the neurons are starting to differentiate.
Neuroepithelium, chick spinal cord, day 3 (Cajal)

SHOWN EARLIER

Golgi stain, staining only the immature cells

Figure removed due to copyright reasons.

Please see:
Cajal, S., and Ramón Y. *Histology of the Nervous System of Man and Vertebrates.*
Translated from the French by Neely Swanson and Larry W. Swanson. 2 vols.
Figure removed due to copyright reasons.

Please see:


Chick spinal cord, day 3 (Cajal), showing early differentiation of neurons more advanced than in previous picture.
Differentiation:
Growth of dorsal and ventral roots

We will return to axonal growth later.
First, a look at the adult spinal cord and brain.
REVIEW

Some neurodevelopment terms to be familiar with

- ectoderm (vs. mesoderm and endoderm),
- ventricular layer, mantle layer, marginal layer
- modes of migration,
- radial glia (radial astrocytes),
- ependyma, cells attached to inner surface of neural tube
- sulcus limitans, alar and basal plates,
- neural crest,
- dorsal and ventral roots and rootlets.

From Nauta & Feirtag, ch.10, and other texts
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.
Left:
Internal structure of spinal cord

Right:
Levels, rostral to caudal

Nissl stain for cell bodies

Figure by MIT OCW.
Different levels, illustrated:

*Note the following things*

- Gray vs. white matter. Gray matter: 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
- Presence of “lateral horn” in thoracic and upper lumbar cord
  - preganglionic motor neurons of the sympathetic nervous system

Comparisons, speculations

• Role of myelin
  – “A crucial vertebrate innovation” (Allman p. 78): Why?
  – 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?
Spinal cord cross section
Lumbar level

Figure by MIT OCW.

Note the laminae of Rexed.

Drawing based on cell - body stain
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
A sketch of the central nervous system and its origins

G. E. Schneider 2005

Part 4: Development and differentiation, spinal level

MIT 9.14 Class 8

CNS structure at the spinal level; autonomic and enteric nervous systems
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
Termination of Dorsal Root Fibers

*Again, note the laminae of Rexed.*

*C fibers are the only unmyelinated axons of dorsal roots*
Adult spinal cord, schematic frontal section: reflex and lemniscal channels

Dorsal root fibers of various sizes

"Spin trac"

Spino reticular: mostly ipsilateral

Flexion reflex, disynaptic
At the rostral end of the spinal cord:

The dorsal column nuclei, namely, the gracile and cuneate nuclei (nuc. gracilis and nuc. cuneatus)

What sensory cell group is found just lateral to these nuclei in the caudal hindbrain and upper cervical spinal cord?

With these cells, there is a representation of the entire body surface at this level around the junction of spinal cord and hindbrain.
Cerebellar channel: Clarke’s Column, illustrated at 5th thoracic segment

Info. On complex joint movements from lower limbs & trunk

Figure by MIT OCW.
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 vestibulospinal)
- “**Propriospinal**” fibers.
Adult spinal cord: some descending and intrinsic axons

- Proprio­spinal axons
- Rubrospinal axons from midbrain
- Reticulospinal, Vestibulospinal, Fastigiospinal (from Cb), Tectospinal from midbrain
- Corticospinal axons from opposite side
Intermission:
The ventricular system; the meninges and glia

• Remember: the origins of the ventricle in the formation of the neural tube

• It’s importance in the mature CNS:
  – Nutrients
  – Fluid balance regulation via specific cell regions
  – Also a communication medium (because of chemical secretions into it) the cerebrospinal fluid

• Where the fluid is made and how it flows:
“Choroid plexus”
Specialized ependymal cells, make cerebrospinal fluid (CSF)

Ventricular system:
The foramena of Luschka (lateral apertures), and the foram of Magendie (median aperture)
The Meninges

1. Define "dura mater" and "pia mater": meaning of the Latin terms, and basic anatomy.
2. Define "arachnoid membrane" and "subarachnoid space".

See Nauta & Feirtag, ch. 10; also P. Brodal, ch. 1, and other texts
Glia

Figure by MIT OCW.
Picture taken with transmission electron microscope (EM):
Astrocytes, pial cells, subarachnoid space
(Peters, Palay & Webster, 1976)

SS = subarachnoid space
PM = pial membrane
Col = collagen fibers
SM = smooth muscle
GL = glia limitans (astrocyte processes)
B = basal lamina
As = astrocyte
arrows, lower fig: attachment points

Photo removed due to copyright reasons.
Autonomic nervous system (ANS)

- **Overview of functions**
- **Schematic overview of structure**
- **Formation of sympathetic ganglia** from the neural crest
- **Sympathetic innervation pattern** (thoracico-lumbar system)
- **Parasympathetic innervation** (cranio-sacral system); dual innervation of smooth muscles and glands.
- **Chemical mediation at synapses** (first discovered by Otto Loewi in 1921.)
## Functions of some autonomic pathways

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>SYMPATHETIC</th>
<th>PARASYMPATHETIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iris</td>
<td>Dilates the pupil (mydriasis)</td>
<td>Constricts the pupil (miosis)</td>
</tr>
<tr>
<td>Lacrimal Gland</td>
<td>Little or no effect on secretion</td>
<td>Stimulates secretion</td>
</tr>
<tr>
<td>Salivary Glands</td>
<td>Secretion reduced in amount and viscid</td>
<td>Secretion increased in amount and watery</td>
</tr>
<tr>
<td>Sweat Glands of Head, Neck, Trunk, and Extremities</td>
<td>Stimulates secretion (cholinergic fibers) nerve fibers</td>
<td>Little or no effect on secretion</td>
</tr>
<tr>
<td>Bronchi</td>
<td>Dilates lumen</td>
<td>Constricts lumen</td>
</tr>
<tr>
<td>Heart</td>
<td>Accelerates rate, augments ventricular contraction</td>
<td>Decreases heart rate</td>
</tr>
<tr>
<td>GI Motility and Secretion</td>
<td>Inhibits</td>
<td>Stimulates</td>
</tr>
<tr>
<td>GI Sphincters</td>
<td>Constricts</td>
<td>Relaxes</td>
</tr>
<tr>
<td>Sex Organs</td>
<td>Contraction of ductus deferens, seminal vesicle, prostatic and uterine musculature; vasoconstriction</td>
<td>Vasodilation and erection</td>
</tr>
<tr>
<td>Urinary Bladder</td>
<td>Relaxes bladder wall, constricts int. sphincter, inhibits emptying</td>
<td>Relaxes int. sphincter, contracts bladder wall, promotes emptying</td>
</tr>
<tr>
<td>Adrenal Medulla</td>
<td>Stimulates secretion (cholinergic nerve fibers)</td>
<td>Little or no effect</td>
</tr>
<tr>
<td>Blood Vessels of Trunk and Extremities</td>
<td>Constricts</td>
<td>No effect</td>
</tr>
</tbody>
</table>

Table by MIT OCW.
Autonomic pathways: schematic of structural arrangements

Note the CNS locations of the preganglionic motor neurons of the two divisions of the ANS.

Figure by MIT OCW.
Another schematic view of ANS
Autonomic pathways:

a simpler schematic view (partial)
Step back a moment:
Arrangement of motor neurons in the three major divisions of the motor system

Somatic: Synaptic
Autonomic: Paracrine
Neuroendocrine: Endocrine

Figure by MIT OCW.
Arrangements within the ANS:
Autonomic (paracrine) innervation

Figure by MIT OCW.
Autonomic innervation of the intestine in several vertebrate classes.

Figure by MIT OCW.
Autonomic nervous system

- Overview of functions
- Schematic overview
- **Formation of sympathetic ganglia** from the neural crest (REVIEW)
- Sympathetic innervation pattern (thoracico-lumbar system)
- Cf. parasympathetic innervation (cranio-sacral system); dual innervation of smooth muscles and glands.
- **Chemical mediation at synapses**: discovery by Otto Loewi in 1921.
Closure of neural tube; **formation of sympathetic ganglia**

- Neural plate
- Neural groove
- Neural tube and neural crest
- Ectoderm
- Notochord
- Roof plate
- Alar plate
- Basal plate
- Floor plate
Autonomic nervous system

• Overview of functions
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INTERNAL STRUCTURE OF THE SPINAL CORD

- Dorsal Root Fibers
- Fasc. Gracilis
- Nuc. Cornucommissuralis Posterior
- Substantia Gelatinosa
- Nuc. Posteromarginalis
- Ventral Root Fibers
- Nuc. Motorii Medialis

Internal Structure

- Zone of Lissauer
- Lat. Corticospinal Tr.
- Nuc. Proprius Cornu Dorsalis
- Nuc. Reticularis
- Nuc. Dorsalis (of Clarke)
- Ant. Spinocerebellar Tr.
- Lat. Spinothalamic Tr.
- Nuc. Motorii Lateralis
- Fasc. Proprius
- Ant. Spinothalamic Tr.
- Vestibulospinal Tr.

- Spinal Cord Segment C1
- Segment C5
- Segment C8
- Segment T2
- Segment T10
- Segment L1
- Segment L4
- Segment S4

Figure by MIT OCW.
Sympathetic nervous system axons, schematic section of spinal cord, thoracic level
Sympathetic Innervation
Autonomic nervous system

- Overview of functions
- Schematic overview
- Formation of sympathetic ganglia from the neural crest
- Sympathetic innervation pattern (thoracico-lumbar system)
- Parasympathetic innervation (cranio-sacral system); dual innervation of smooth muscles and glands.
- Chemical mediation at synapses: discovery by Otto Loewi in 1921.
Vagus nerve (10\textsuperscript{th} cranial nerve)
Parasympathetic Innervation

Figure by MIT OCW.
Autonomic nervous system

- Overview of functions
- Schematic overview
- Formation of sympathetic ganglia from the neural crest
- Sympathetic innervation pattern (thoracico-lumbar system)
- Parasympathetic innervation (cranio-sacral system); dual innervation of smooth muscles and glands.
- Chemical mediation at synapses: discovered by Otto Loewi in 1921. (REVIEW)
Autonomic pathways with neurotransmitters showing accelerator & decelerator nerves of the heart

Sympathetic

Para sympathetic

ACH

NE

ACH
Enteric nervous system

The “little brain” in the gut:
Perhaps as many neurons as in the entire spinal cord.

In the wall of the intestine:
  • Myenteric plexus (the outer plexus)
  • Submucous plexus (the middle plexus)
  • Villous plexus (inner plexus)
  • Periglandular plexus (inner plexus)
Innervation by vagus nerve

Cardiac ganglion: Does the heart have a brain?

Various neurotransmitters
Levels of control in the ANS: the temperature regulation systems

• See reviews by Evelyn Satinoff
Selected References


