9.14 - Brain Structure and its Origins
Spring 2005
Massachusetts Institute of Technology
Instructor: Professor Gerald Schneider

A sketch of the central nervous system and its origins

G. Schneider 2005

Part 1: Introduction

MIT 9.14 Class 1

Orientation; neuron basics

1. Introduction

a) The plan for this class

1) The goal: learn an outline of vertebrate, especially mammalian, neuroanatomy.
2) Reaching the goal will be facilitated by studies of origins, using material from studies of development, comparative anatomy and evolution.
3) Since adaptive function is the driver of evolution, we will pay close attention to functions.

b) Initial topics

1) Some terminology
2) Neurons: their evolution and how we study them

Talking about the CNS: terminology

- **Directions *(illustrated)***
  - **Rostral *vs.* caudal; *cf.* anterior *vs.* posterior**
  - **Dorsal *vs.* ventral; *cf.* superior *vs.* inferior**
  - **Medial *vs.* lateral**
- **Planes of section *(illustrated)***
  - **Sagittal (mid-sagittal, parasagittal)**
  - **Coronal (frontal; transverse; cross-section)**
  - **Horizontal**
  - **Oblique**
- Major parts of the CNS: You will soon know these!
- About the terms we use:
  - Multiple synonyms or near-synonyms
  - English, Latin or Greek
  - Pronunciation problems

Directions

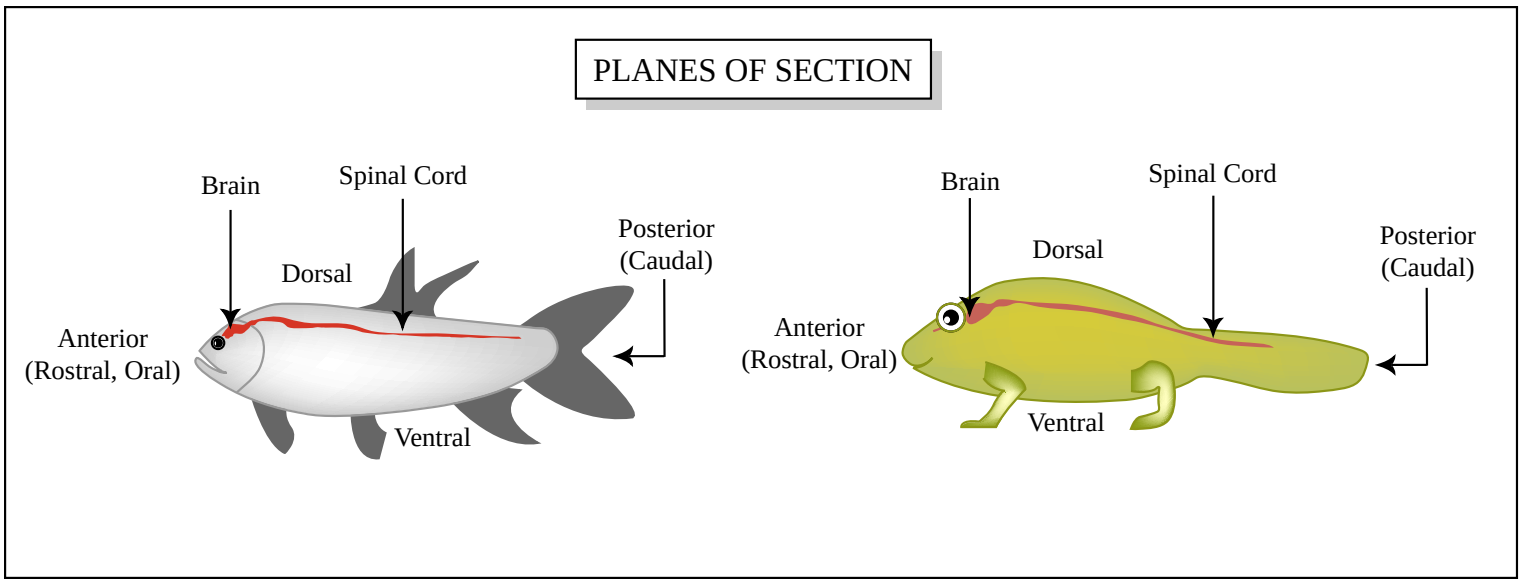


Figure by MIT OCW.

Tetrapod

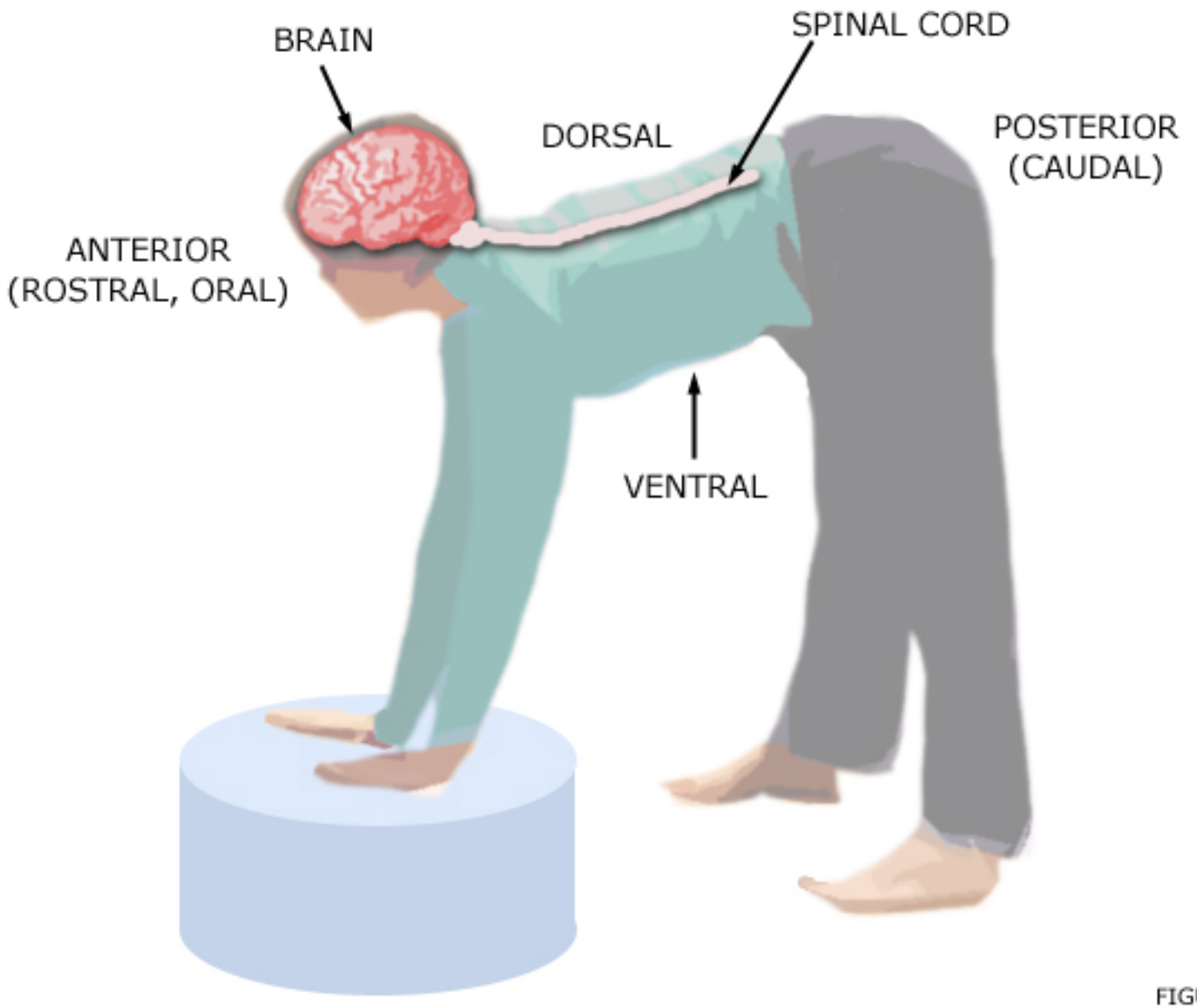


FIGURE BY MIT OCW.

Man and Bird

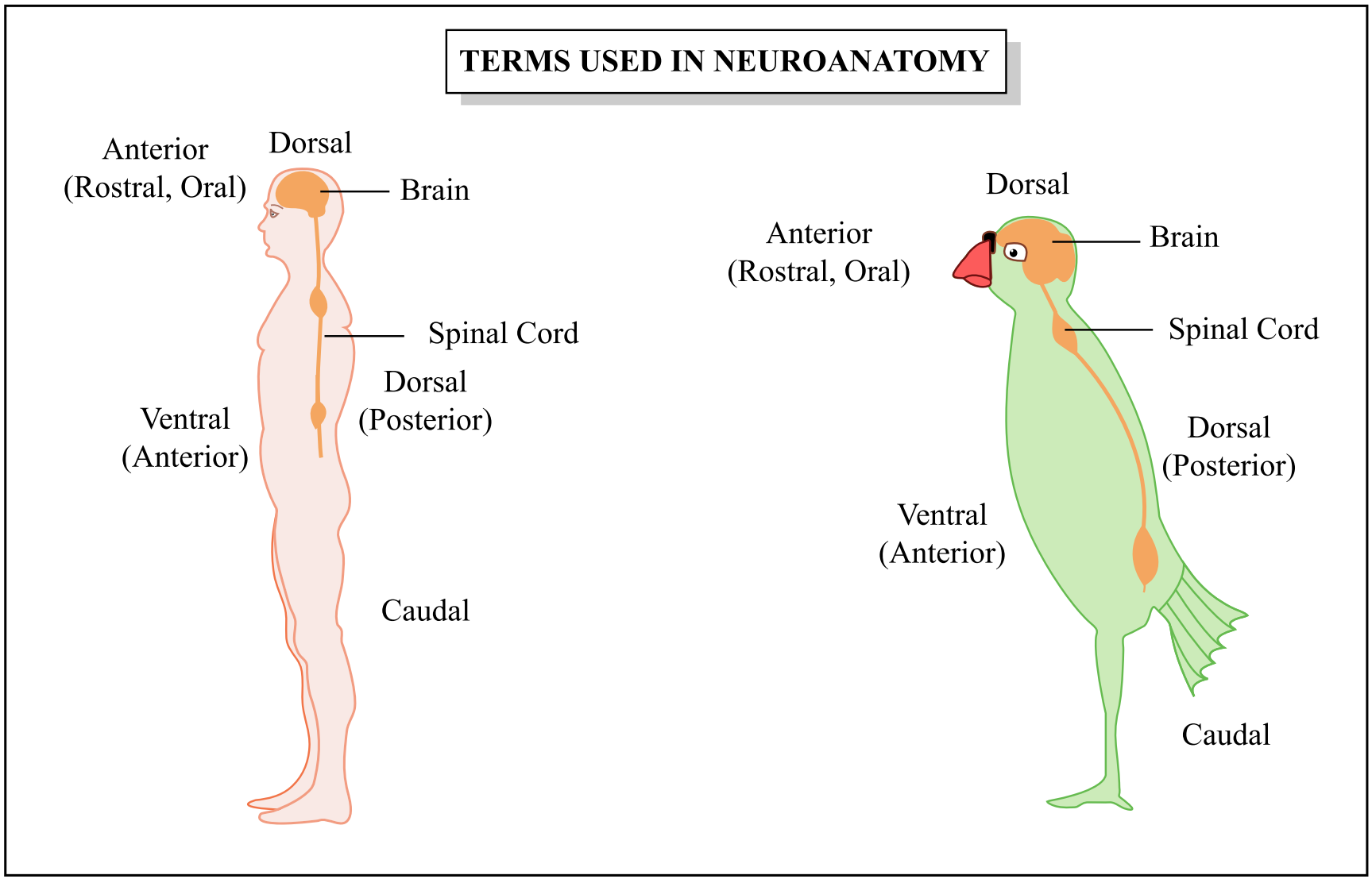
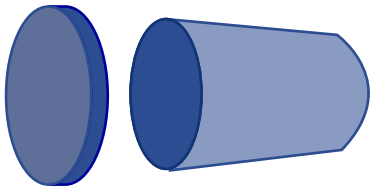
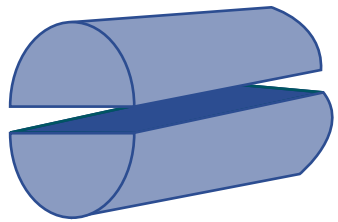


Figure by MIT OCW.

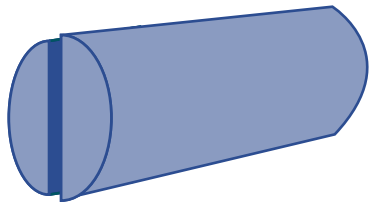
Sections



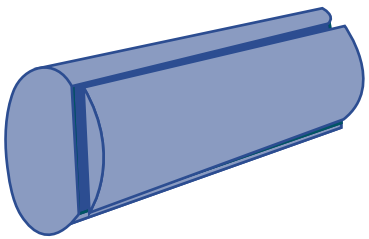
TRANSVERSE
(Frontal)



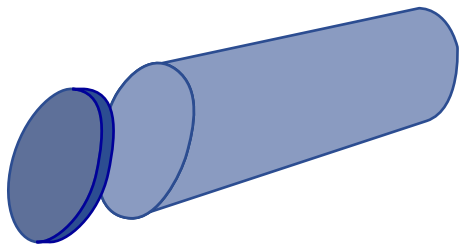
HORIZONTAL



MIDSAGITTAL



PARASAGITTAL
(Sagittal)



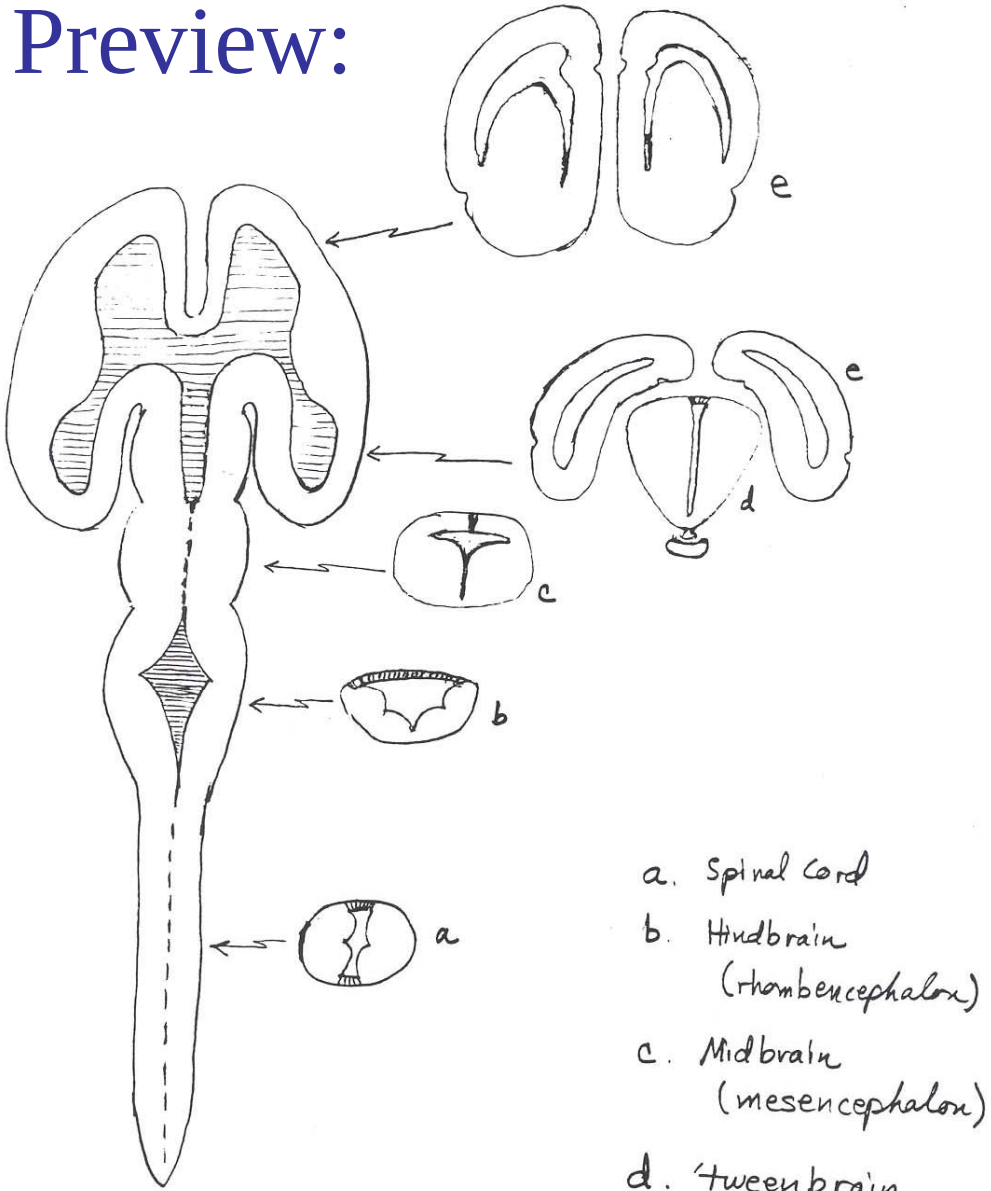
OBLIQUE

Figure by MIT OCW.

Talking about the CNS: terminology

- Directions *(illustrated)*
  - Rostral *vs.* caudal; *cf.* anterior *vs.* posterior
  - Dorsal *vs.* ventral; *cf.* superior *vs.* inferior
  - Medial *vs.* lateral
- Planes of section *(illustrated)*
  - Sagittal (mid-sagittal, parasagittal)
  - Coronal (frontal; transverse; cross-section)
  - Horizontal
  - Oblique
- **Major parts of the CNS:** These will be discussed repeatedly, from various points of view. Soon you will remember them! [Illustration]
- **The terms we use:**
  - **Multiple synonyms or near-synonyms**
  - **English *vs.* Latin or Greek**
  - **Pronunciation problems**

Preview:



a. Spinal cord
b. Hindbrain (rhombencephalon)
c. Midbrain (mesencephalon)
d. 'tweenbrain (diencephalon)
e Endbrain (telencephalon)

The thickening embryonic neural tube

What is the nature of the CNS?

"One of the difficulties in understanding the brain is that it is like nothing so much as a lump of porridge."

-- R.L. Gregory, 1966 [an experimental psychologist]

- CNS as a tissue:
  - What kind of tissue?
  - What kind of cells? How can we see them?
  - Levels of observation; techniques.
- CNS as a system:
  - Communication system: information flow/handling
  - Secretory organ
  - What is its functional architecture? *[We will illustrate this in a basic way, considerably simplifed, at the outset.]*
- Basic elements of CNS *[This week we will have a look at some nerve cells and their properties.]*

The gross anatomy: A young human

Photograph removed due to copyright reasons.
Please see:
Gluhbegovic, Nedzad, and Terence H. Williams.
The Human Brain : A Photographic Guide.
Published/Created: Hagerstown, MD: Harper & Row, 1980.
ISBN: 0061409456.

Primitive cellular mechanisms

present in one-celled organisms and retained in the evolution of neurons

- **Irritability and conduction**
- **Specializations of membrane for irritability**
- Movement
- Secretion
- Parallel channels of information flow; integrative activity
- Endogenous activity

Why do organisms need neurons? Protozoa do these things!

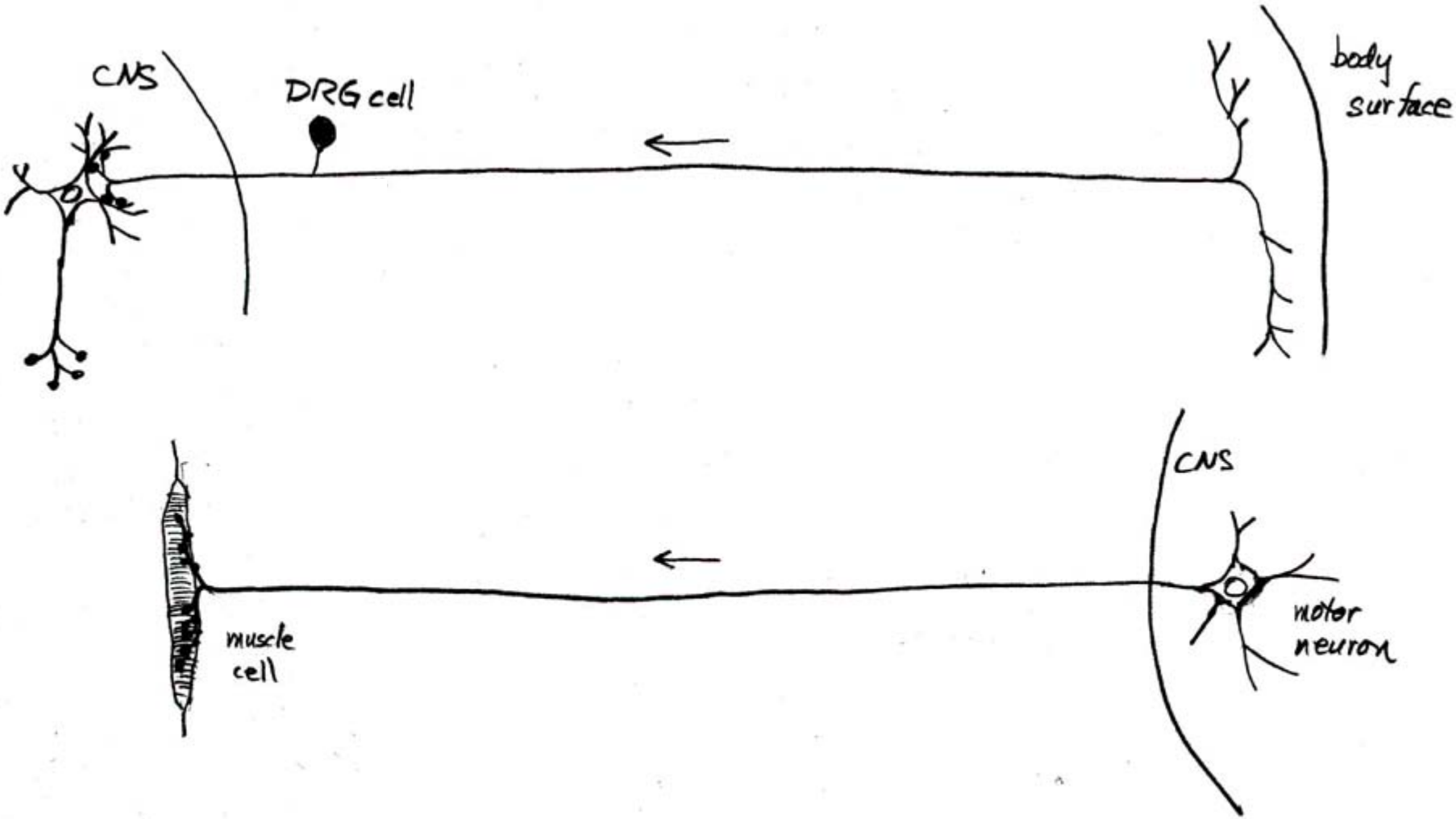
- Limitations of being a single cell are many, especially limits due to small size.
- Hence, the evolution of multicellular organisms had to occur eventually.

Specializations for irritability: introduction

- Protozoa: responses to stimulation
- Sponges and other metazoans: specialized cells responsive to contact or chemicals
- Coelenterates (Parker's studies): primary sensory neurons plus neurons responsive to other neurons
- Worms with forward locomotion, e.g., nematodes and annelids: head receptors and their consequences

(We will return to these topics later.)

Irritability and conduction: Examples of two neurons



A note from comparative anatomy

- The position of the cell body of somatosensory neurons: The pseudounipolar shape is “recent” in evolution.
- Ramon y Cajal’s picture:

Primary somatosensory neurons in an animal series

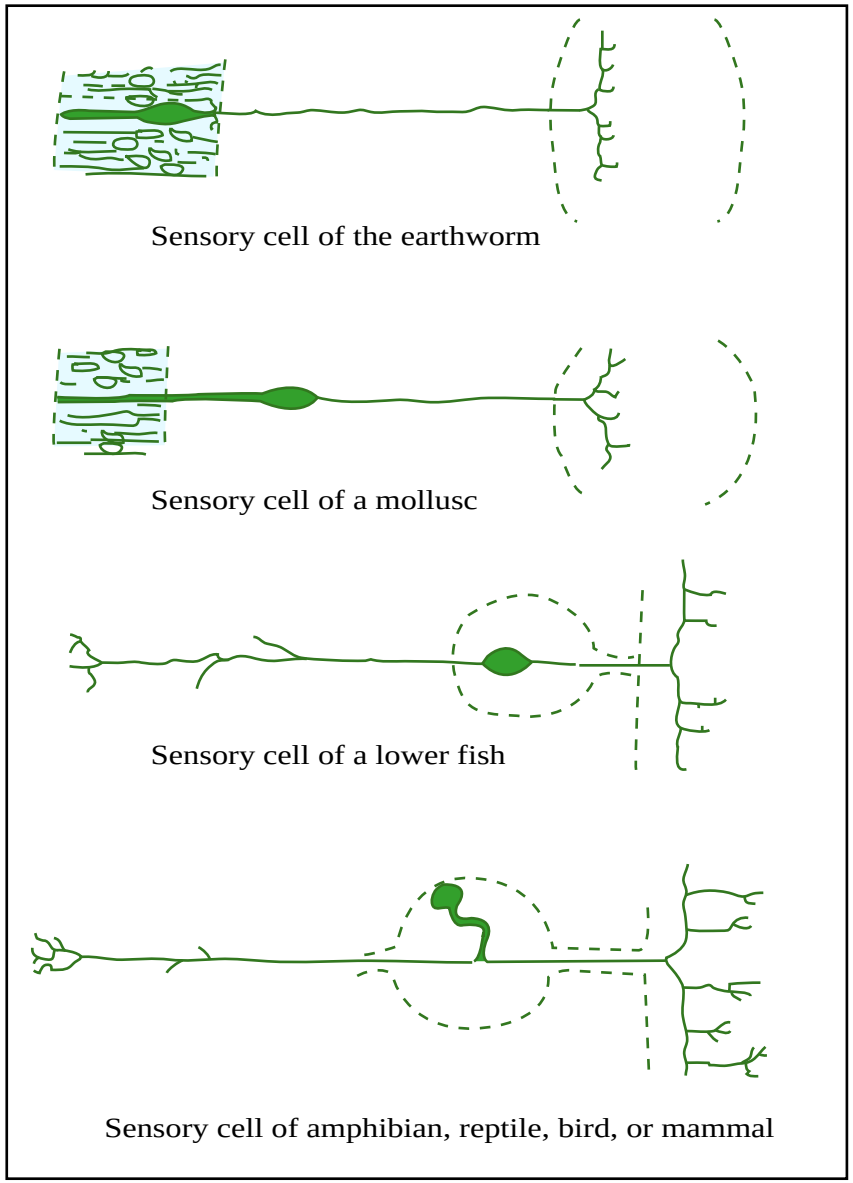
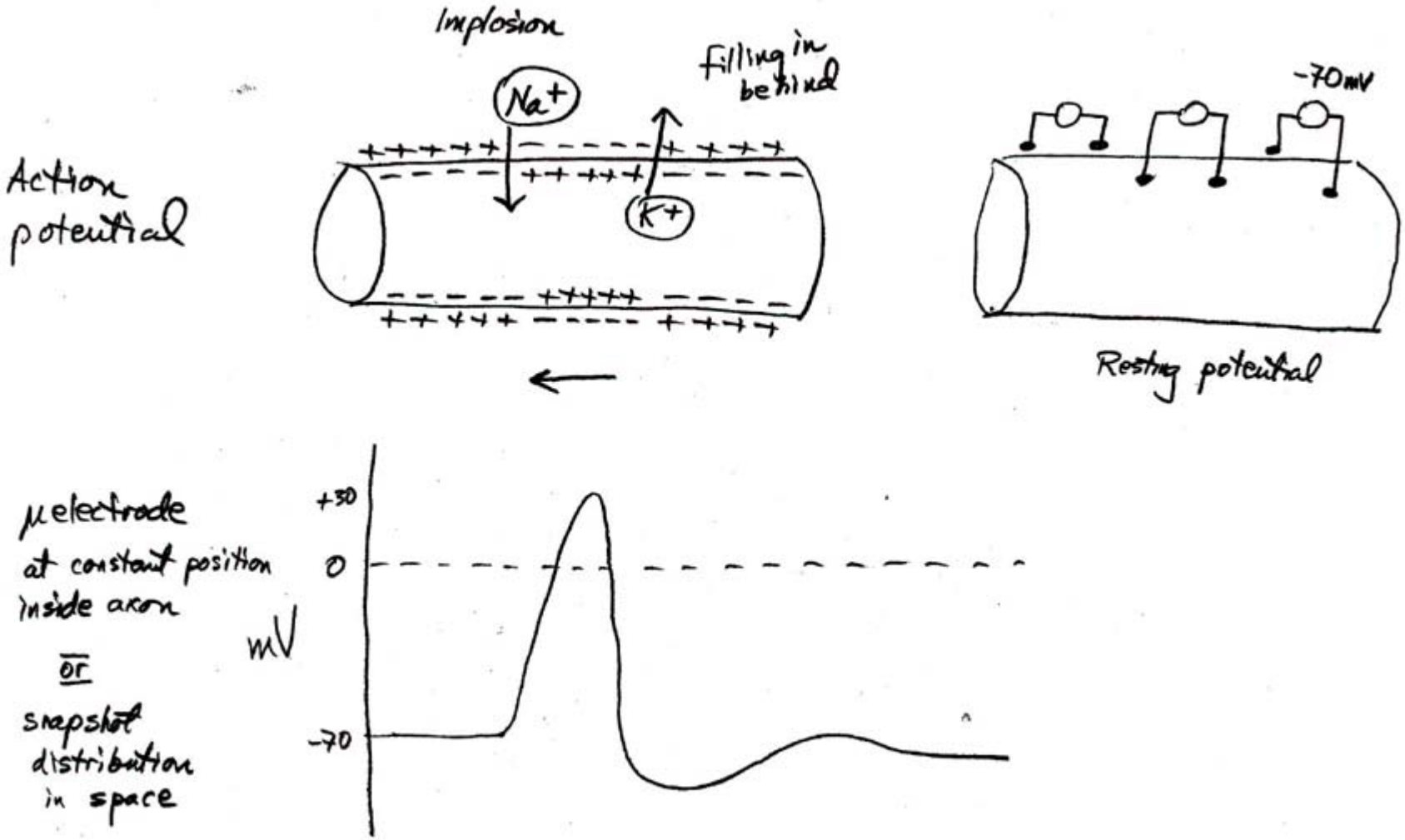


Figure by MIT OCW.

Names for major parts and activities of neurons

- Cell body (soma) and its branches (dendrites)
  - Membrane potential
  - The cell's irritability: depolarization when stimulated. This is called excitation.
  - Graded conduction of membrane potential change away from the point of stimulation
- Axon and its end arborization (telodendria) with "synaptic" contacts on other neurons or muscle or gland cells
  - The axonal membrane is specialized for non-decremental conduction; it conducts "action potentials".
  - Action potentials are triggered in a non-decremental fashion.

Membrane potentials in neurons; in axons



Primitive cellular mechanisms

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Movement

- Contractile proteins: actin and myosin
- Actin is abundant in growing neurons
- But neurons are not specialized for moving themselves except early in development.
- Muscle cells retain and specialize in that property.

Primitive cellular mechanisms

present in one-celled organisms and retained in the evolution of neurons

- Irritability and conduction
- Specializations of membrane for irritability
- Movement
- **Secretion**
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Secretion as an output mechanism:

- In protozoa
- In sponges
- It evolved, or was retained, also in neurons.

Otto Loewi's discovery: chemical transmission at the synapse

- Loewi's dream: He saw how chemical transmission at the synapse could be demonstrated
- Innervation of the frog heart: accelerator nerve and decelerator nerve
- Two frog hearts in separate petri dishes
- Evidence for "Acceleransstoff" and "Vagusstoff"

Synapses: varied structural arrangements:

Consider the functional possibilities

1. **Axo-somatic**
2. **Axo-dendritic**
   (to dendritic shaft or dendritic spine)
3. **Axo-axonal**
   Presynaptic inhibition and facilitation.
4. (Also: dendro-dendritic, dendro-axonal…)
5. Reciprocal synapses
6. Serial synapses
   Gating mechanisms…
7. Synapses without a postsynaptic site

Secretion: terms

- Neurotransmitters
- Neural hormones
- Cf. endocrine glands
- Multiple types of synapses

- **Exocytosis**
- **Endocytosis**
- **Intracellular transport**

Common cellular dynamics with neuronal specializations

- exocytosis
- endocytosis
- **intracellular transport** of organelles and molecules

  Retrograde (involving dynein)

  Anterograde (involving kinesin)

NEXT: How such cellular dynamics are used in experimental studies of the CNS:

Primitive cellular mechanisms

present in one-celled organisms and retained in the evolution of neurons

- Irritability and conduction
- Specializations of membrane for irritability
- Movement
- Secretion
- **Parallel channels of information flow; integrative activity**
- Endogenous activity

The need for integrative action in multi cellular organisms

- How does one end of the animal influence the other end?
- How does one side coordinate with the other side?
- With multiple inputs and multiple outputs, how can conflicts be avoided?
- Hence, the **evolution of interconnections** among multiple subsystems of the nervous system.

How can such connections be studied?

- The methods of neuroanatomy (neuromorphology)
- *Cf.* the roles of neurophysiology, neurochemistry, behavioral studies

Selected References

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