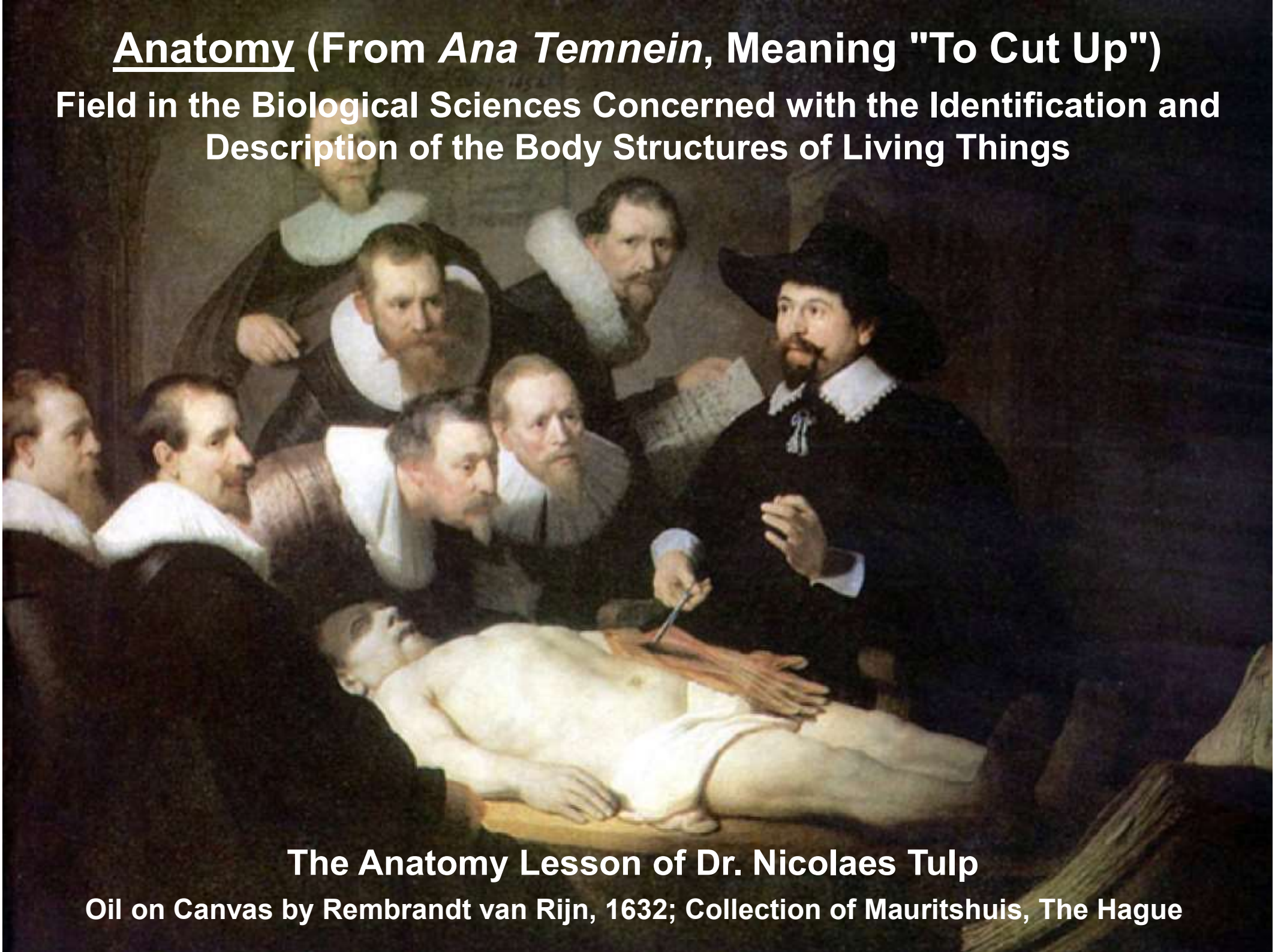
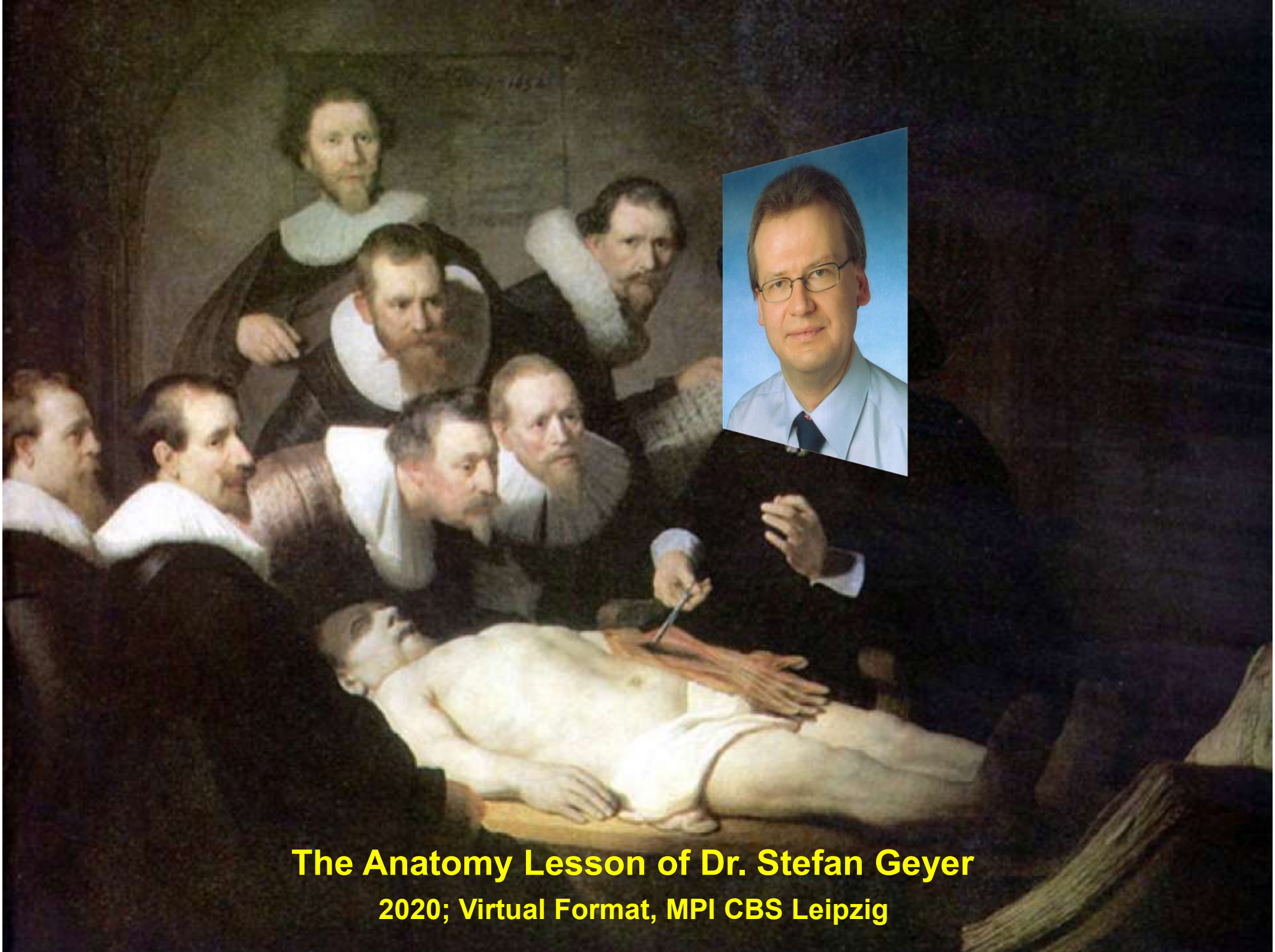
Anatomy (From *Ana Temnein*, Meaning "To Cut Up")

Field in the Biological Sciences Concerned with the Identification and Description of the Body Structures of Living Things



The Anatomy Lesson of Dr. Nicolaes Tulp

Oil on Canvas by Rembrandt van Rijn, 1632; Collection of Mauritshuis, The Hague



The Anatomy Lesson of Dr. Stefan Geyer

2020; Virtual Format, MPI CBS Leipzig

Foundations of Neuroscience – Course Schedule

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Exam

Wednesday, November 11

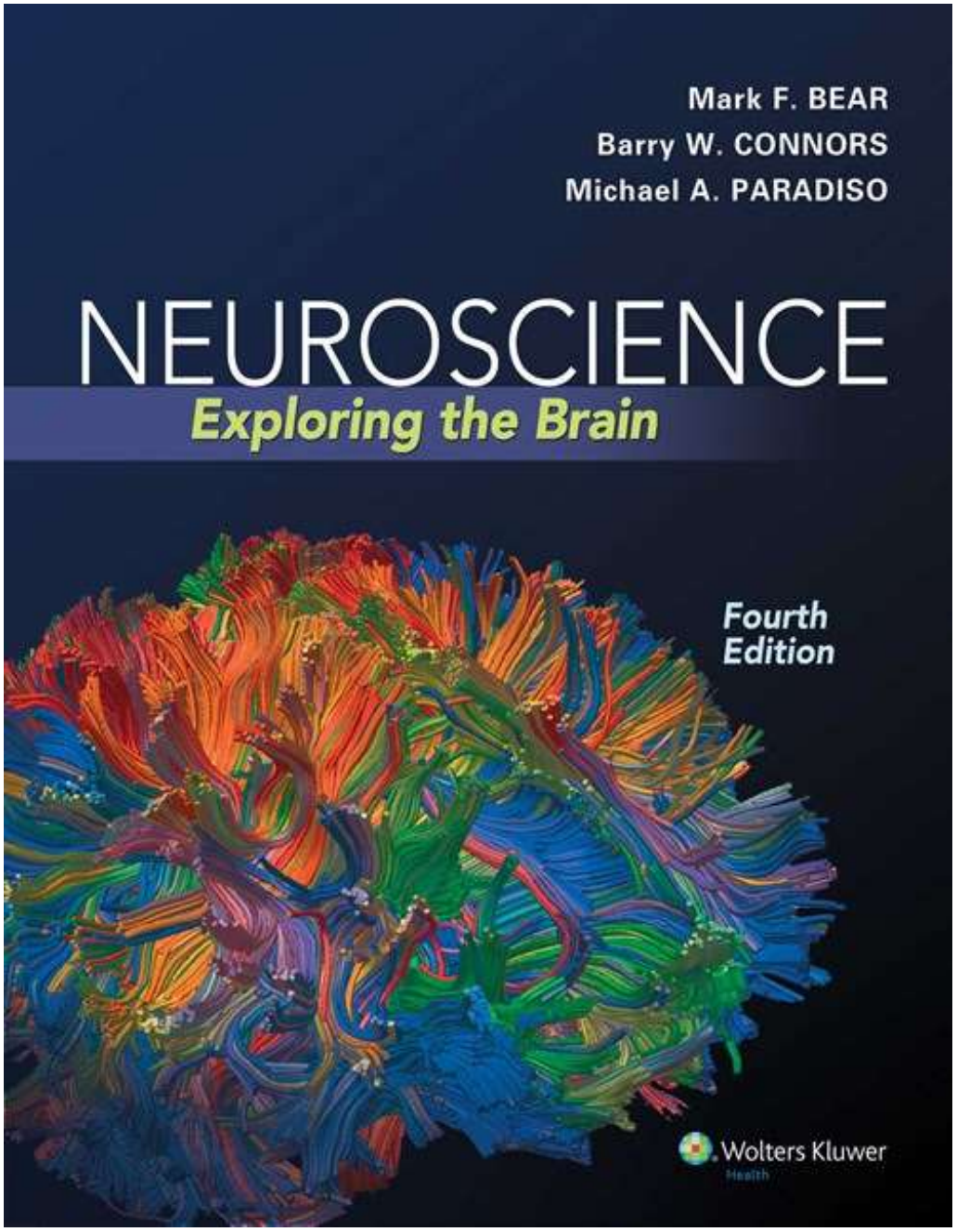
11:00 a.m.

Format still Open due to Corona Restrictions

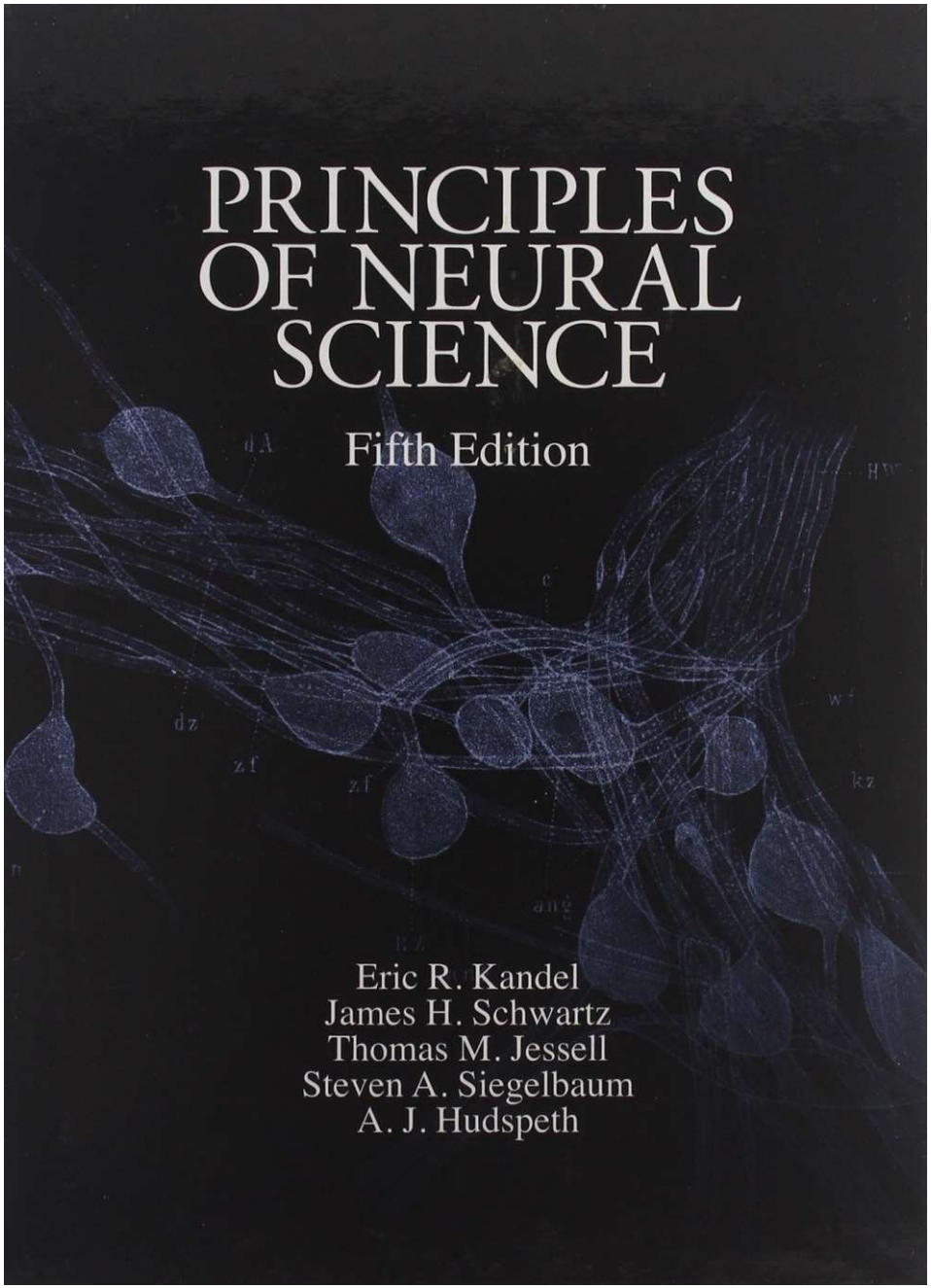
Probably Written Exam with Multiple Choice Questions

Details Will be Announced in Due Course

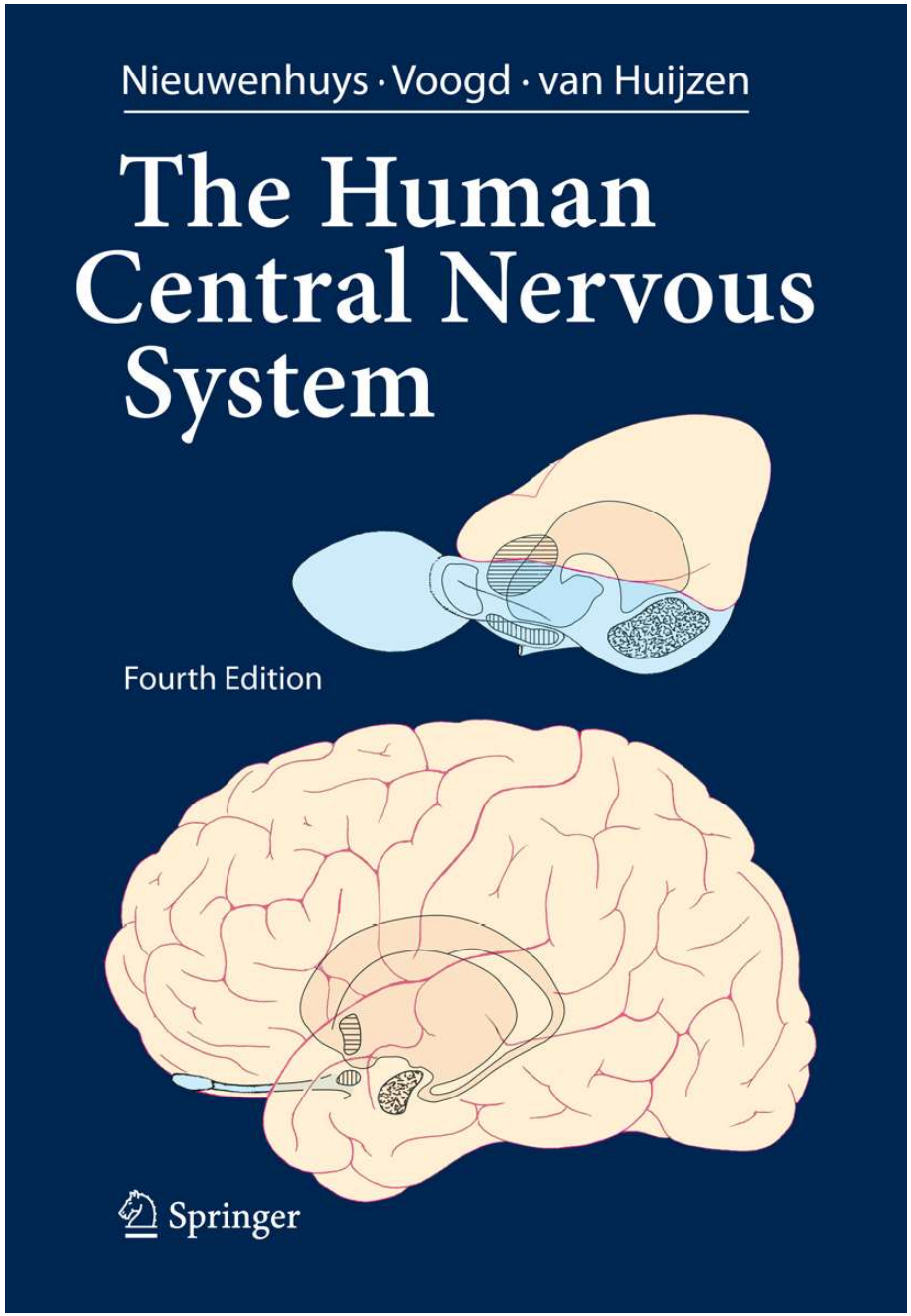
English Textbooks and Atlases



English Textbooks and Atlases



English Textbooks and Atlases



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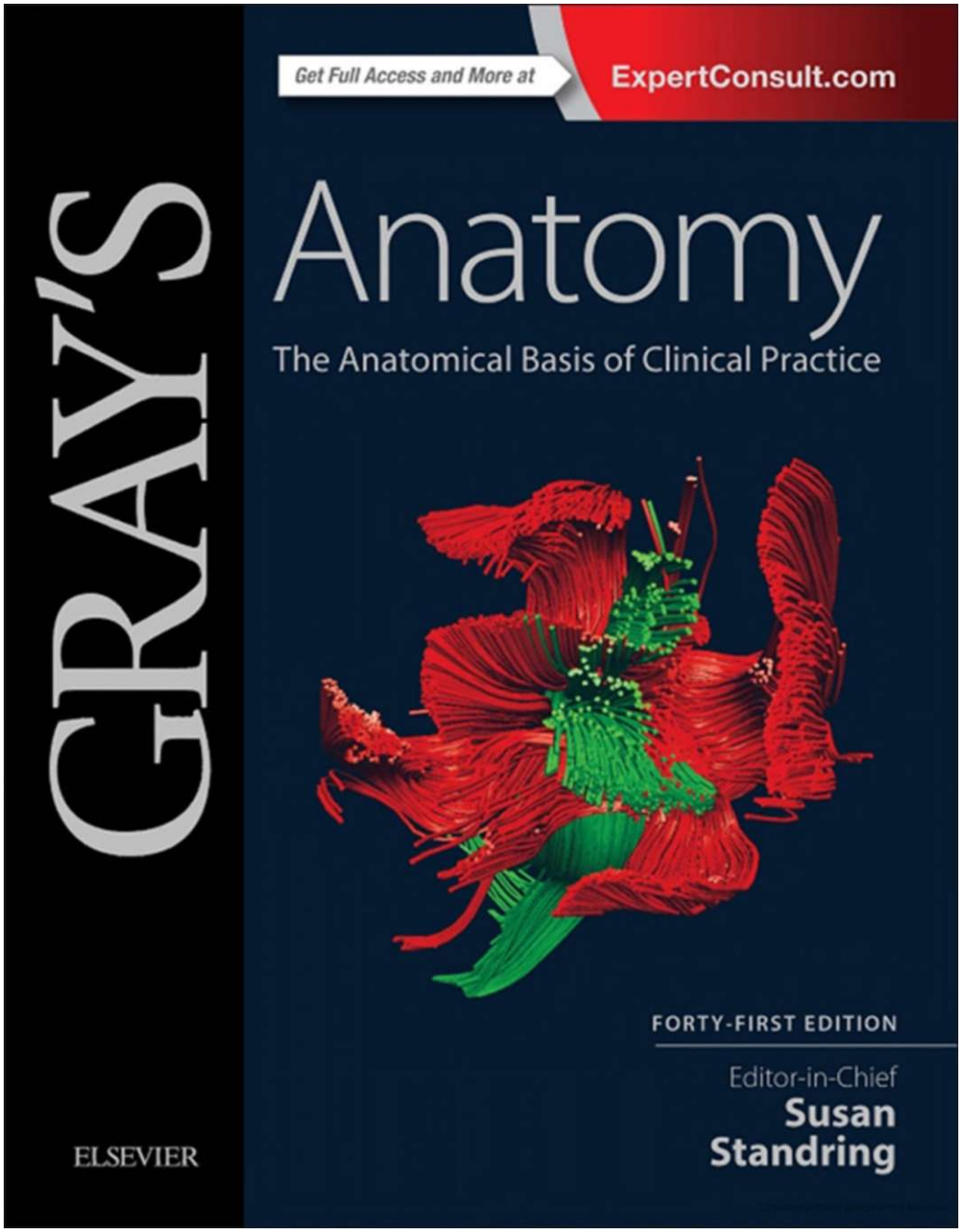
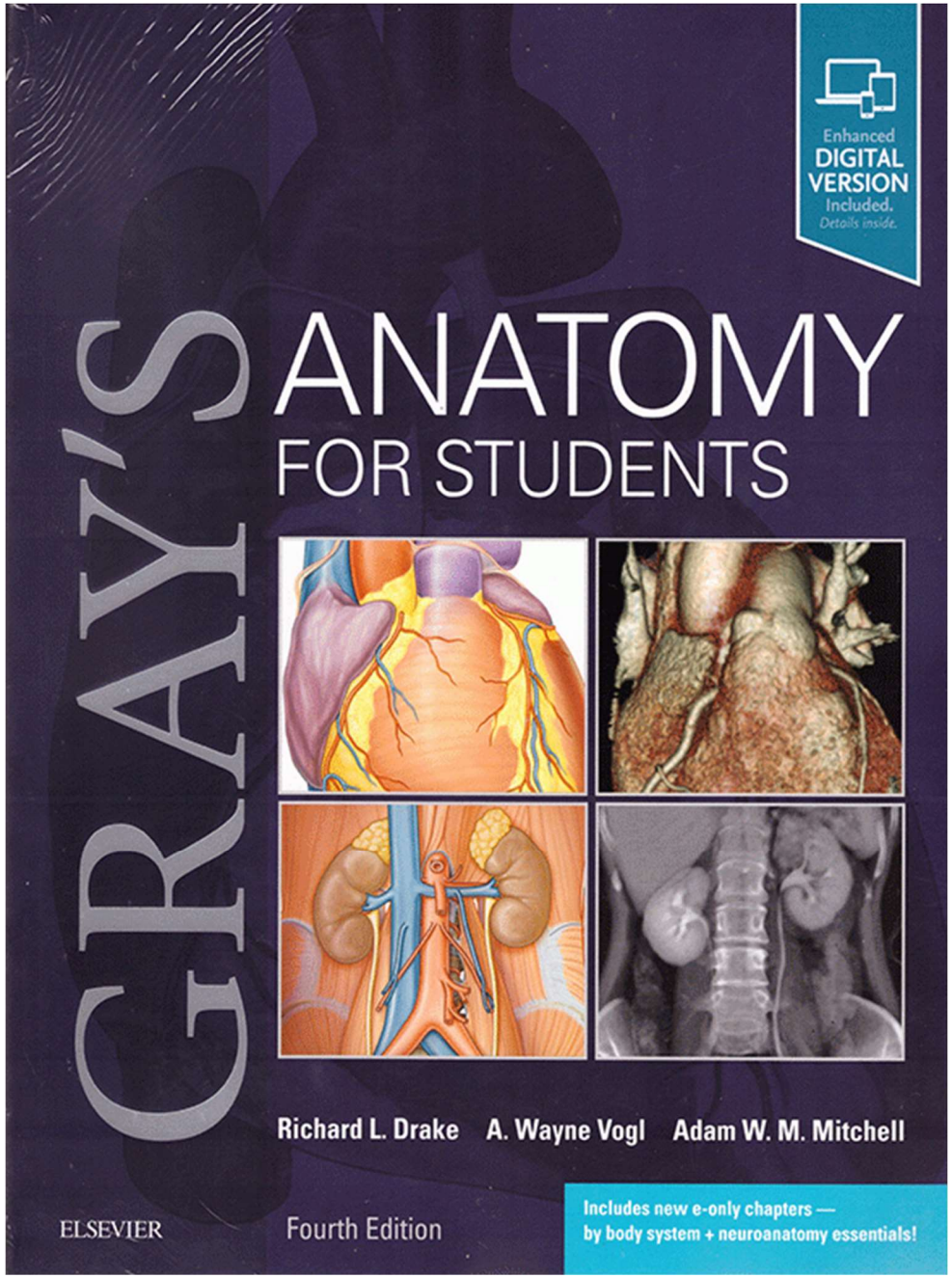
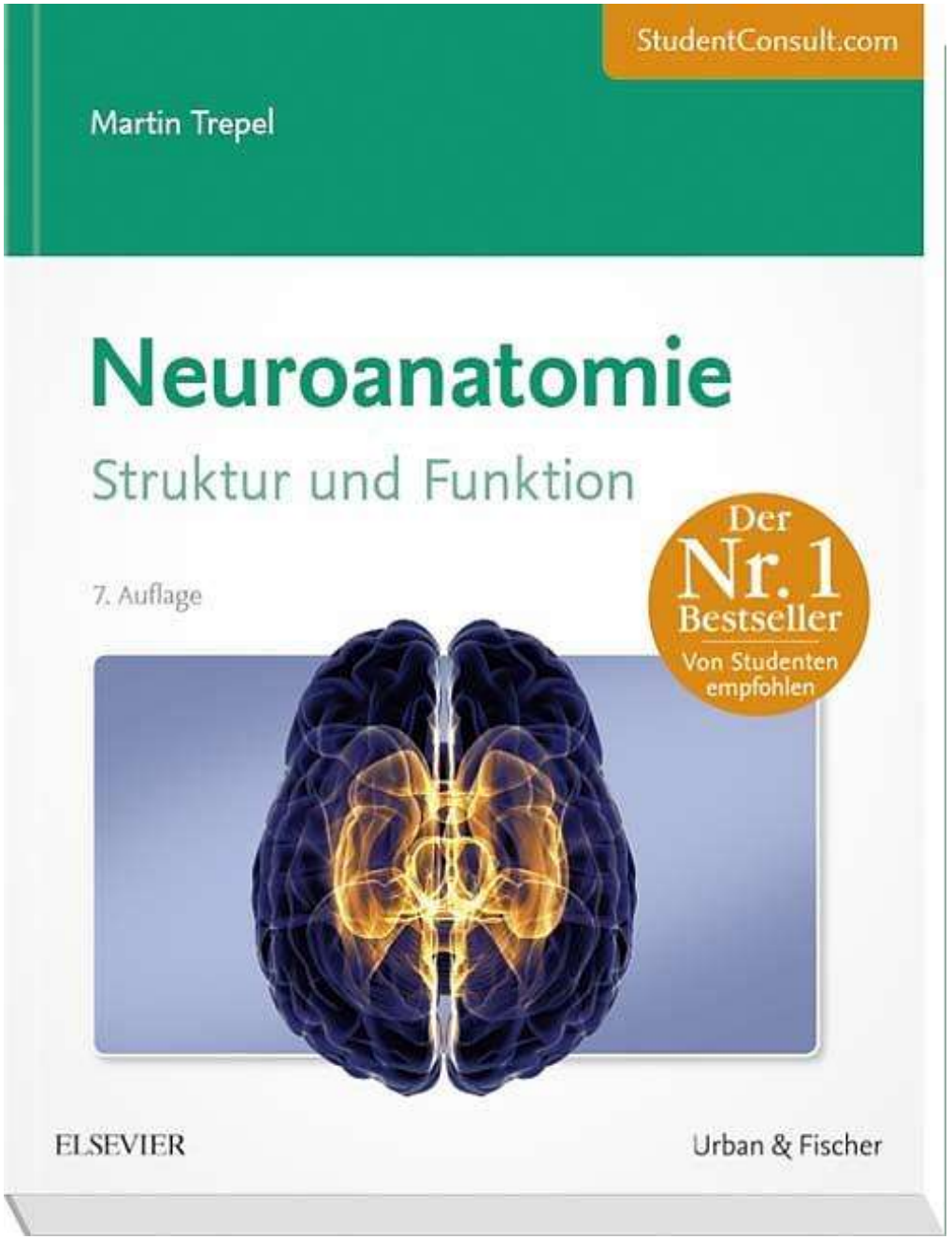




German Textbooks and Atlases



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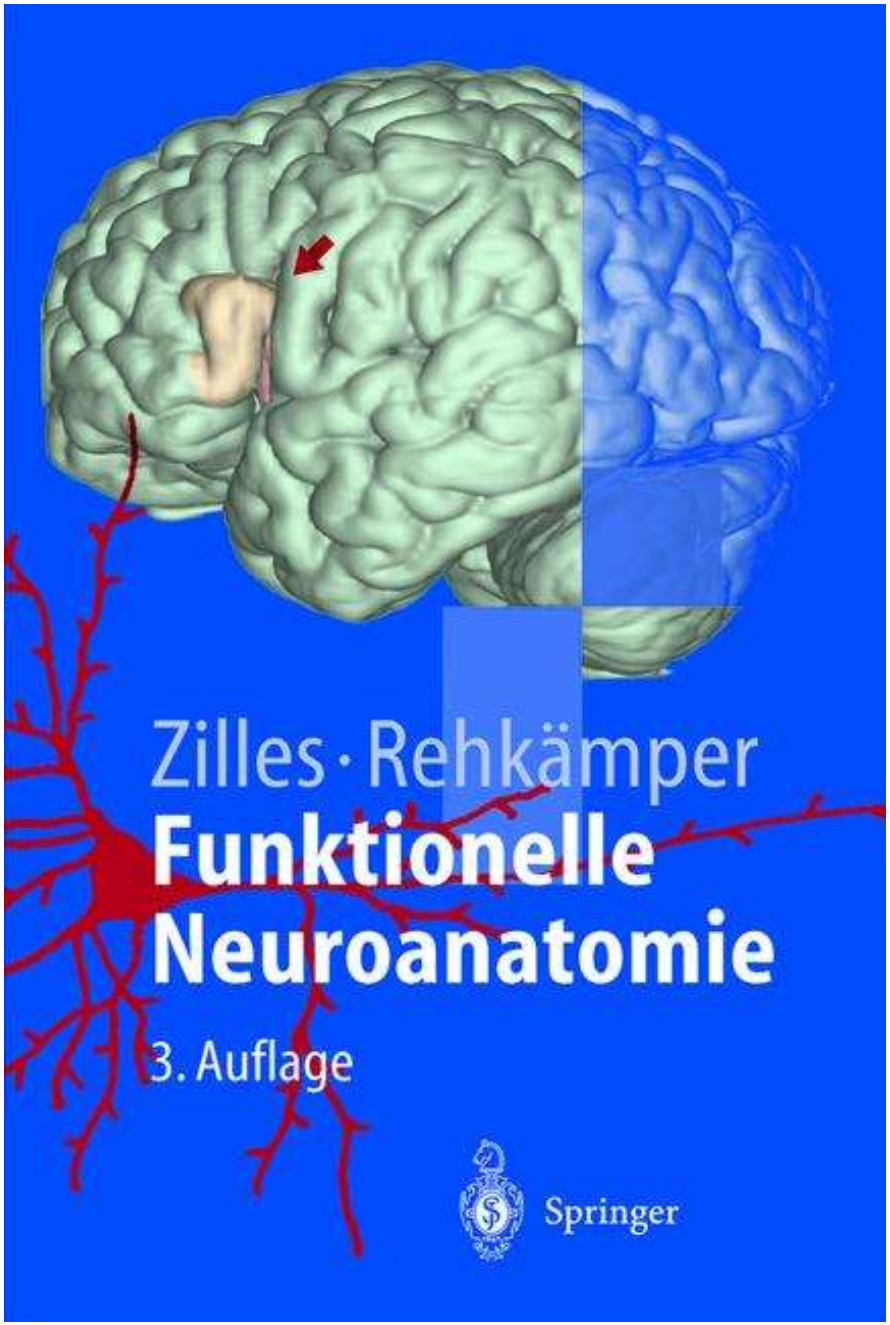

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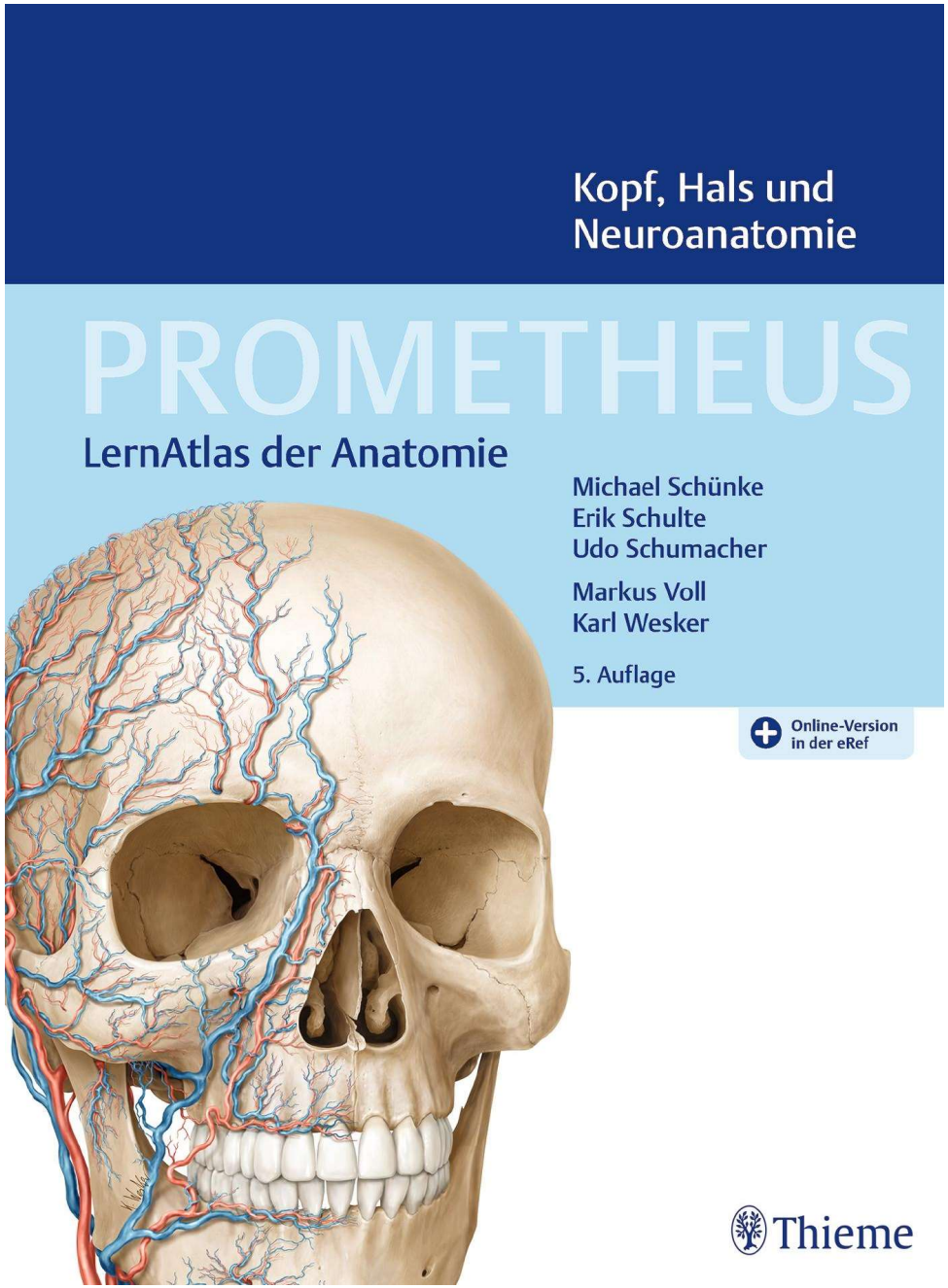

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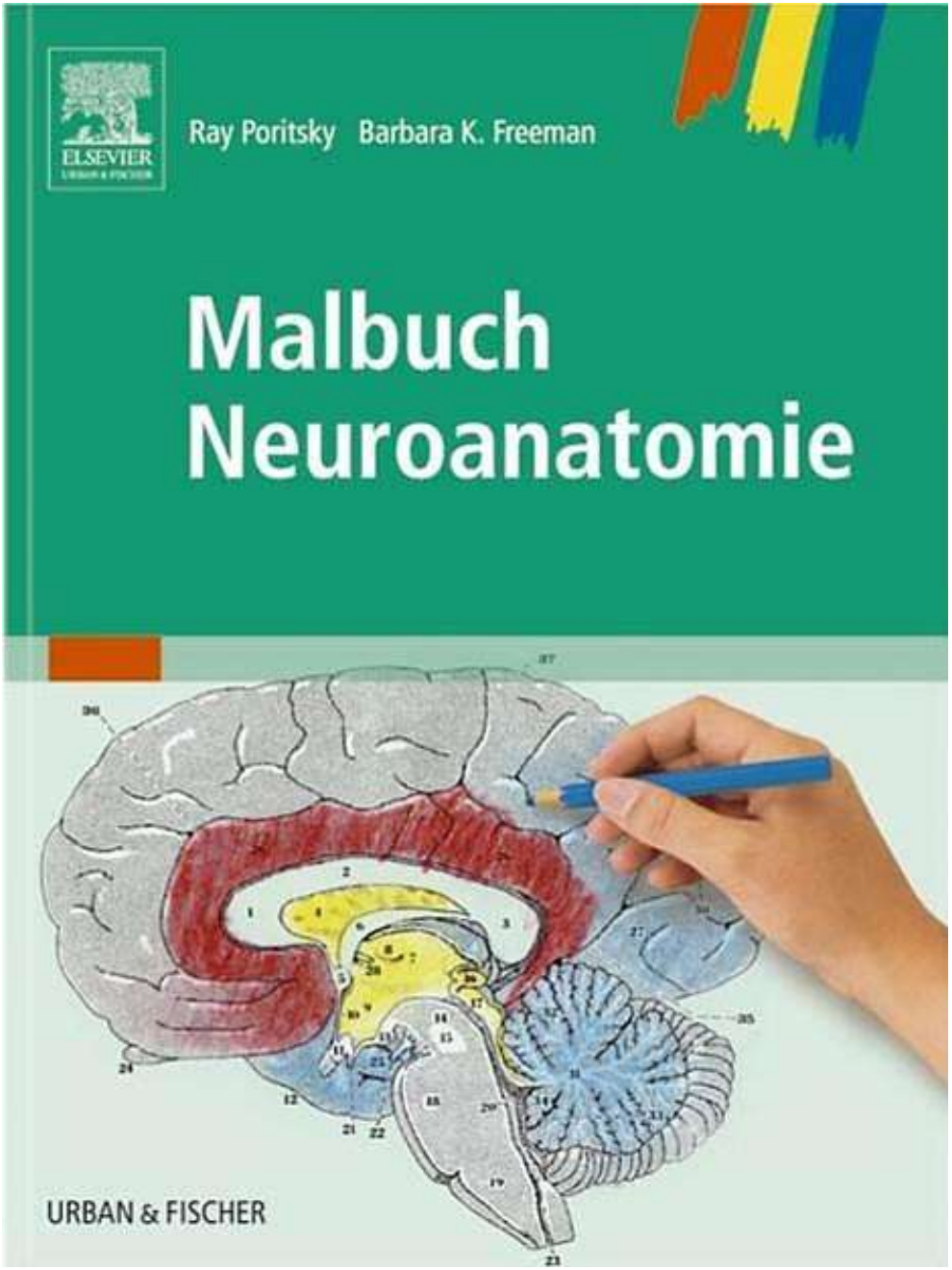

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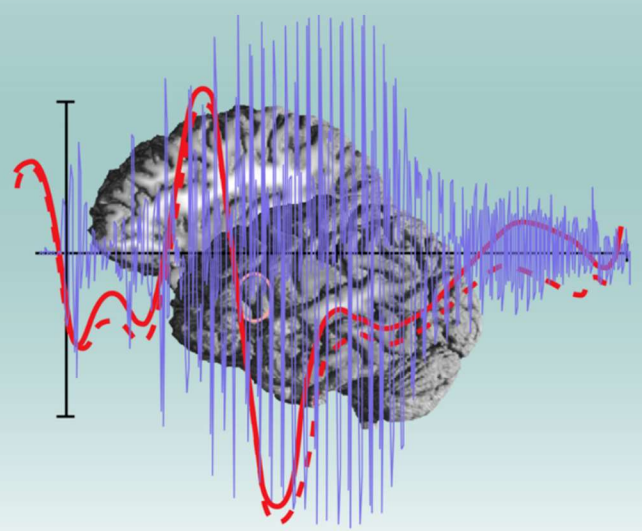
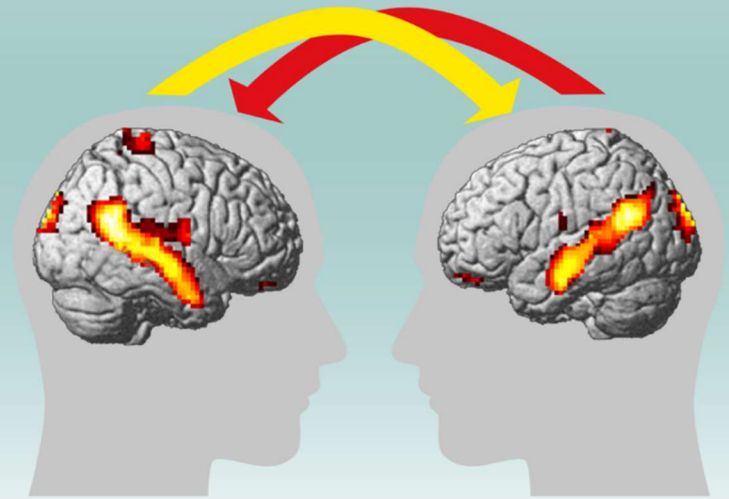


Module I
Language and Communication



Module II
Cognitive and Affective Neuroscience

Course Material – Download Instructions

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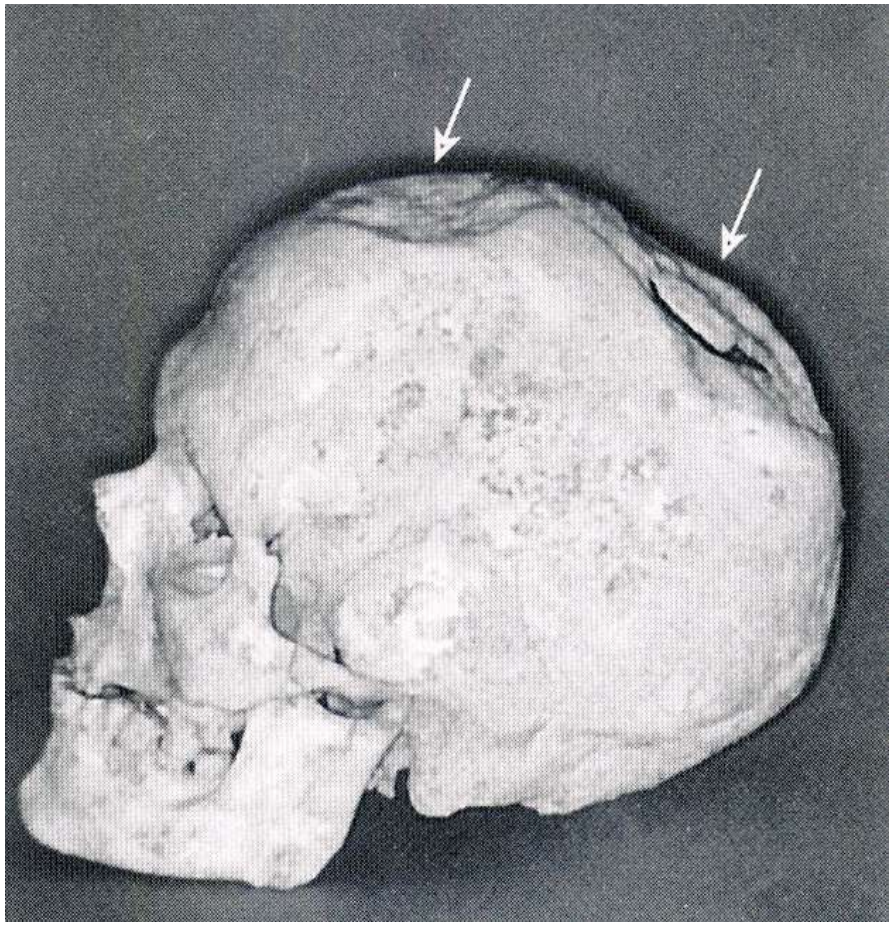
Sunrise over the Brain

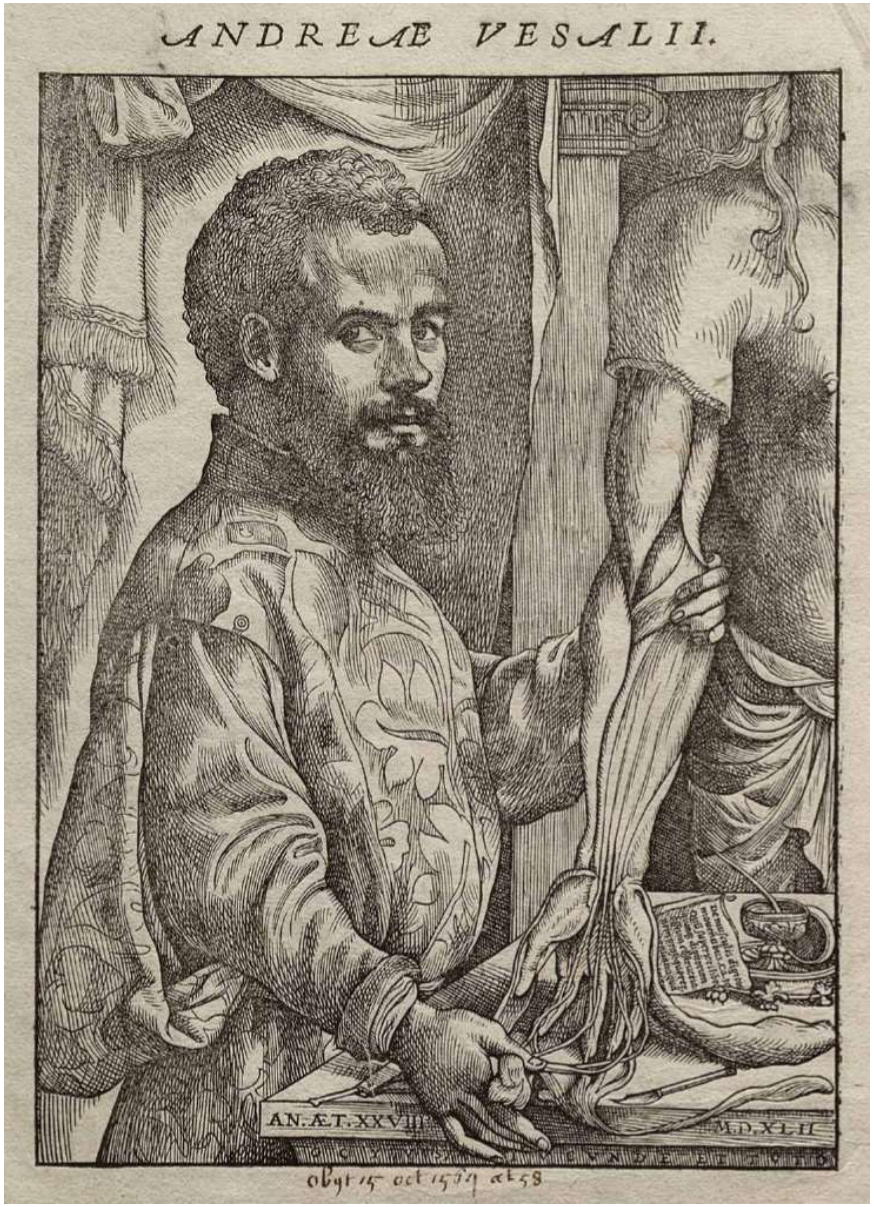
The Ascent

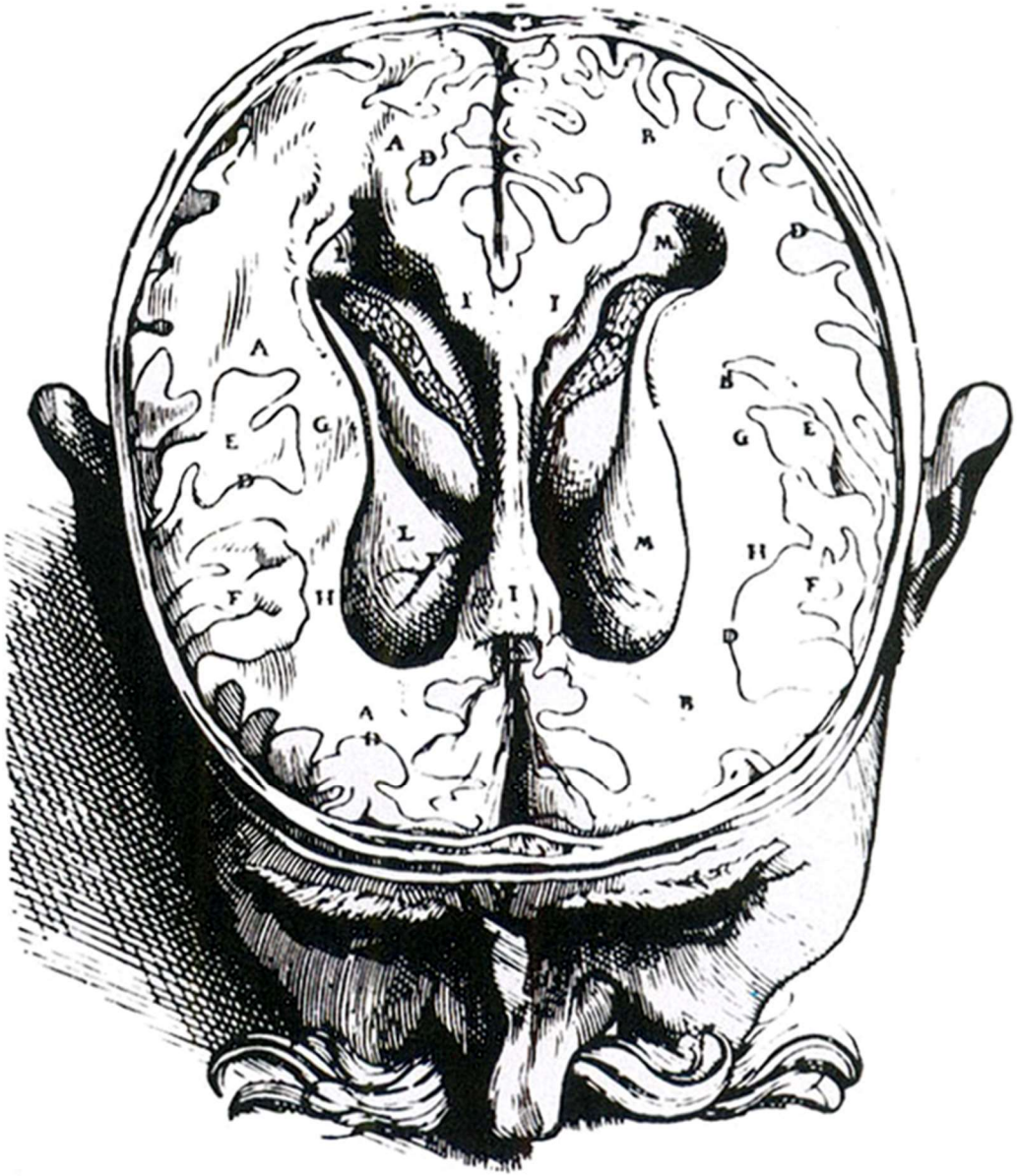
"Neuroscience" in Prehistoric Times



Evidence of Prehistoric Brain Surgery
Trepanation of a Skull more than 7000 Years ago
... Carried out on Living Subjects … and They Survived it !

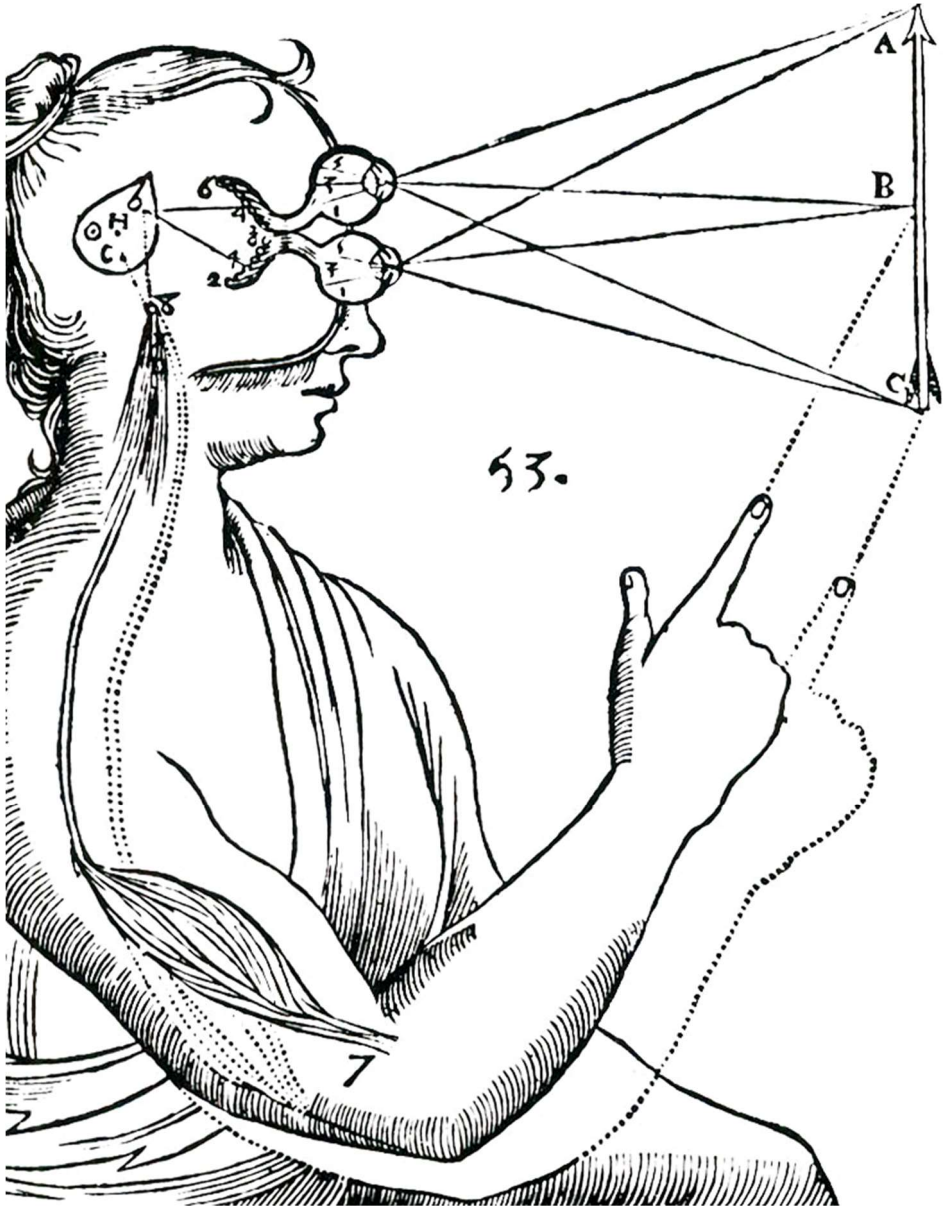
A Renaissance View of the Human Brain





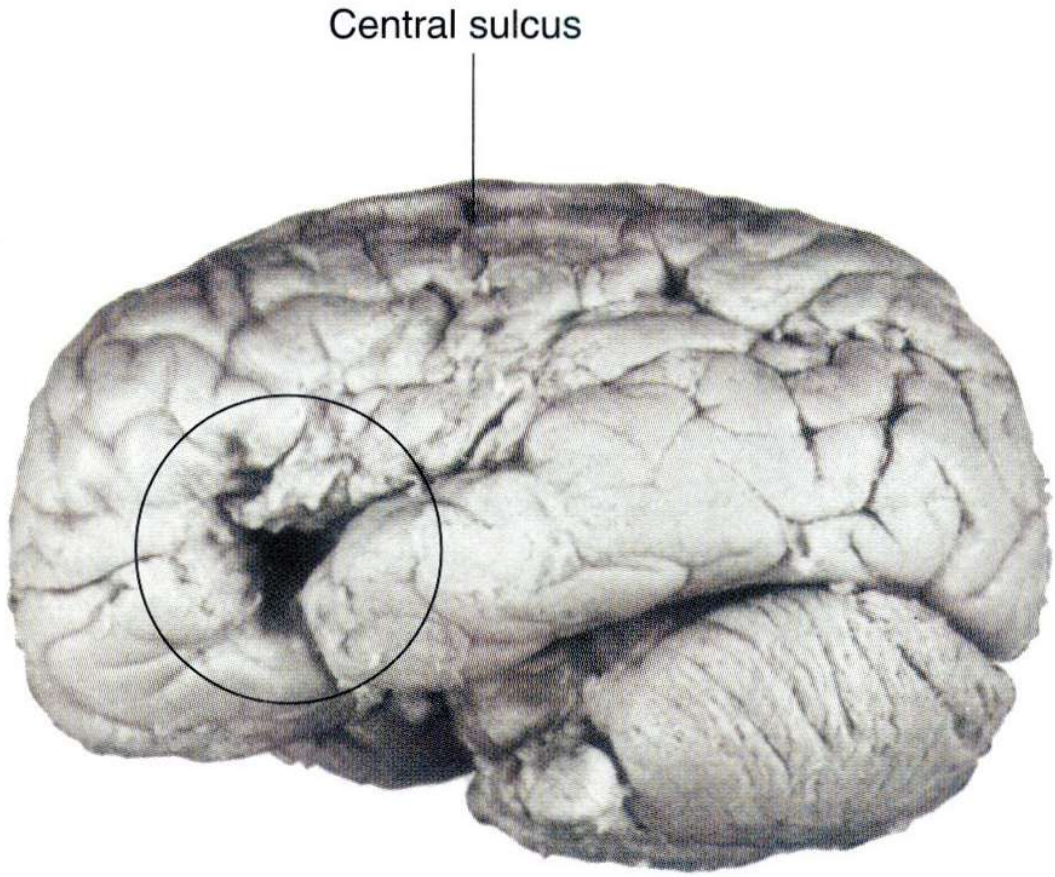
Drawing from *De Humani Corporis Fabrica* (1543) by Andreas Vesalius

The Brain According to Descartes



Drawing from *De Homine* (1662) by René Descartes

Separation of Functions in the Brain



The Brain of *Monsieur Leborgne ("Tan")* Examined by Paul Broca (1861)

Separation of Functions in the Brain

Journal of the History of the Neurosciences, 22:47–52, 2013

ISSN: 0964-704X print / 1744-5213 online
DOI: 10.1080/0964704X.2012.667528

Routledge
Taylor & Francis Group

Mysterious "*Monsieur Leborgne*": The Mystery of the Famous Patient in the History of Neuropsychology is Explained

CEZARY W. DOMANSKI

Institute of Psychology, Maria Curie-Sklodowska University, Lublin, Poland

As of spring 2011, 150 years have passed since the death of one of the most famous neurological patients of the nineteenth century. A Frenchman, "Monsieur Leborgne" also known by the nickname "Tan," was hospitalized due to an almost complete loss of speech. His case was presented in 1861, during a seating of the Société d'Anthropologie de Paris by a physician, Pierre Paul Broca (1824–1880), who used this occasion to report that he had discovered, in the middle part of patient's left frontal lobe, the cortical speech center. This area was later named "Broca's area." Both the patient and his medical records were the subject of numerous descriptions and citations in the medical literature. The patient's full identity and social background has remained a mystery until now. This article presents biographical data concerning Leborgne and his family based on archive registers in France.

Separation of Functions in the Brain

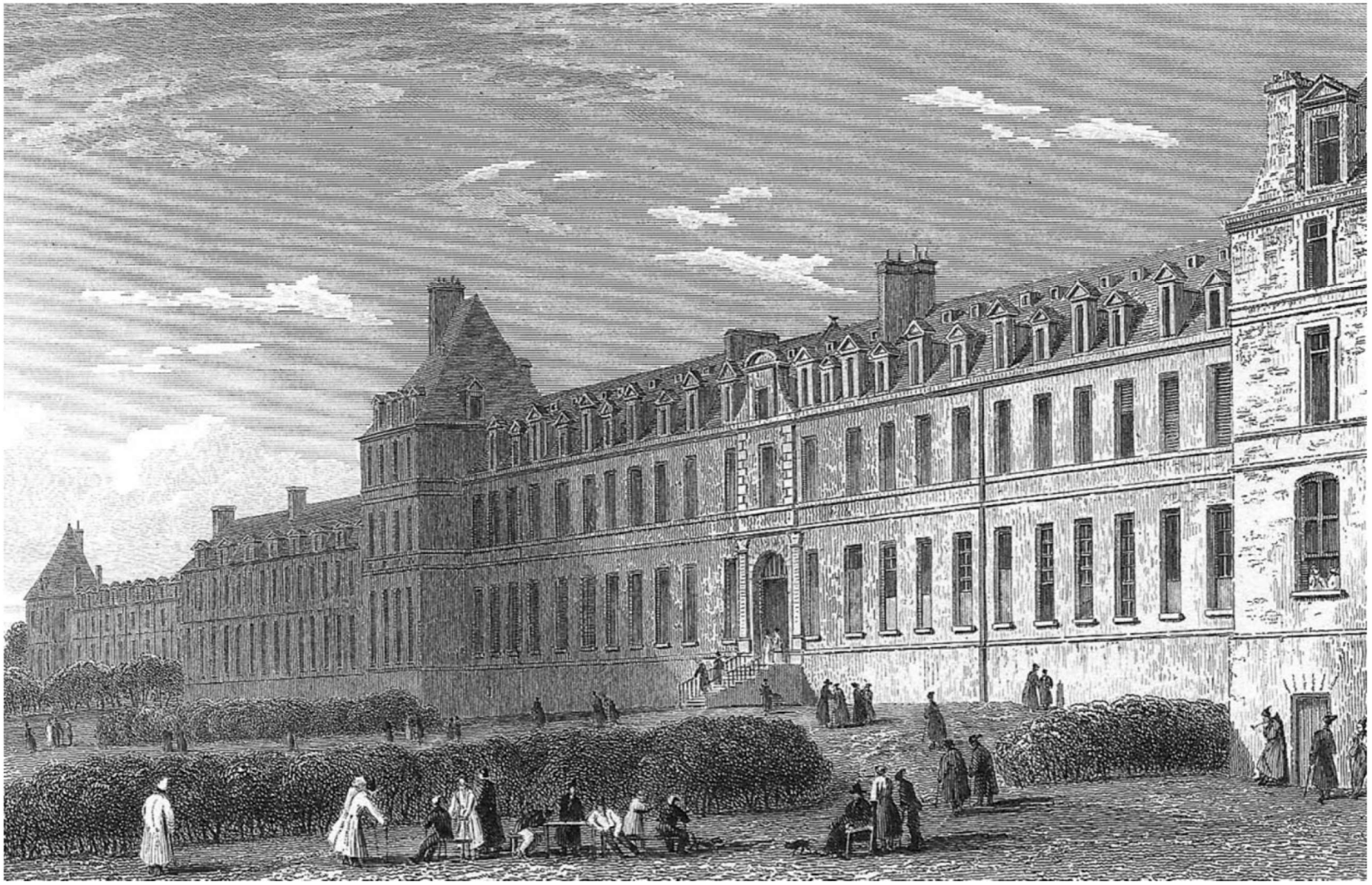
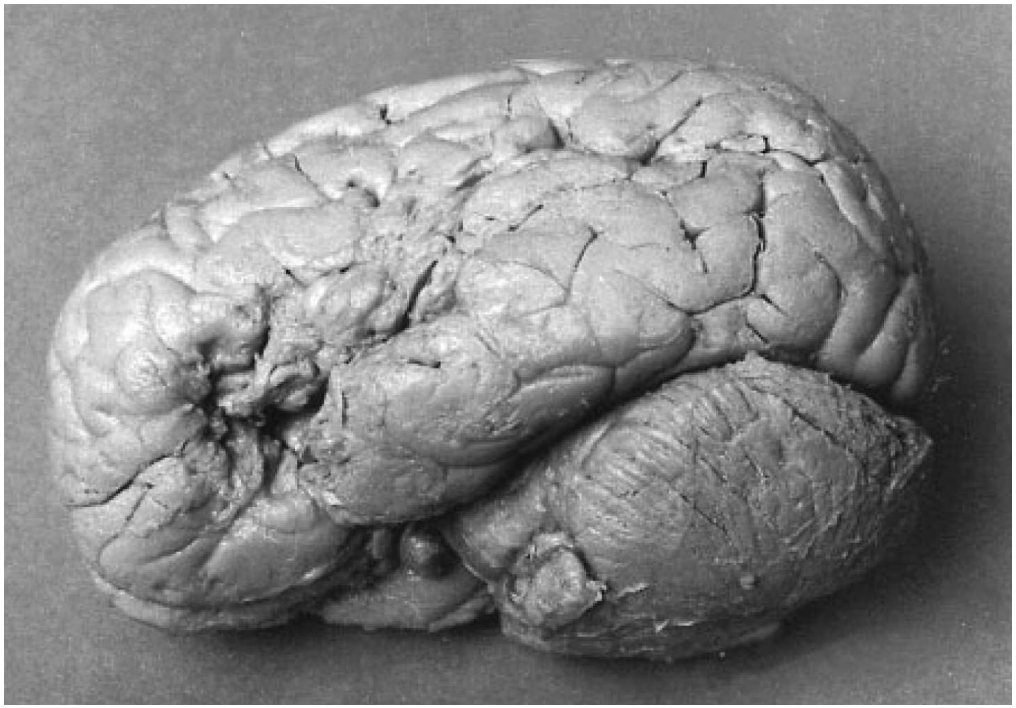


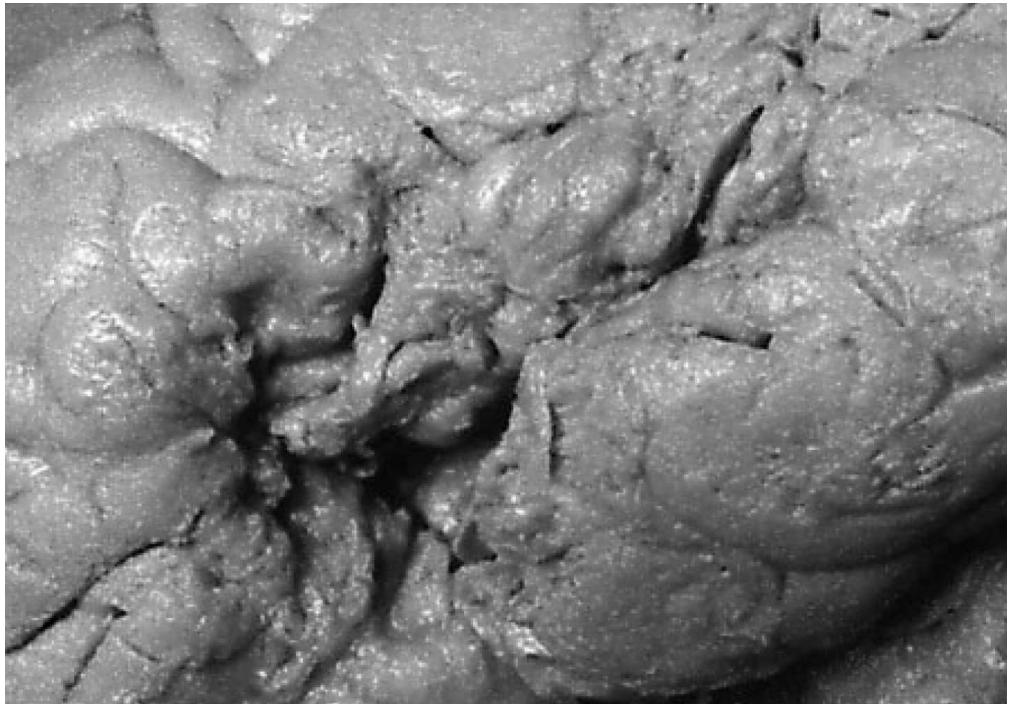
Figure 1. The Bicêtre Hospital near Paris (ca. 1830). Steel engraving drawn by T. Nash, engraved by Miss Letitia Byrne (illustration in author's collection).

Domanski
Journal of the History of the Neurosciences 2013

Separation of Functions in the Brain

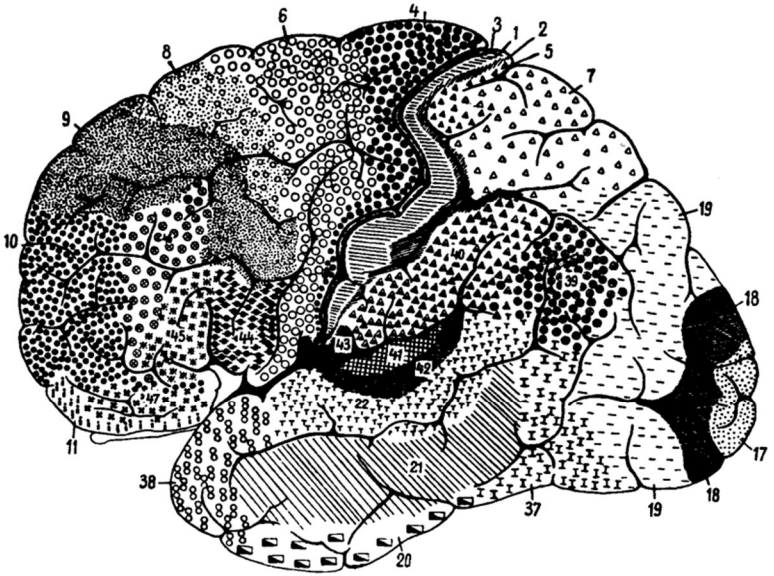


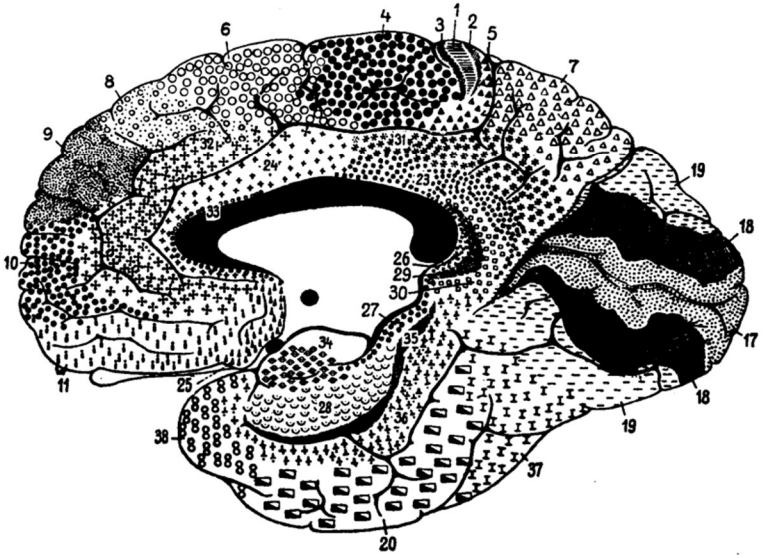
The Brain of
Monsieur Leborgne



Dronkers et al. Brain 2007

… and its Anatomical Correlate

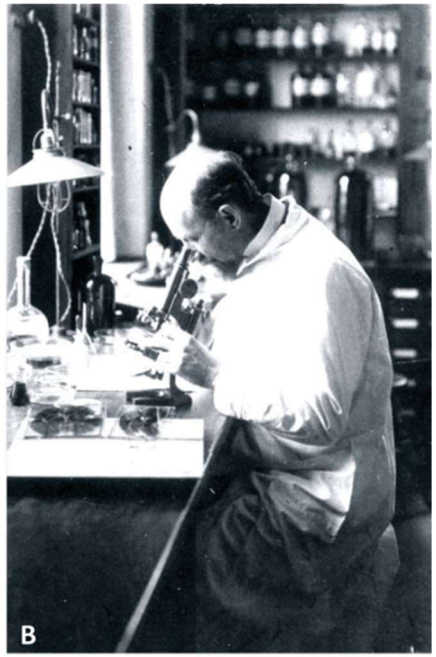


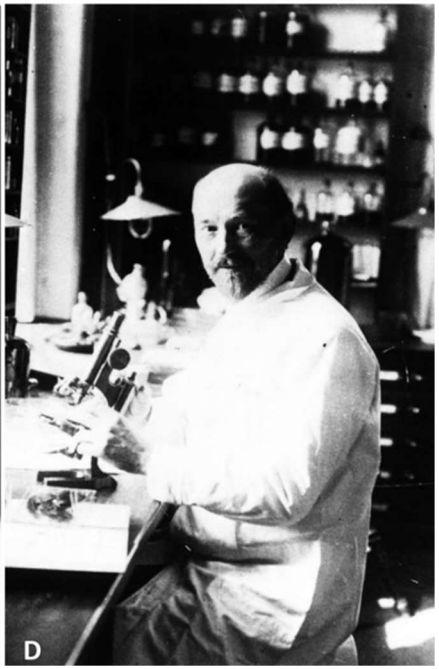


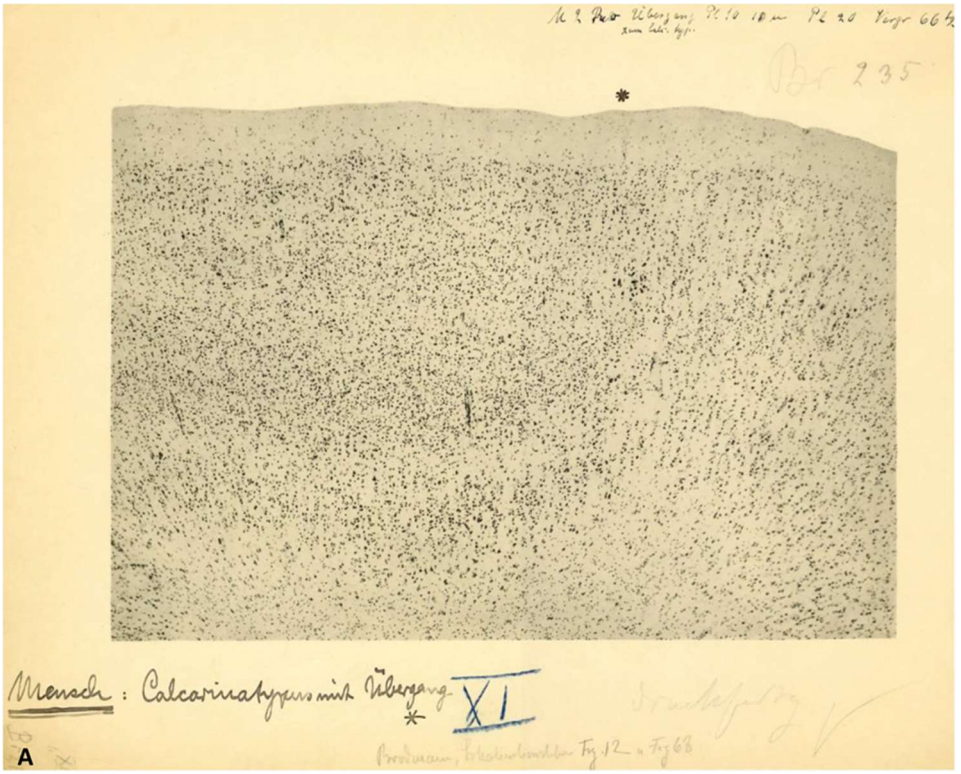
Cytoarchitectonic Brain Map (1909) by Korbinian Brodmann

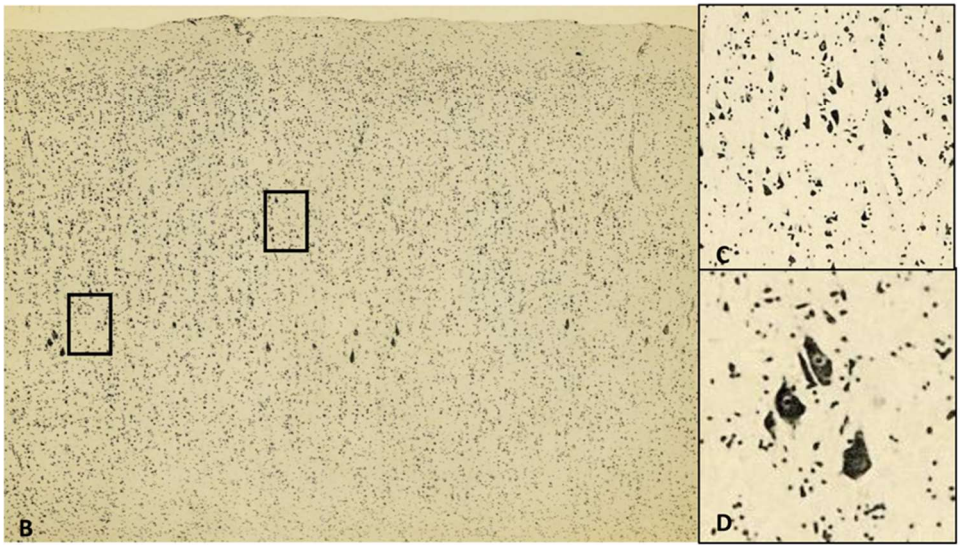
… and its Anatomical Correlate

Neurobiological Central Station
Berlin, Magdeburger Str. 16



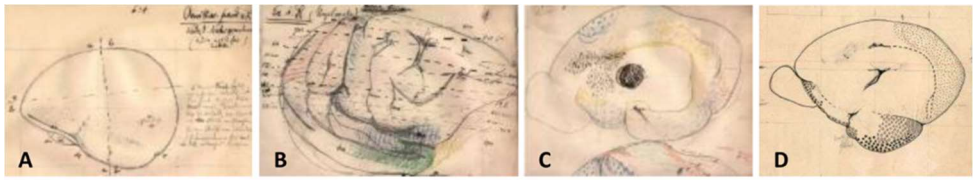


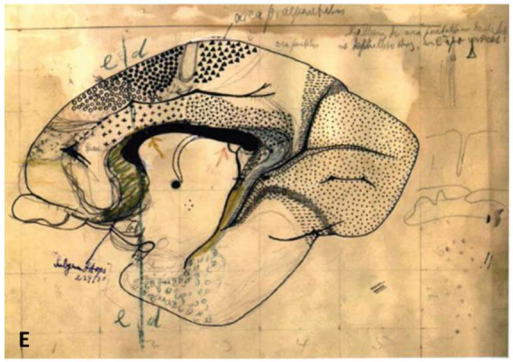


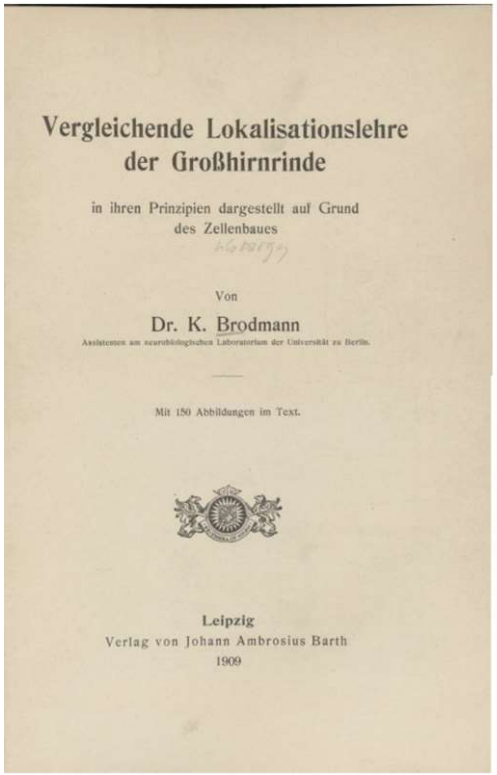


Zilles
Brain
2018

… and its Anatomical Correlate







Vergleichende Lokalisationslehre
der Großhirnrinde

in ihren Prinzipien dargestellt auf Grund
des Zellenbaues

Von

Dr. K. Brodmann

Assistenten am neurobiologischen Laboratorium der Universität zu Berlin.

Mit 150 Abbildungen im Text.

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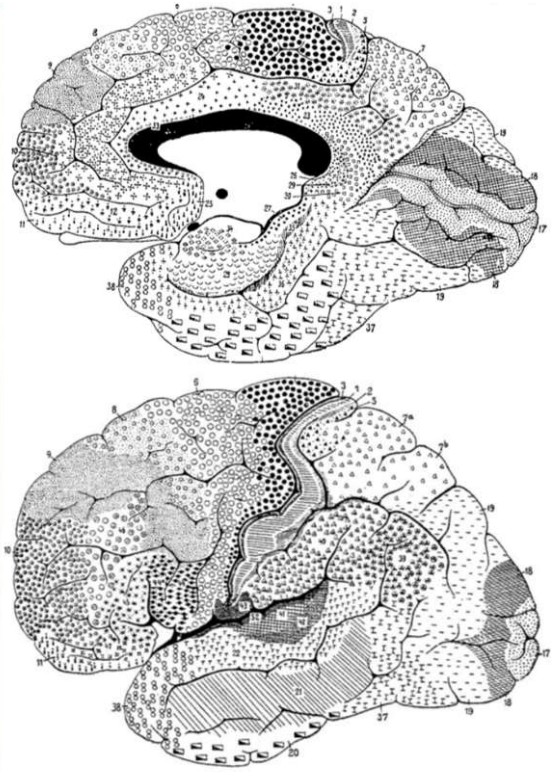
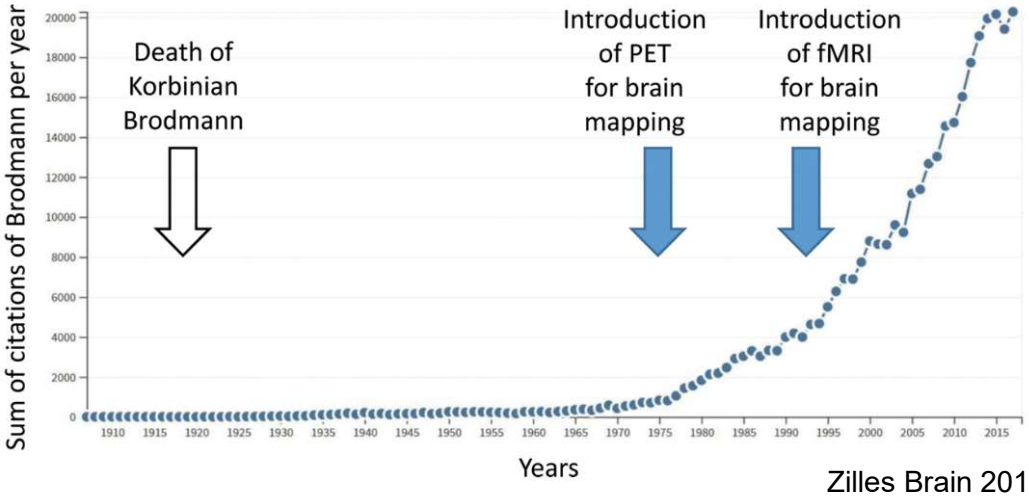
Verlag von Johann Ambrosius Barth
1909





Zilles Brain 2018

Modern Neuroscience

Molecular Neuroscience

Cellular Neuroscience

Systems Neuroscience

Behavioral Neuroscience

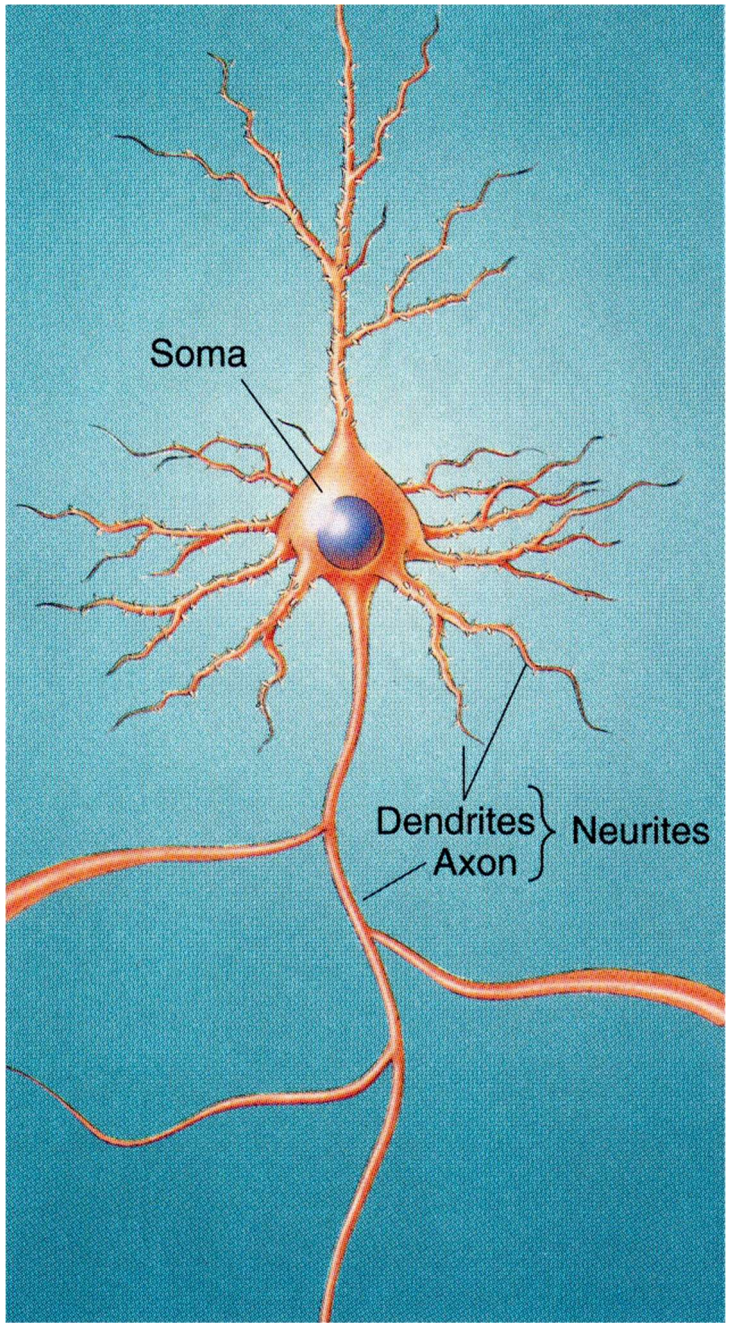
Cognitive Neuroscience

Nervous Tissue – Cell Types

Neurons or Nerve Cells

Glia or Glial Cells ("Connective Tissue")

Neuron – Structure

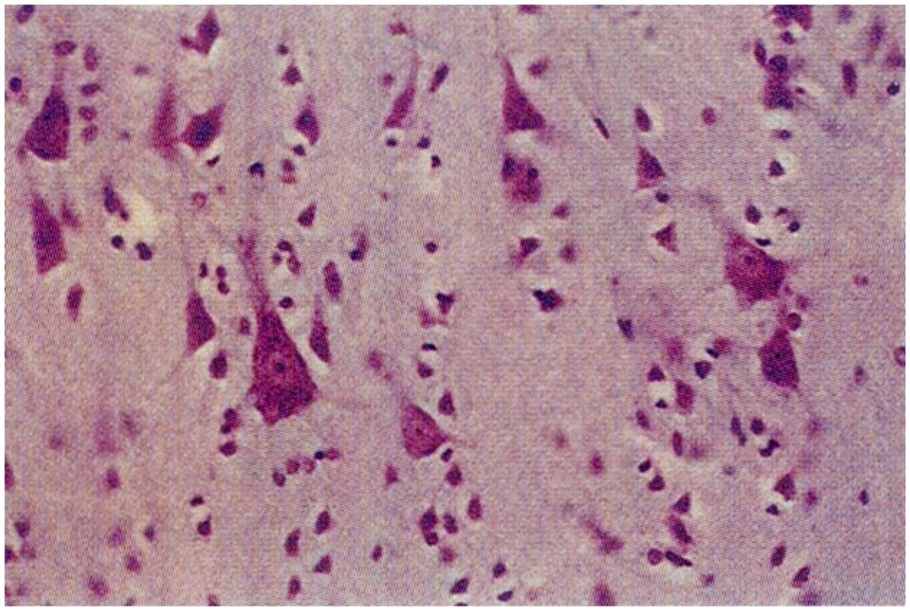


Cell Body = Soma = Perikaryon

Cell Processes = Neurites

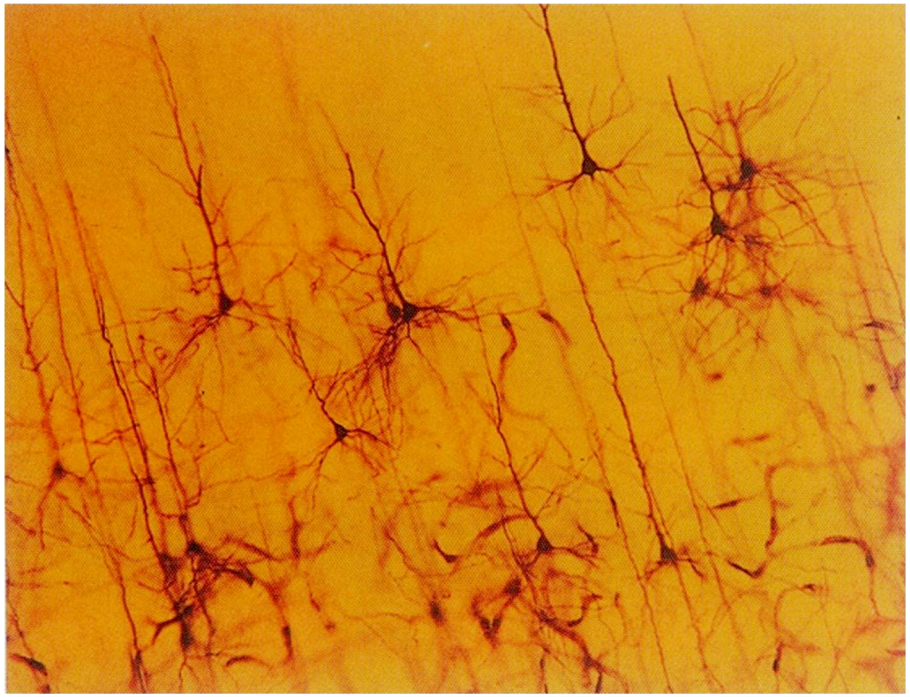
Axon	**Dendrites**
Usually one Axon	Usually several Dendrites
Long (Up to 1 Meter !)	Short (Several Millimeters !)
Few Branches	Many Branches
"Transmitter"	"Receiver"

Neuron – Histology



Nissl Stain (Basic Dye):

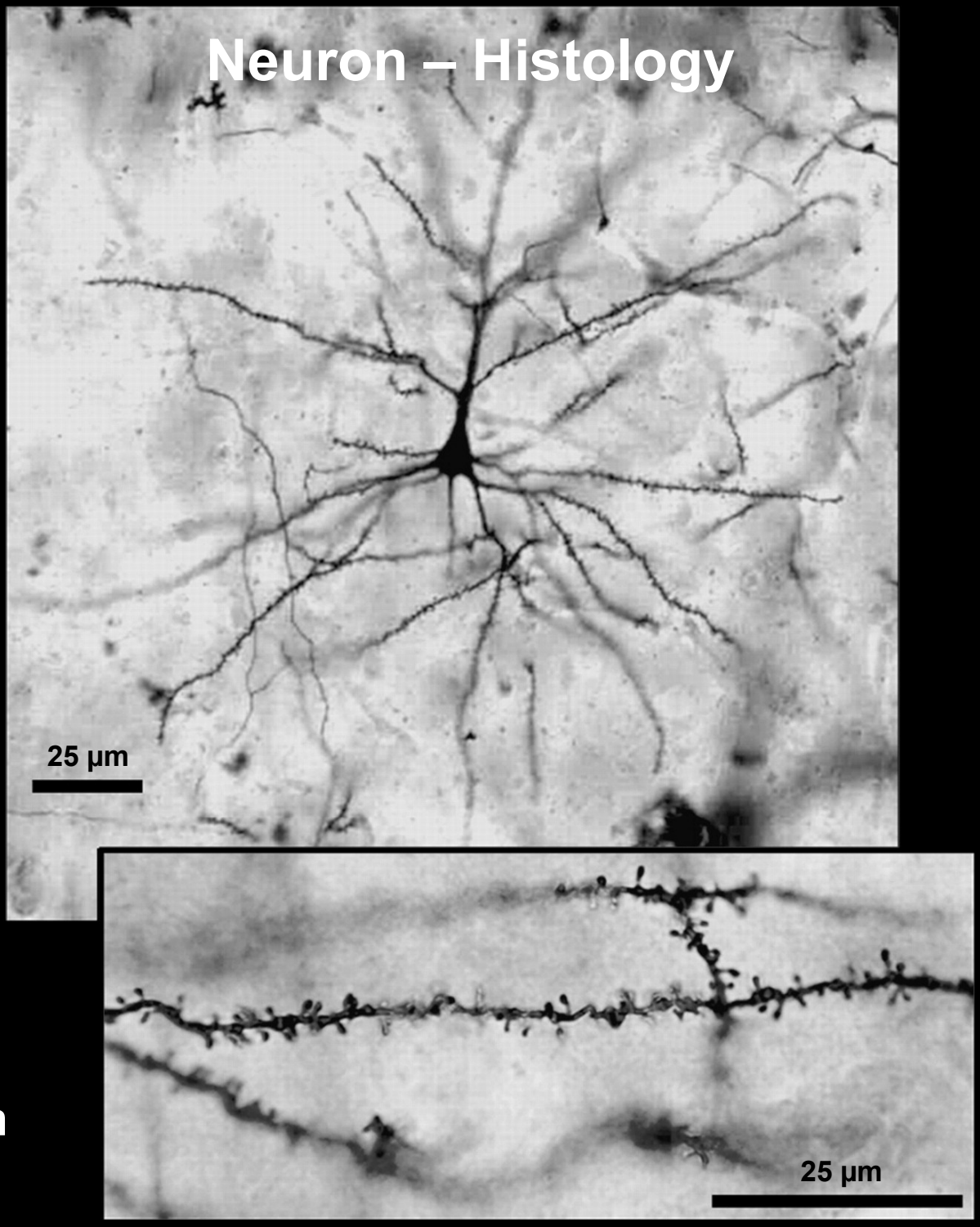
- **Nucleus (DNA) and Nucleolus (RNA)**
- **Clumps of Deeply Stained Material in the Cytoplasm (Rough Endoplasmic Reticulum) = Nissl Bodies**



Golgi Stain (Silver Impregnation):

- **Cell Body (Perikaryon)**
- **Axon**
- **Dendrites**

Neuron – Histology



Golgi Impregnation

Anderson et al.
Cerebral Cortex 2009

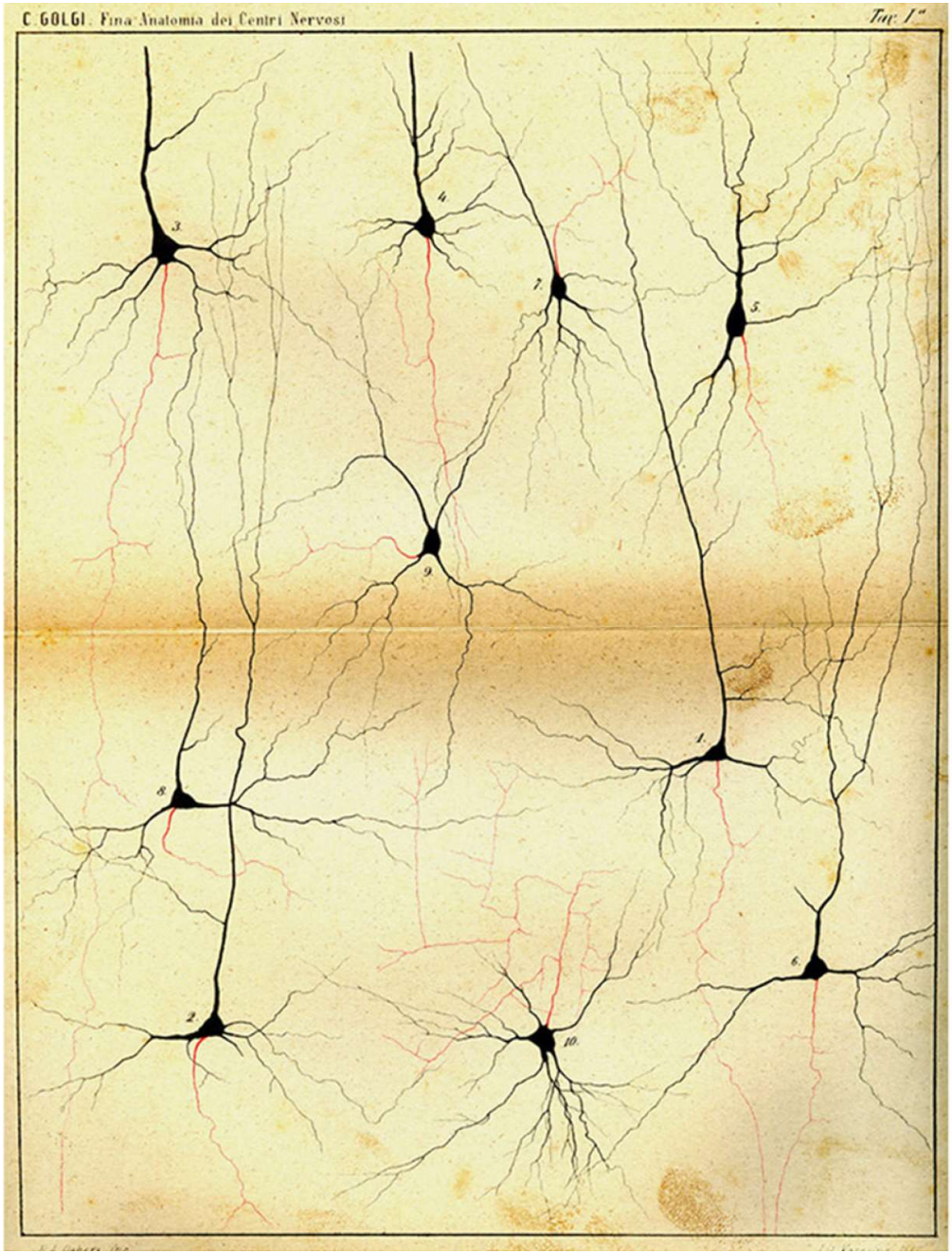
Camillo Golgi – University of Pavia – Around 1920

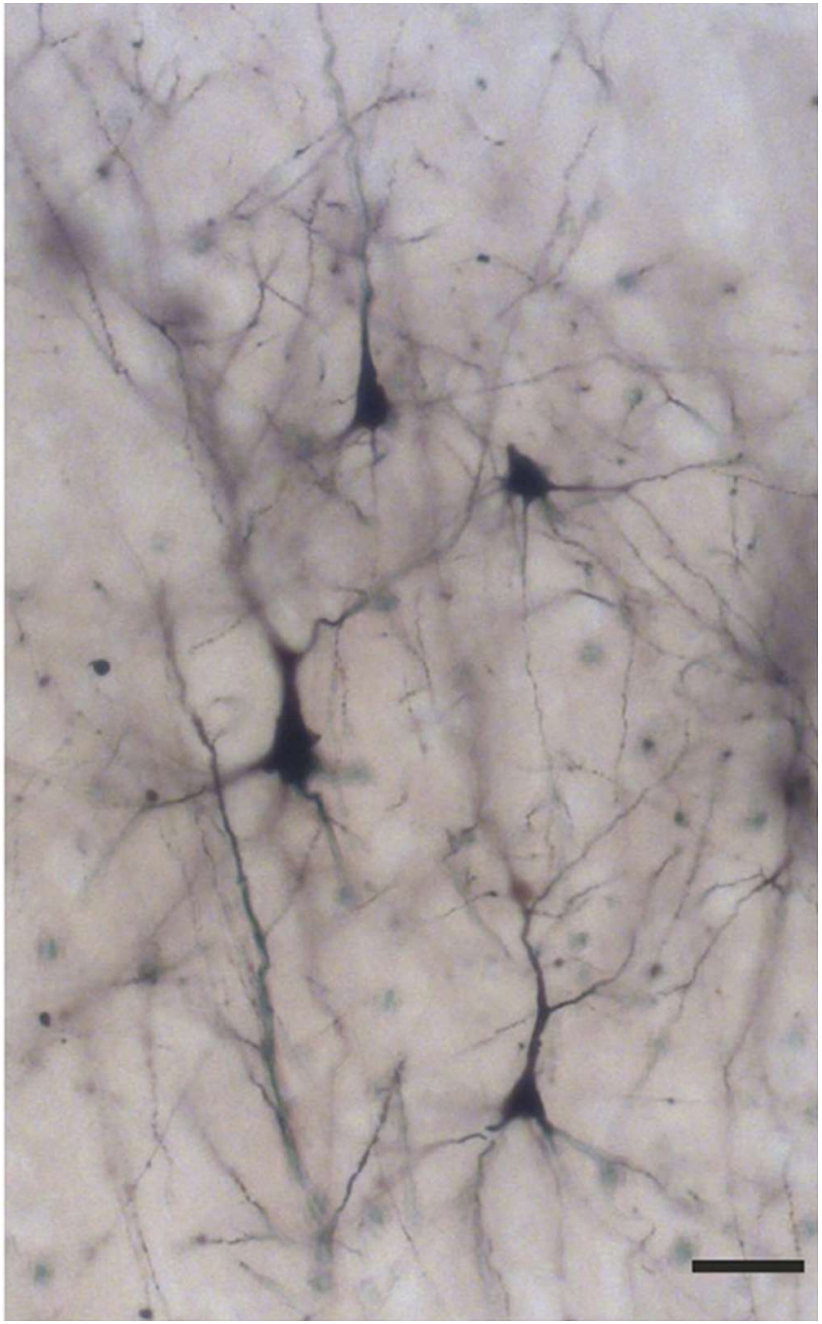
Bentivoglio et al. Frontiers in Neuroanatomy 2019

Equipment of Golgi‘s Lab – Around 1875

Bentivoglio et al. Frontiers in Neuroanatomy 2019

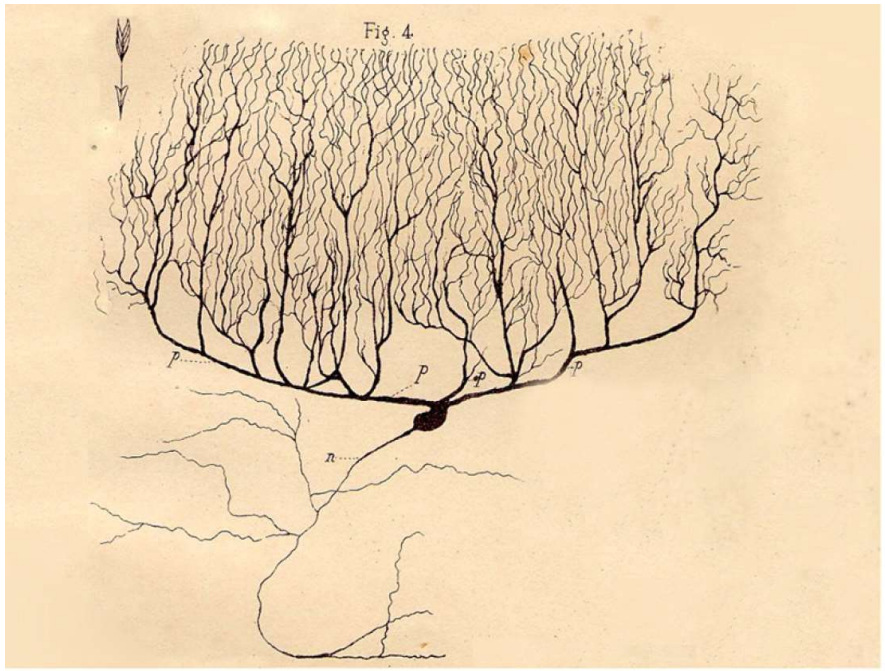
Golgi-Impregnated Neurons – Cerebral Cortex

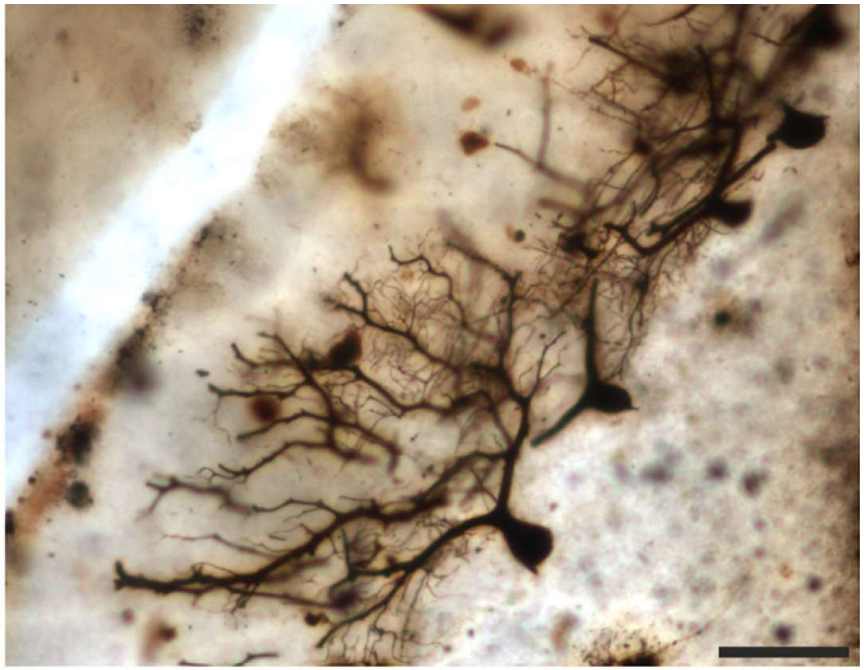


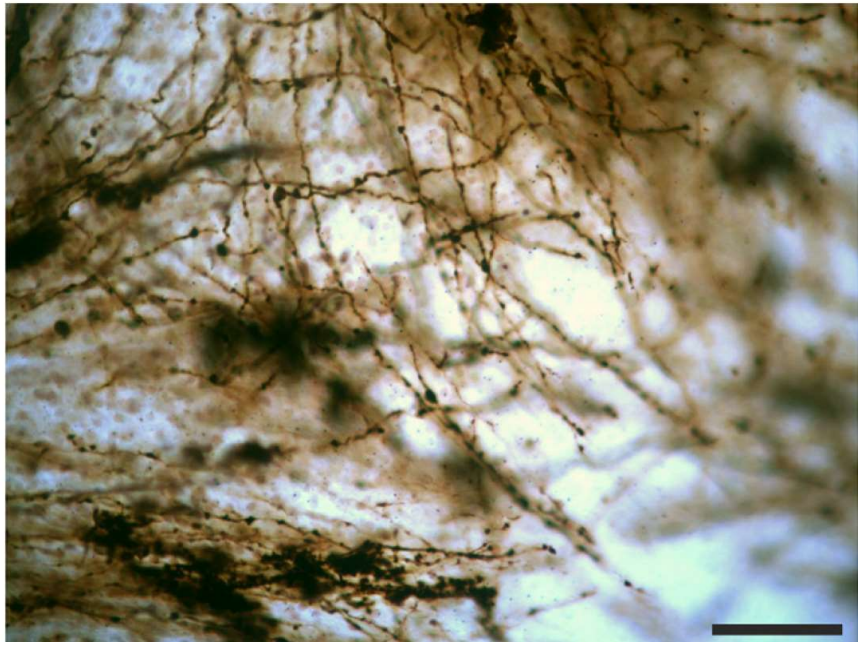


Bentivoglio et al. Frontiers in Neuroanatomy 2019

Golgi-Impregnated Neurons (Purkinje Cells) – Cerebellum

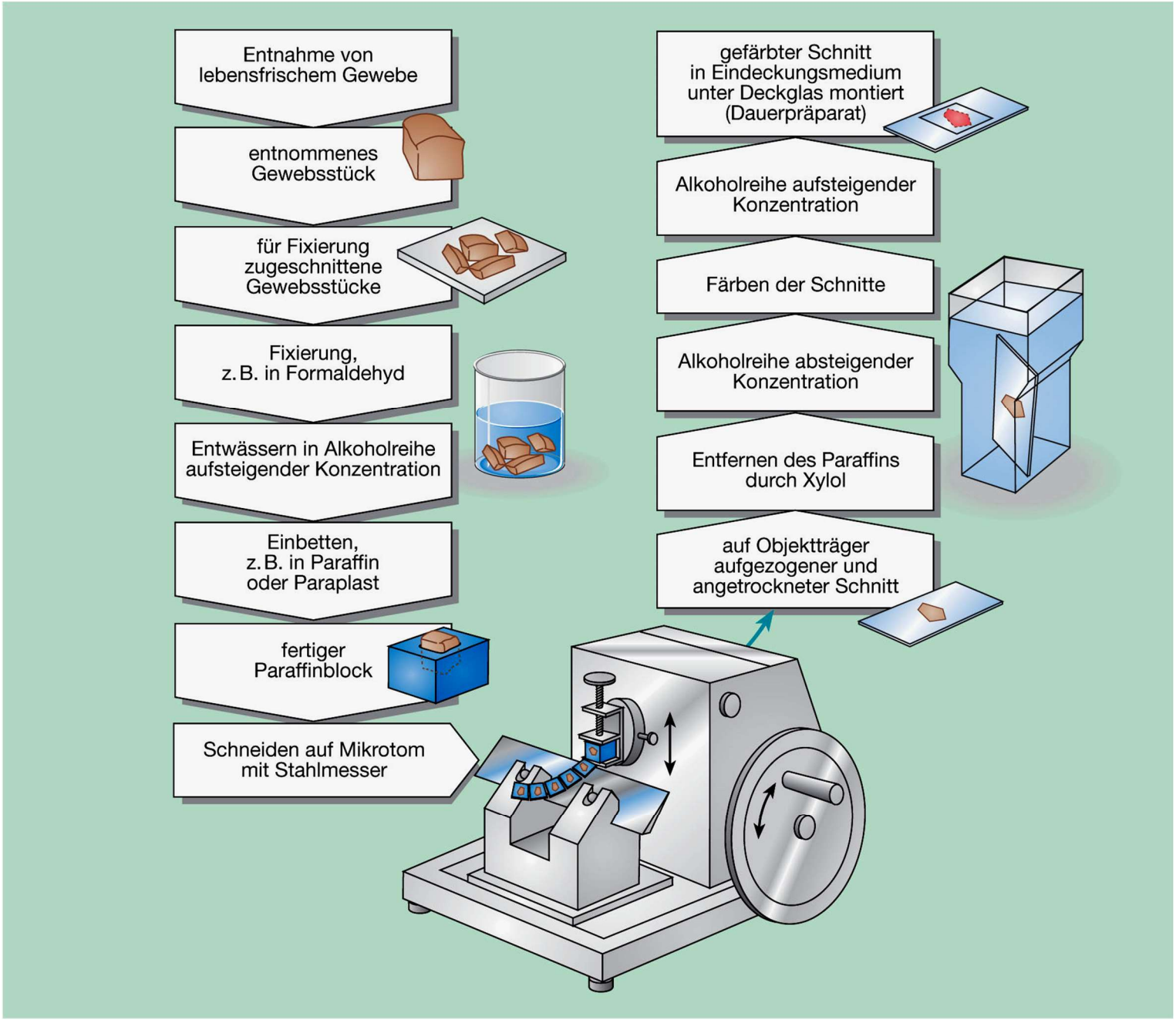




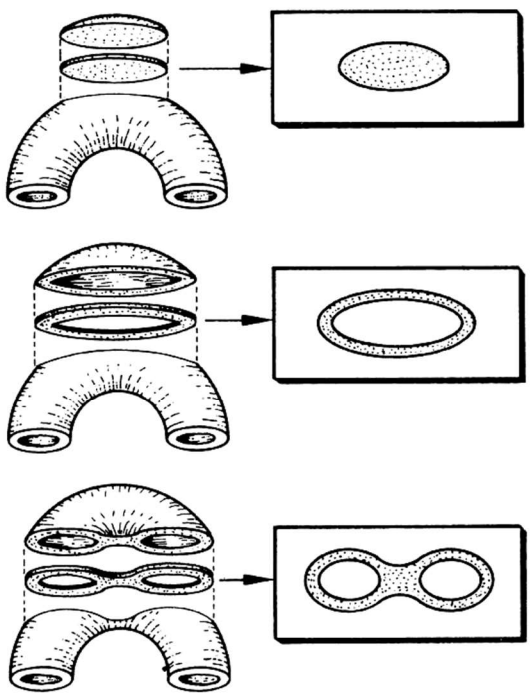


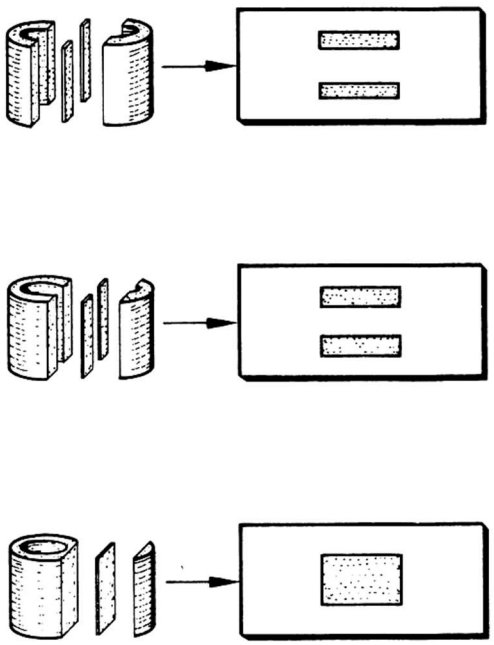
Bentivoglio et al. Frontiers in Neuroanatomy 2019

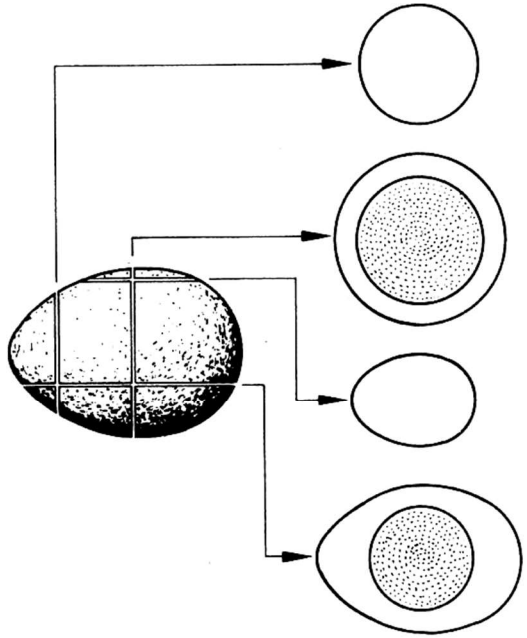
Histology Techniques

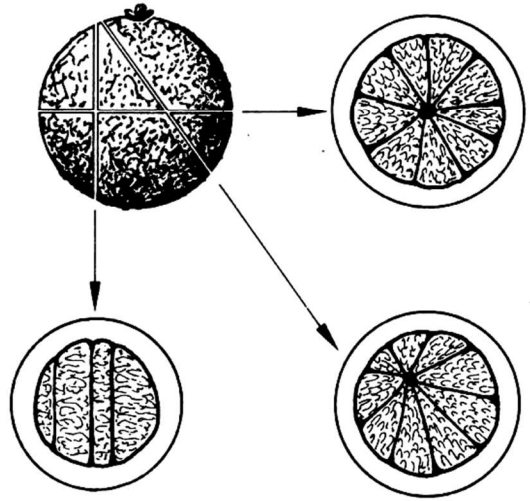


From 2-D to 3-D



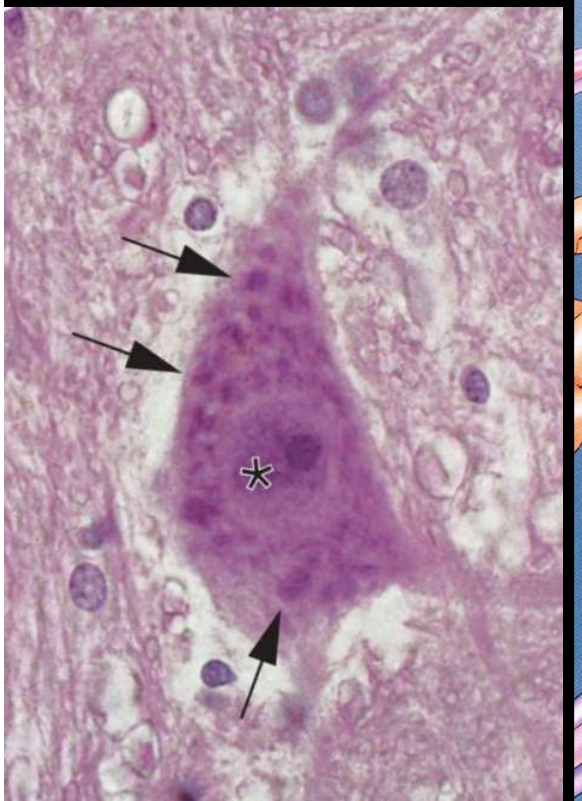






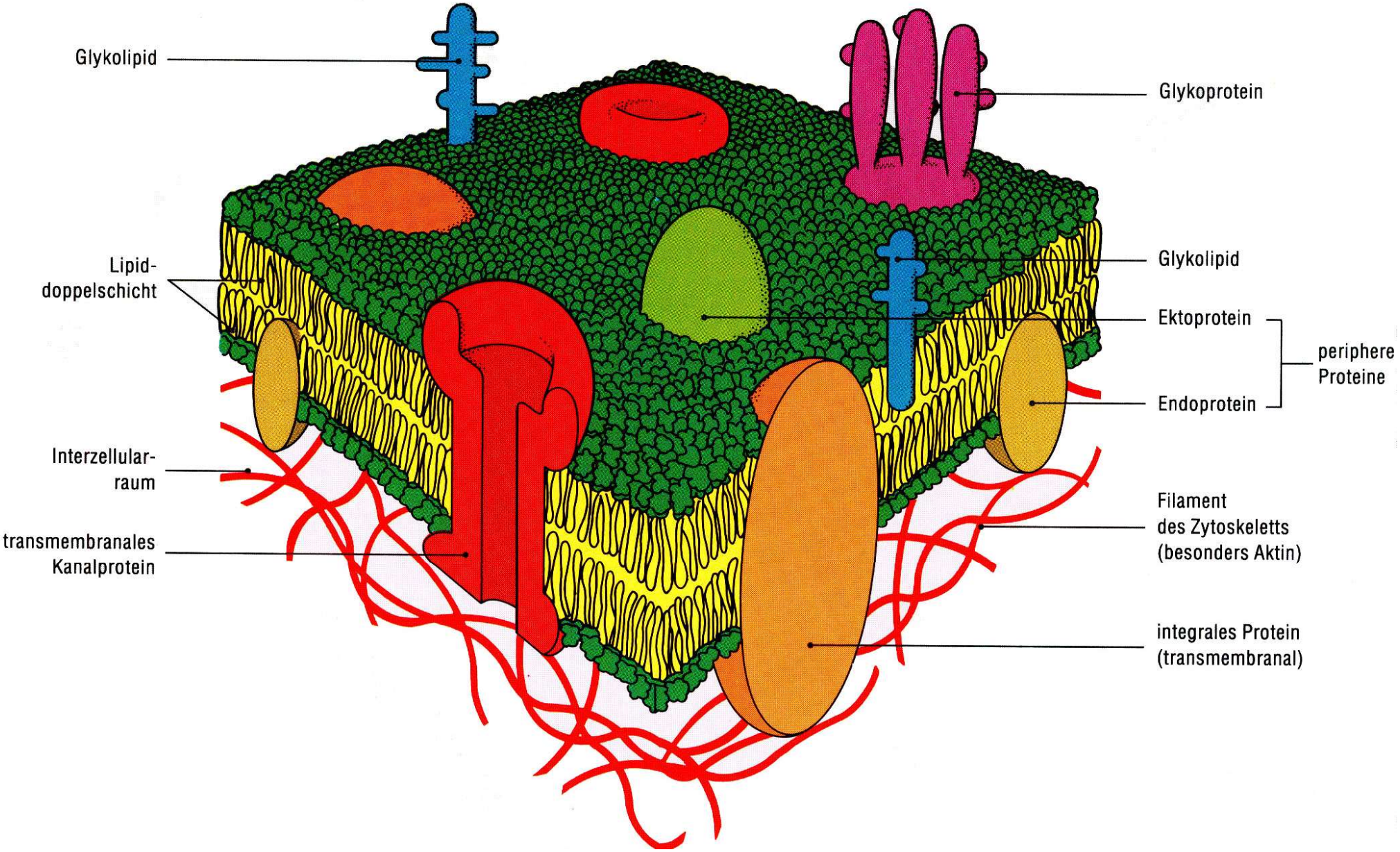
Correct Interpretation of Sections

Prototypical Neuron

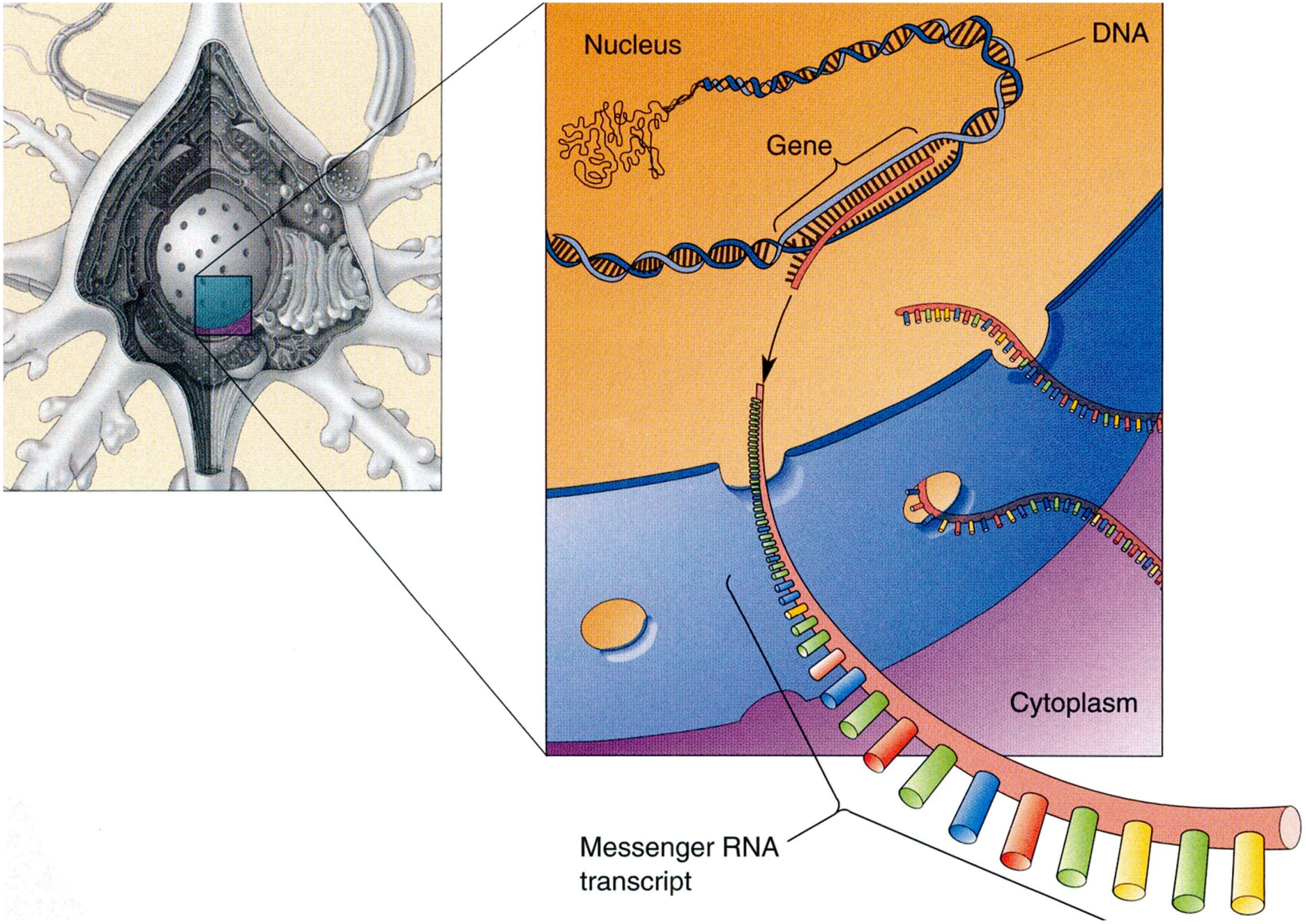


Neuronal membrane
Mitochondrion
Nucleus
Rough ER
Ribosomes
Polyribosomes
Golgi apparatus
Smooth ER
Axon hillock
Microtubules
Axon

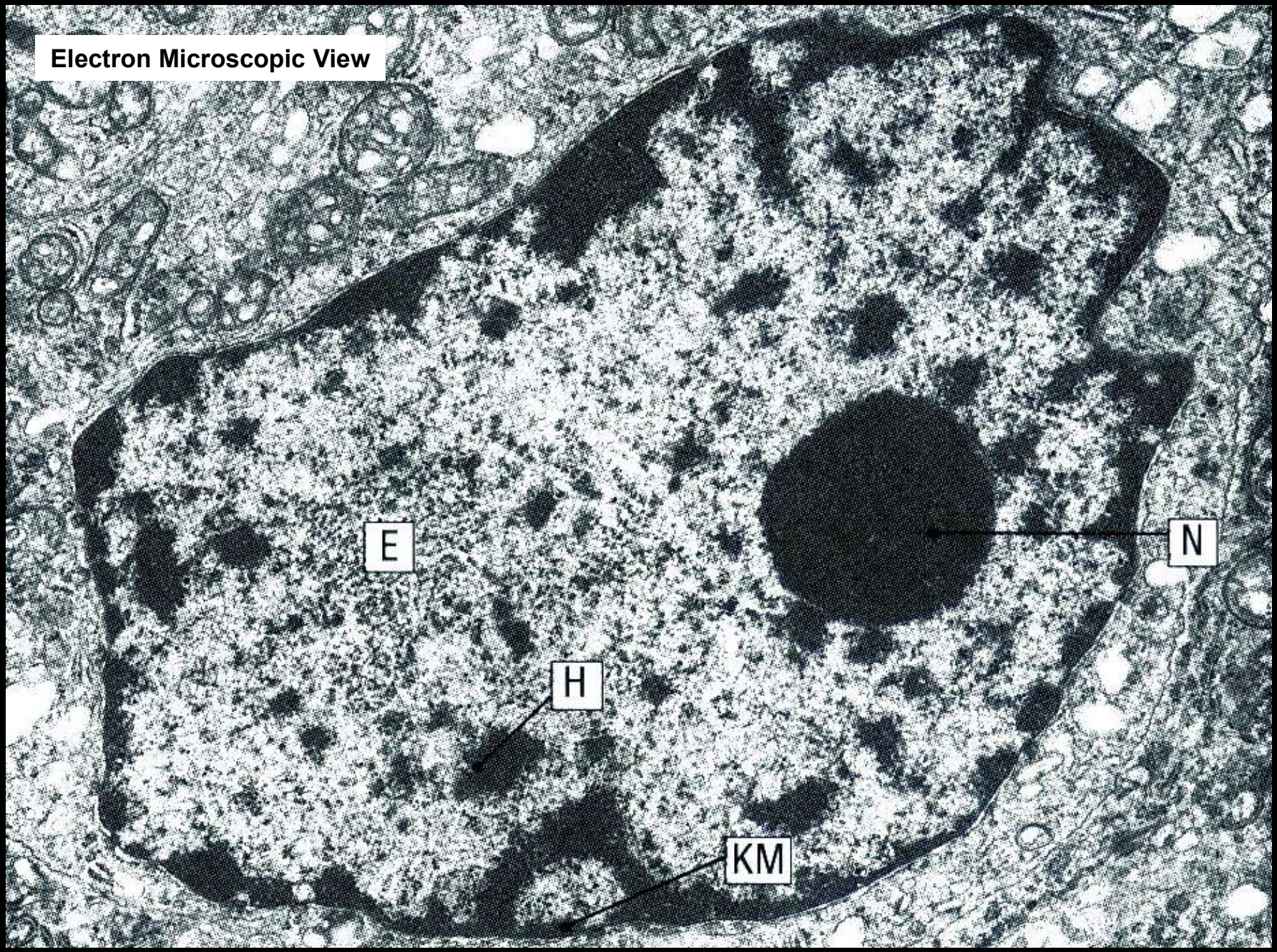
Prototypical Neuron – Cell Membrane



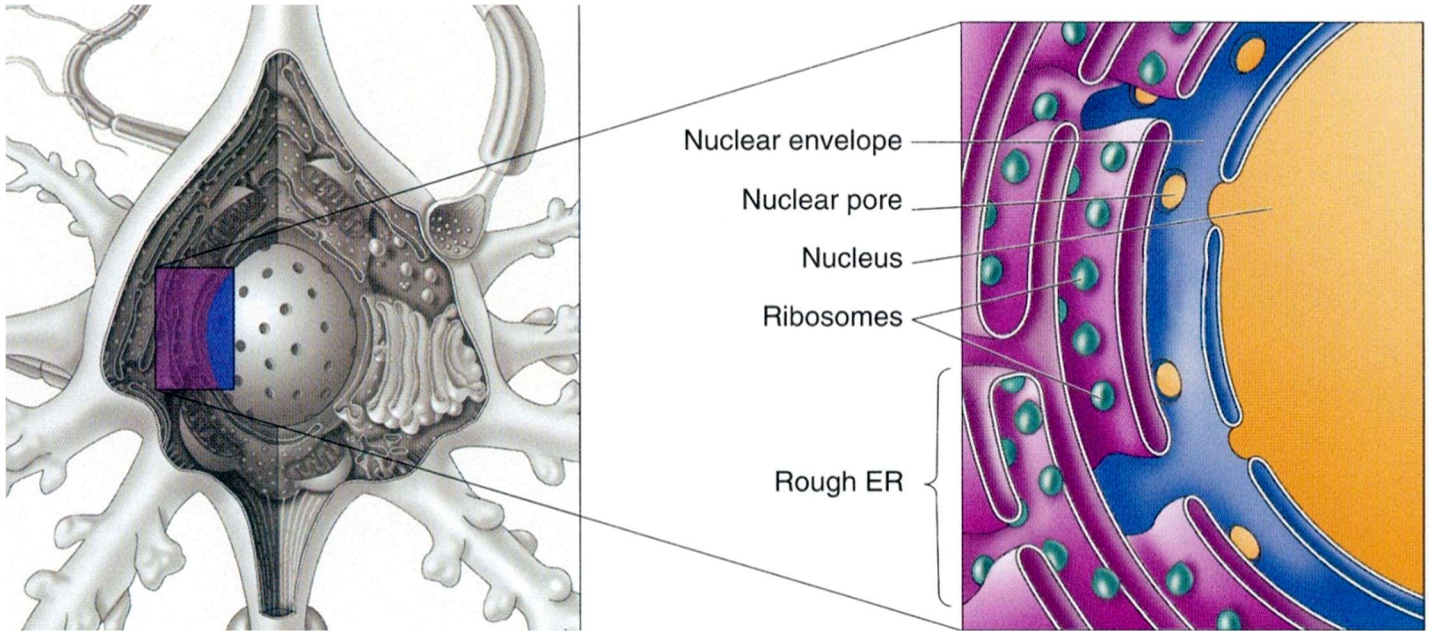
Prototypical Neuron – Nucleus

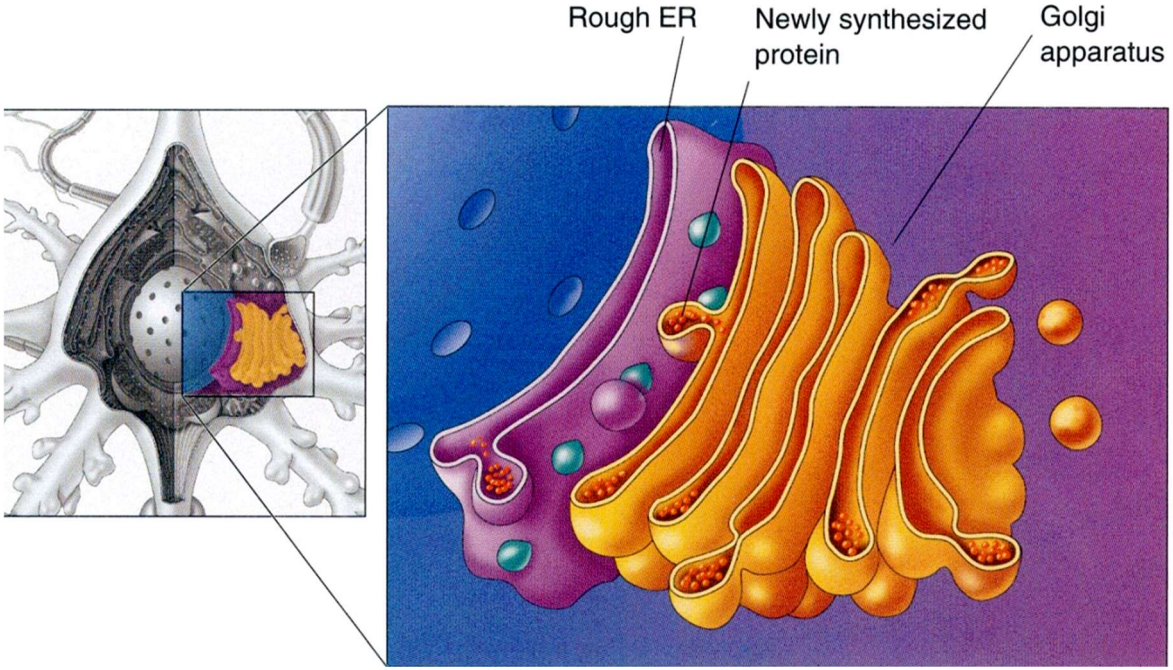


Prototypical Neuron – Nucleus



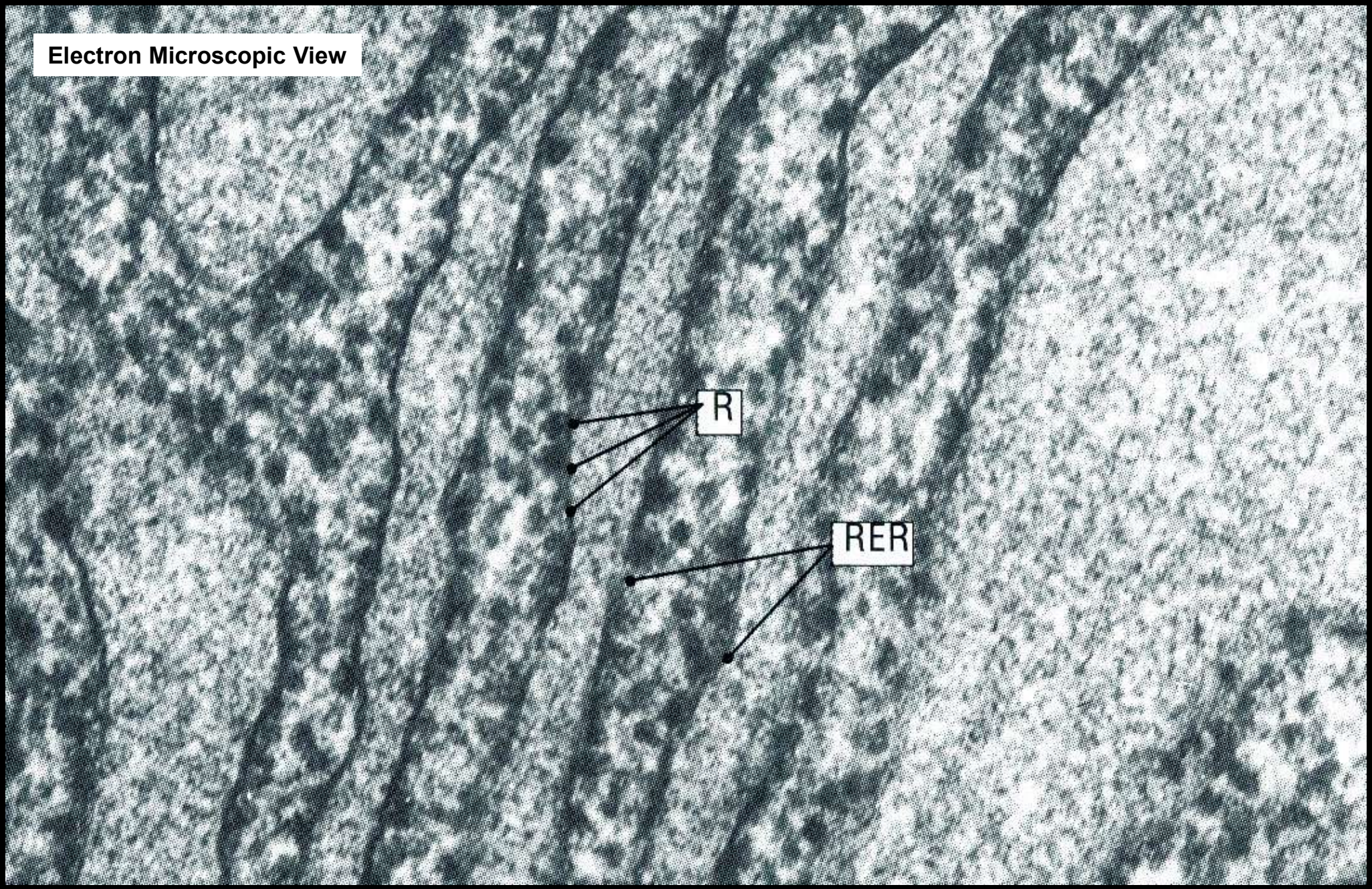
Prototypical Neuron – Rough ER and Golgi Apparatus



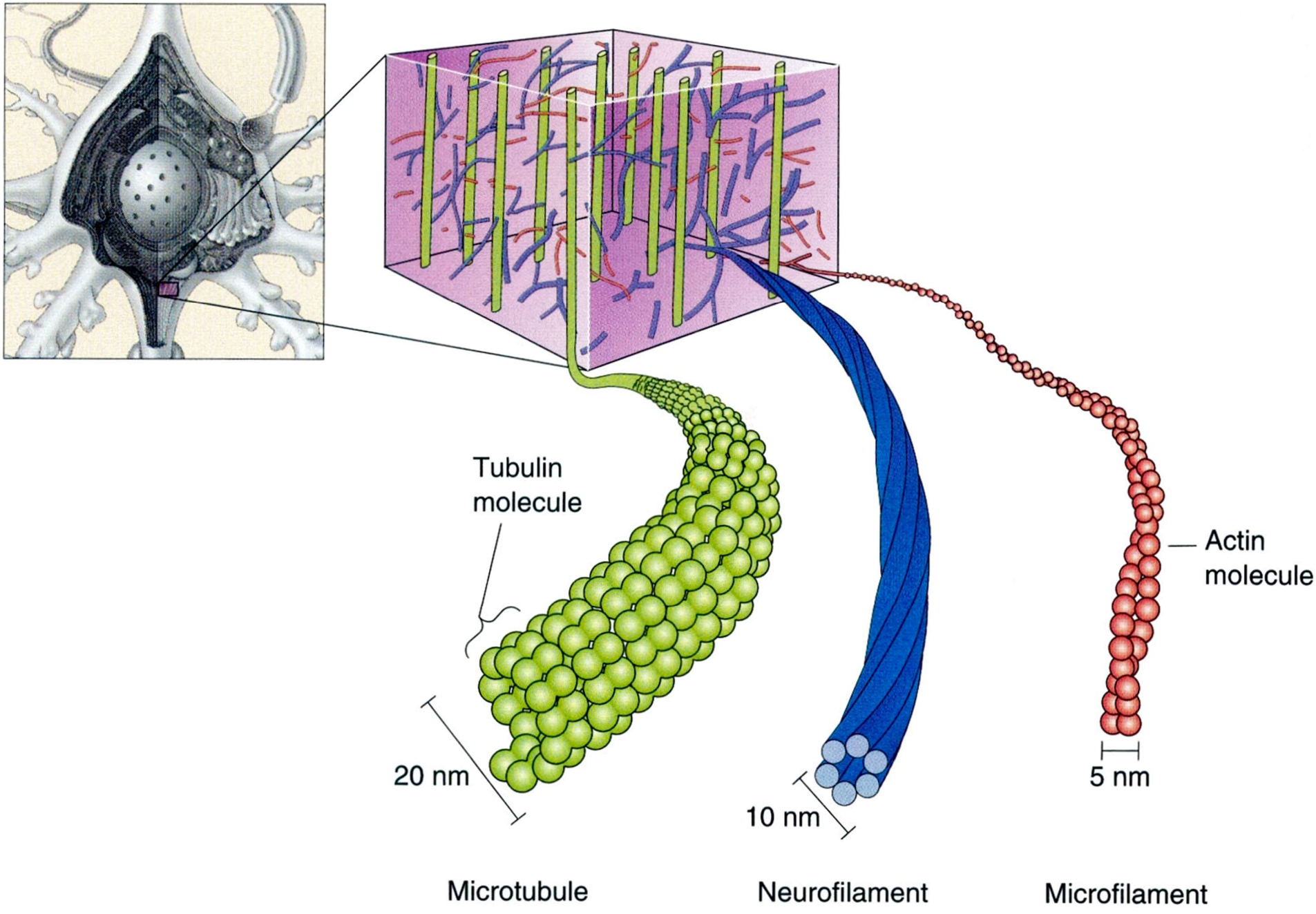


Nissl Bodies

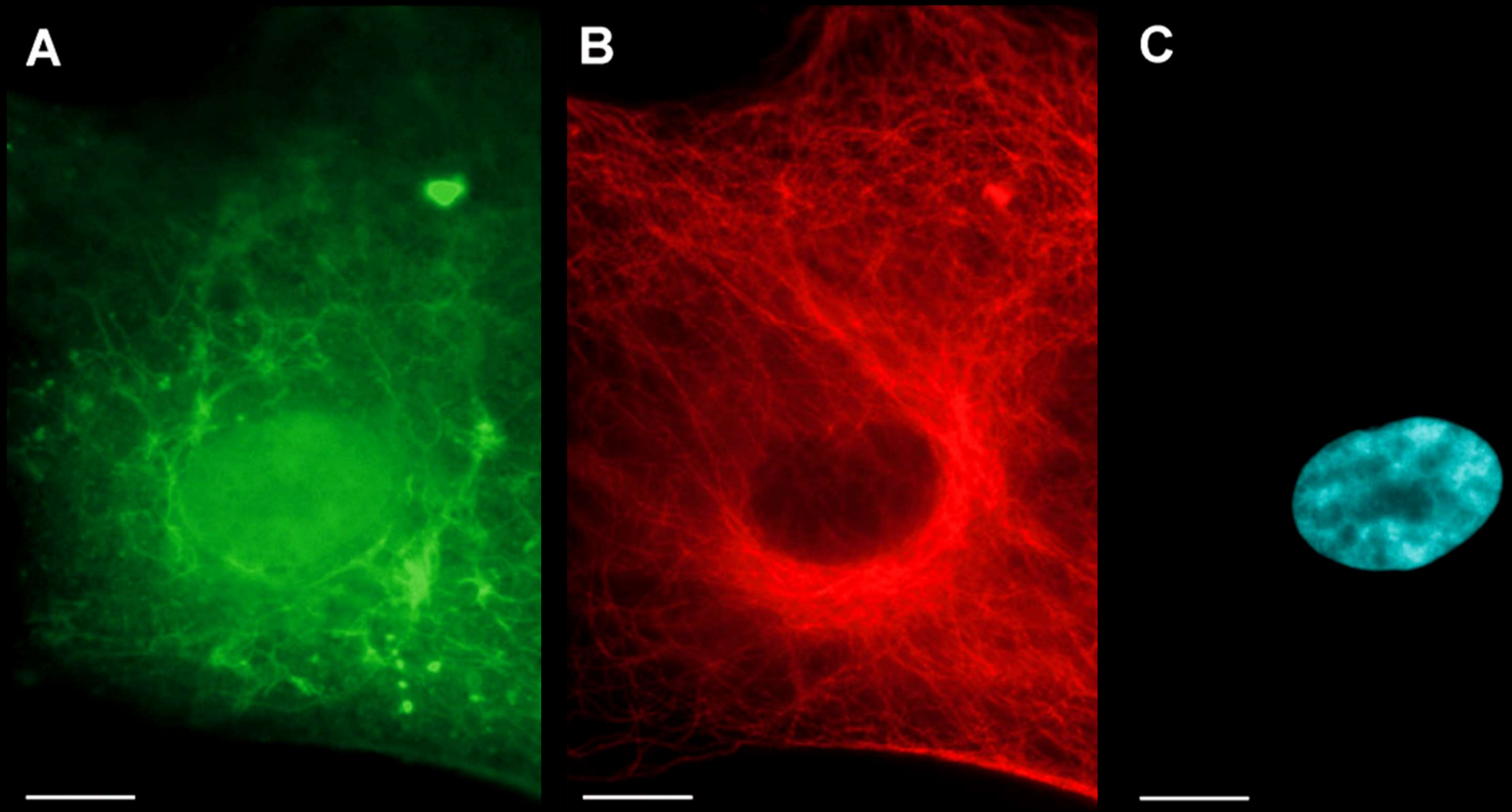
Prototypical Neuron – Rough ER



Prototypical Neuron – Cytoskeleton



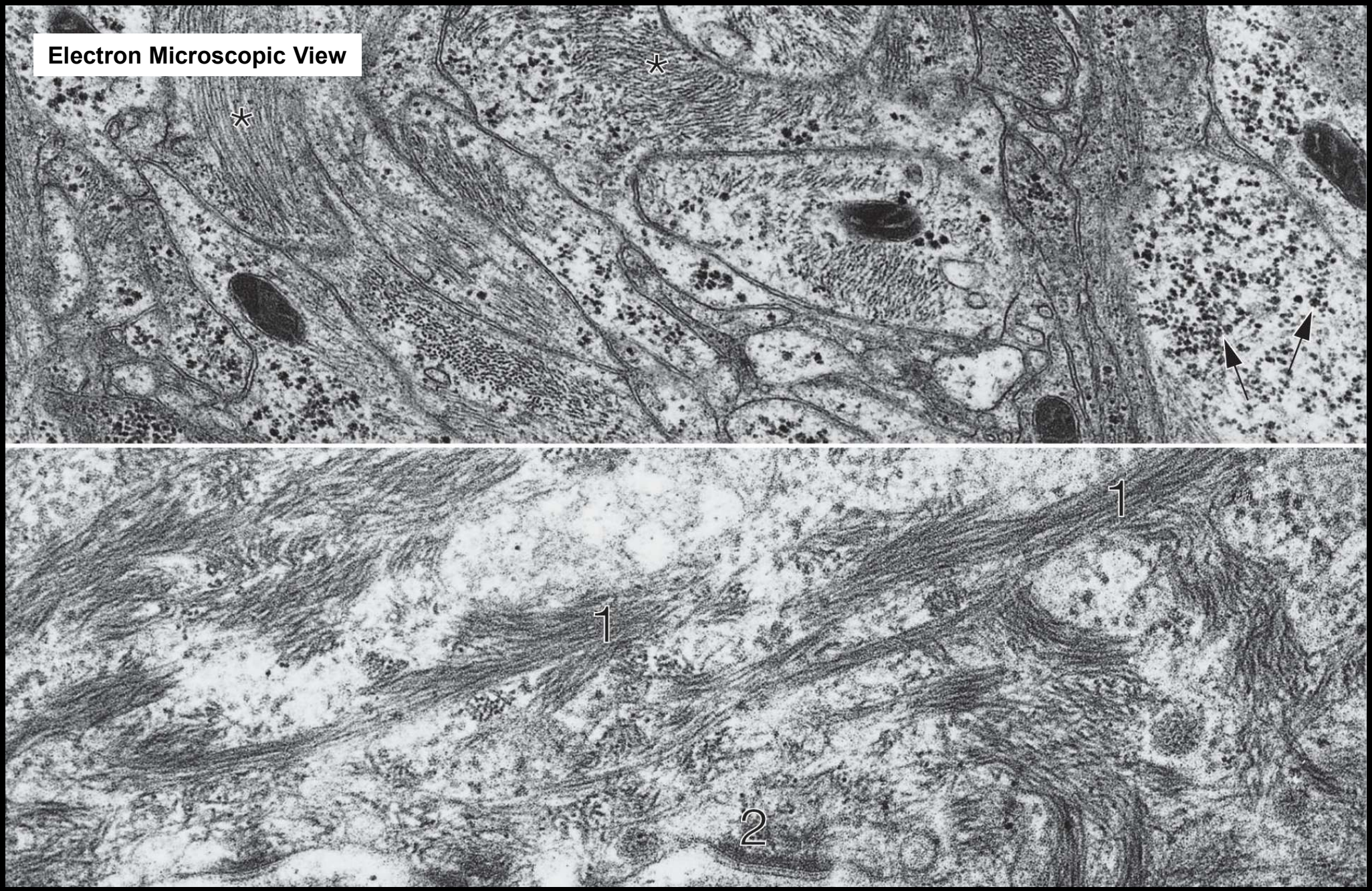
Prototypical Neuron – Cytoskeleton



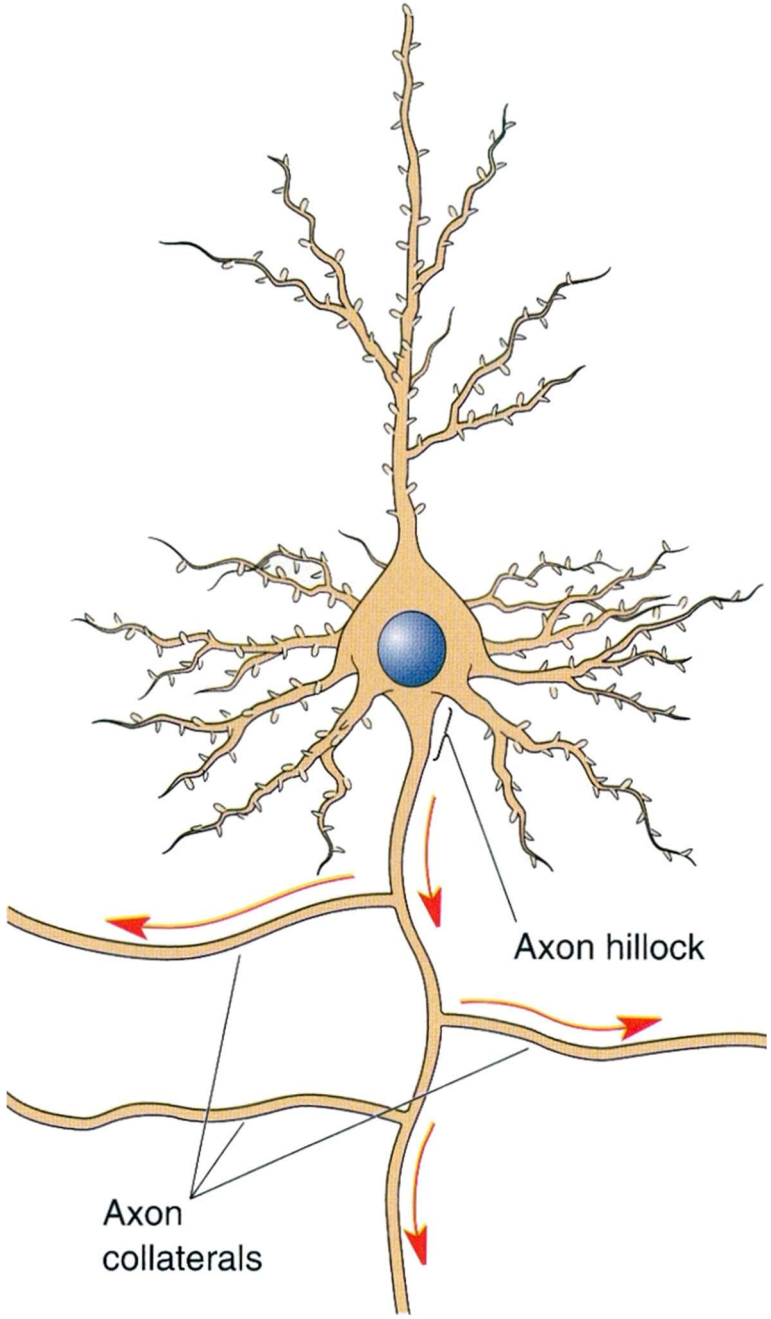
Arrangement of Nestin Filaments (A) and Microtubules (B) in the Same Cell

Veselska et al.
BMC Cancer 2006

Prototypical Neuron – Cytoskeleton



Prototypical Neuron – Axon



Prototypical Neuron – Axon Terminal, Synapse

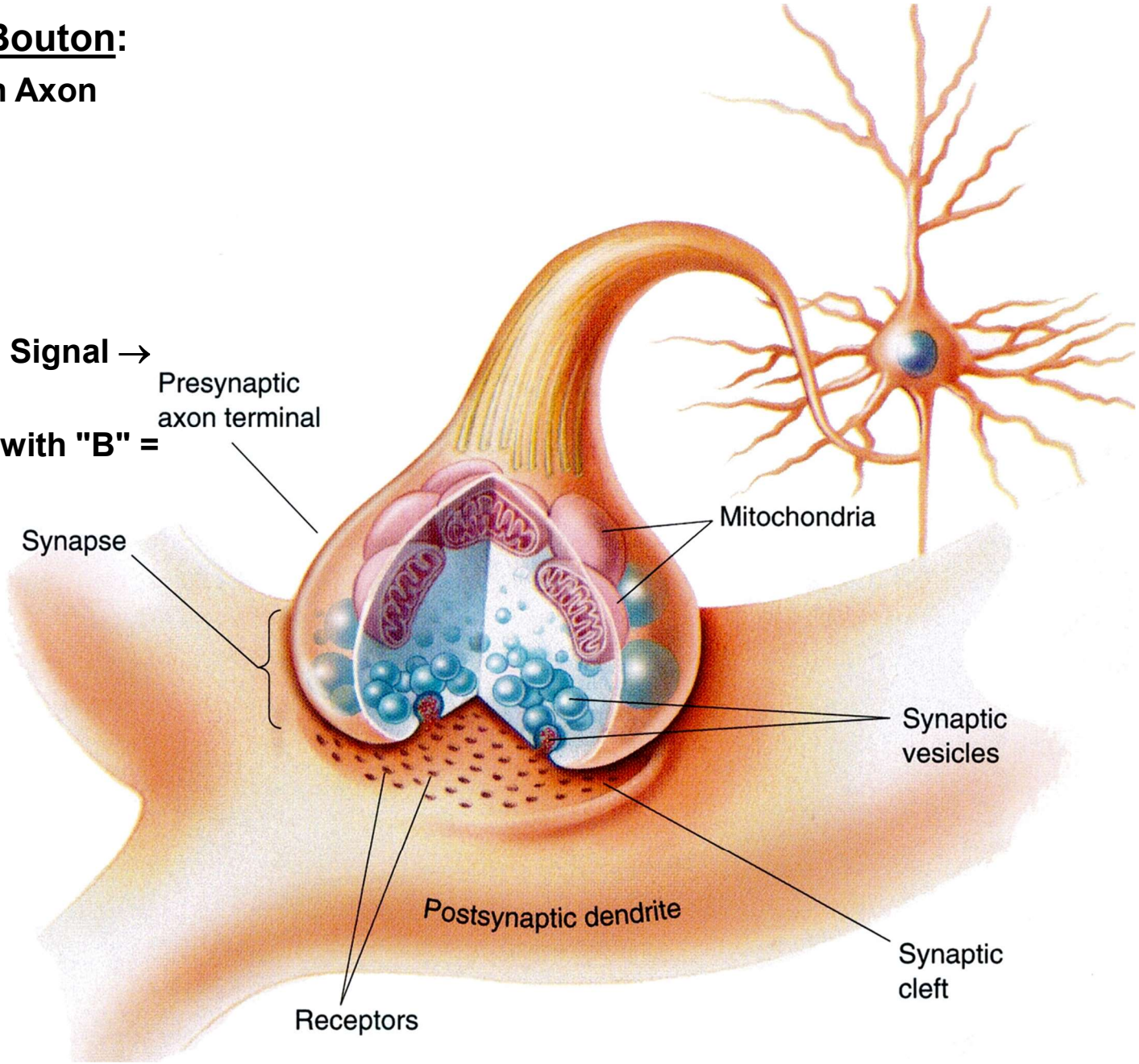
Axon Terminal = Terminal Bouton:

- Swollen Disc at the End of an Axon

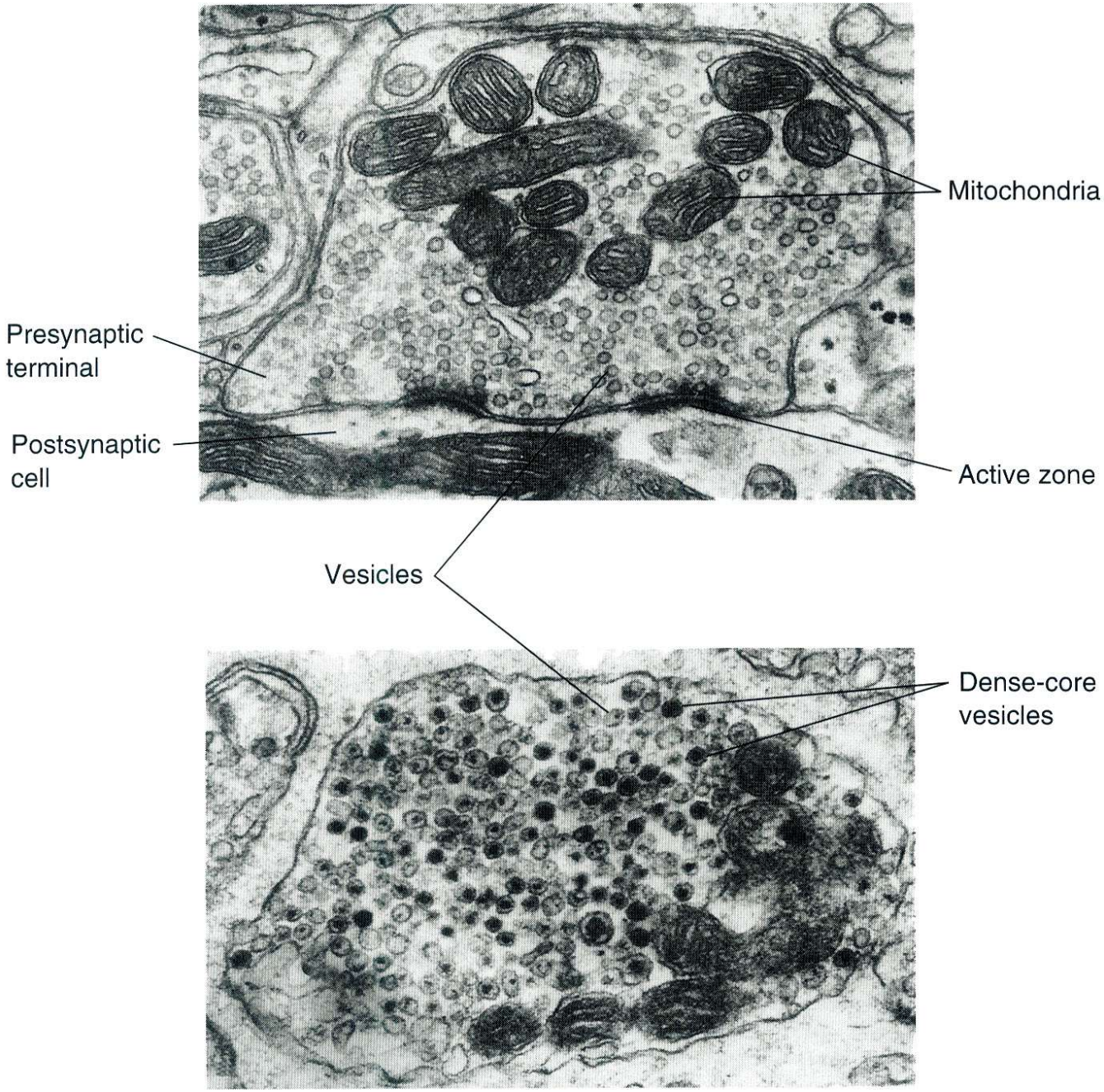
Synapse:

- Presynaptic Membrane
- Synaptic Cleft
- Postsynaptic Membrane
- Electrical Signal → Chemical Signal → Electrical Signal
- "A" Makes Synaptic Contact with "B" = "A" Innervates "B"

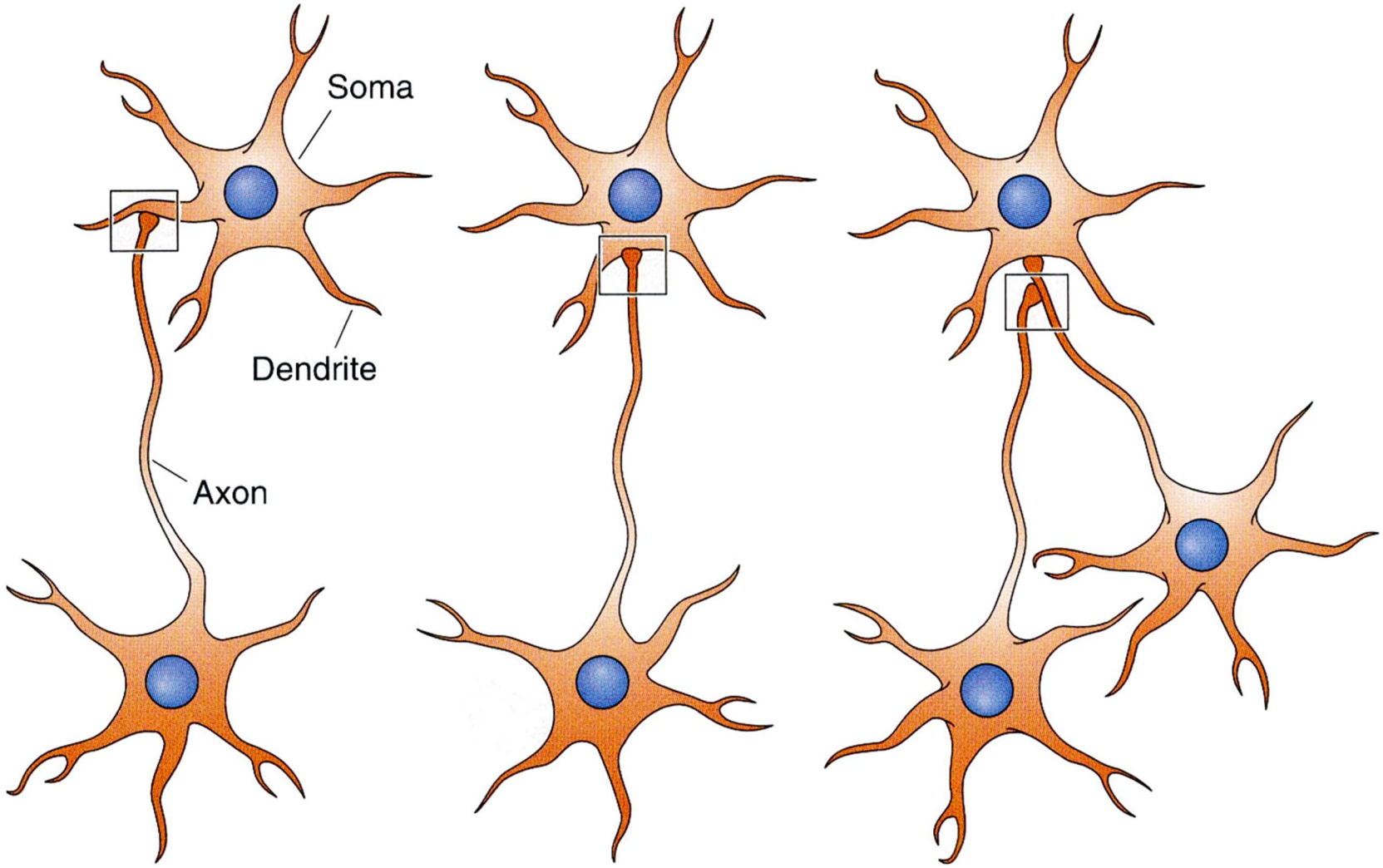
Transfer of Information (Synaptic Transmission) "One-Way Street" !



Prototypical Neuron – Synapse

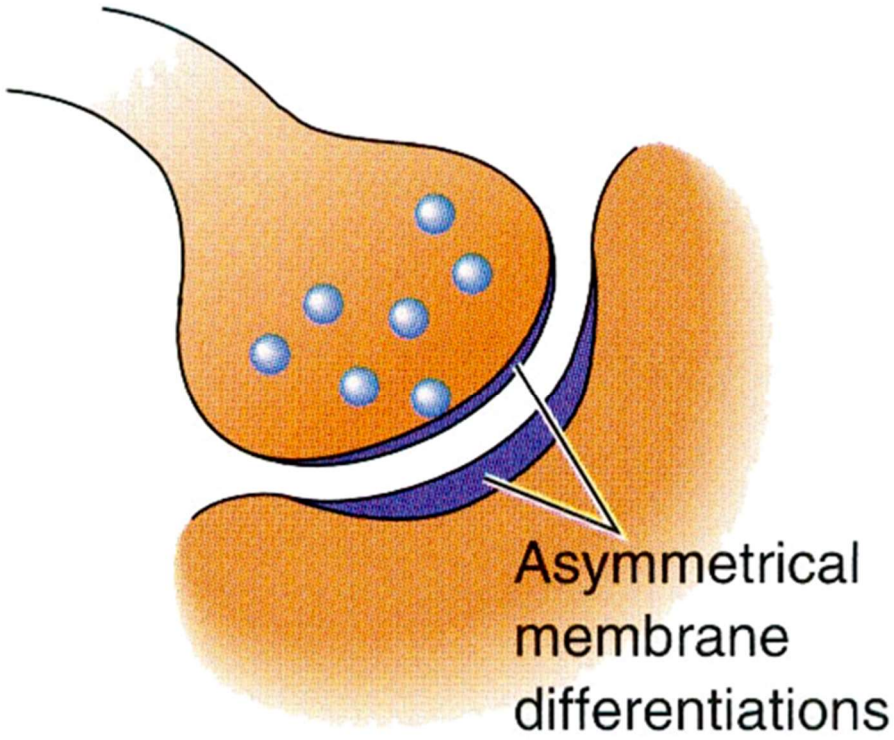


Prototypical Neuron – Synapse



axo-dendritic **axo-somatic** **axo-axonic**

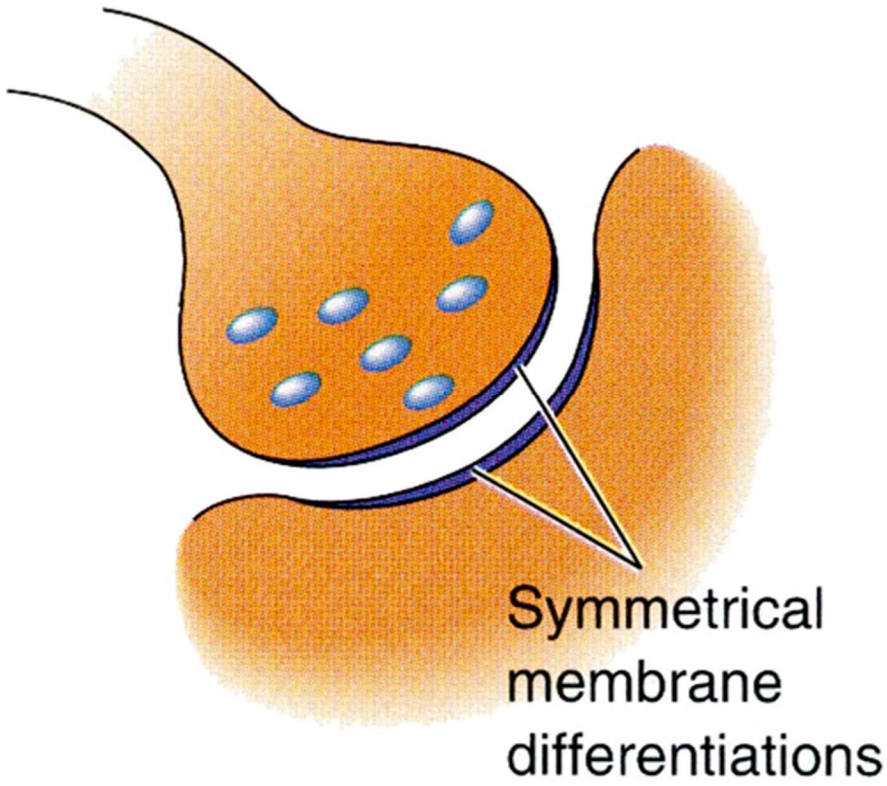
Prototypical Neuron – Synapse



Postsynaptic Density > Presynaptic Density

Asymmetrical Synapse (Gray's Type I)

Usually Excitatory

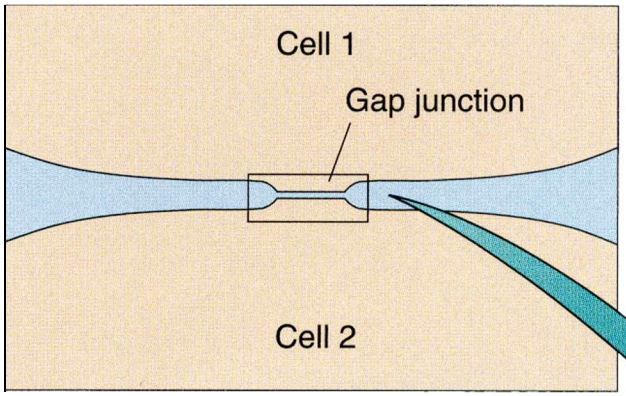


Postsynaptic Density ≈ Presynaptic Density

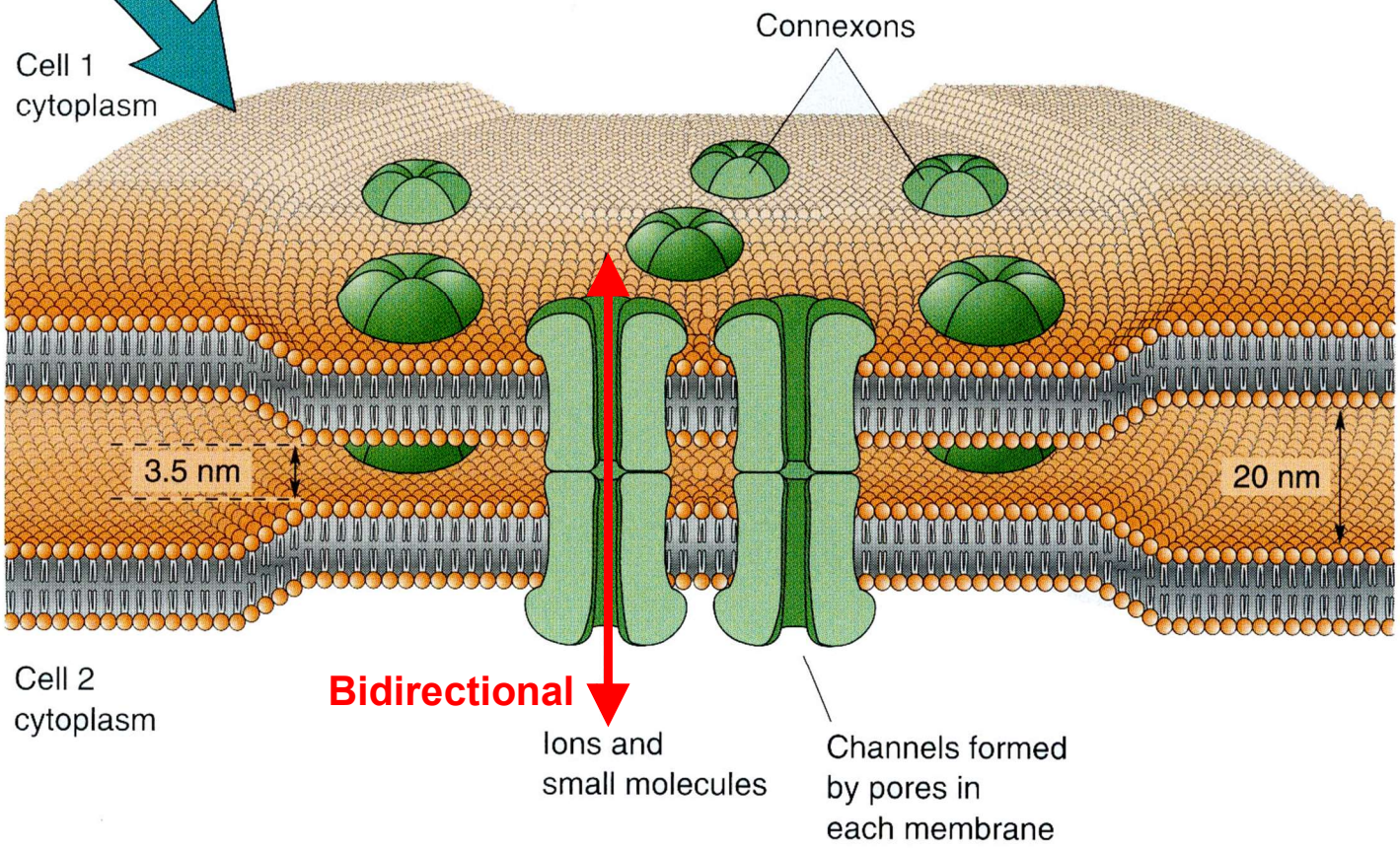
Symmetrical Synapse (Gray's Type II)

Usually Inhibitory

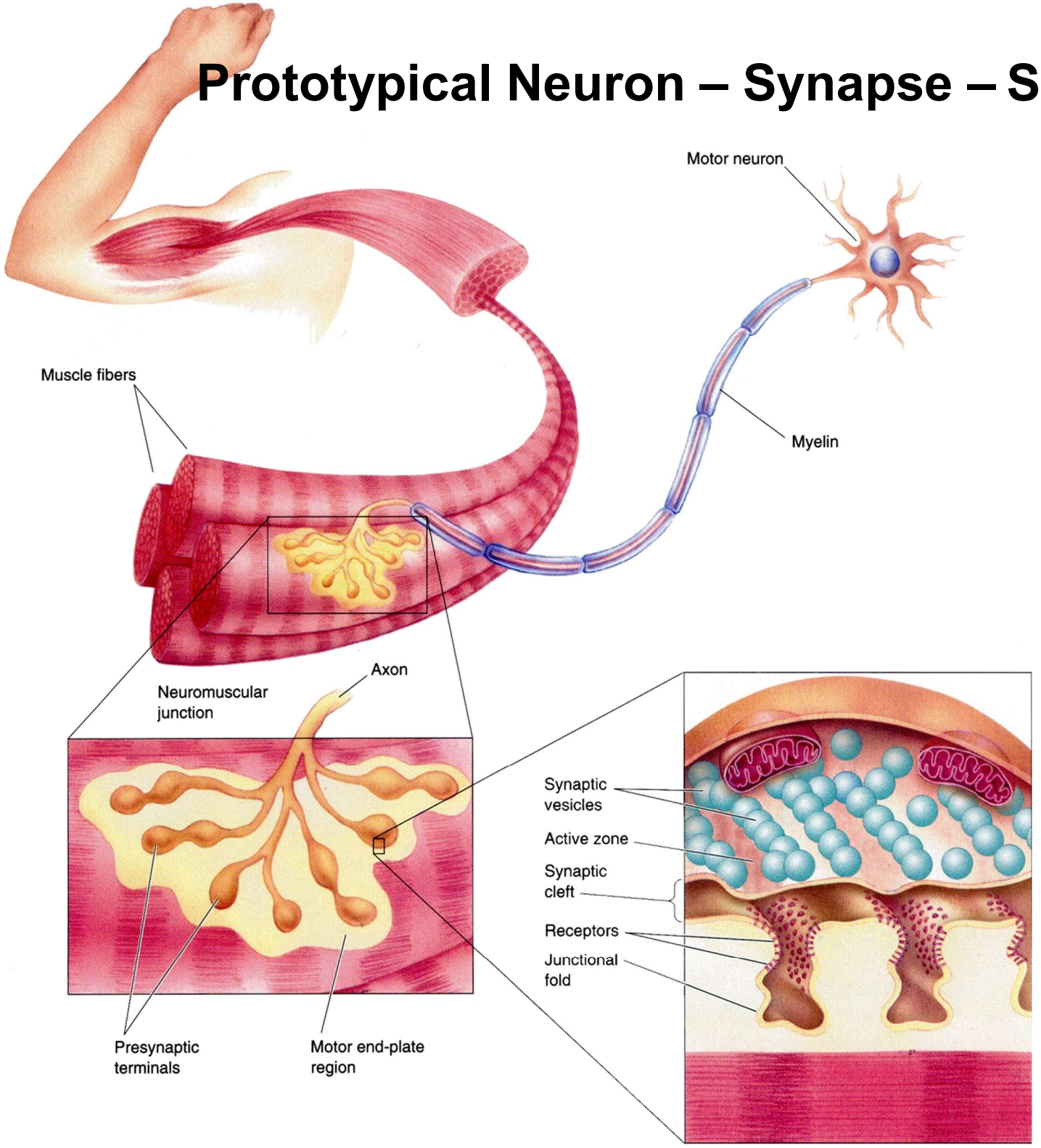
Prototypical Neuron – Synapse – Special Types



Electrical Synapse (Gap Junction)



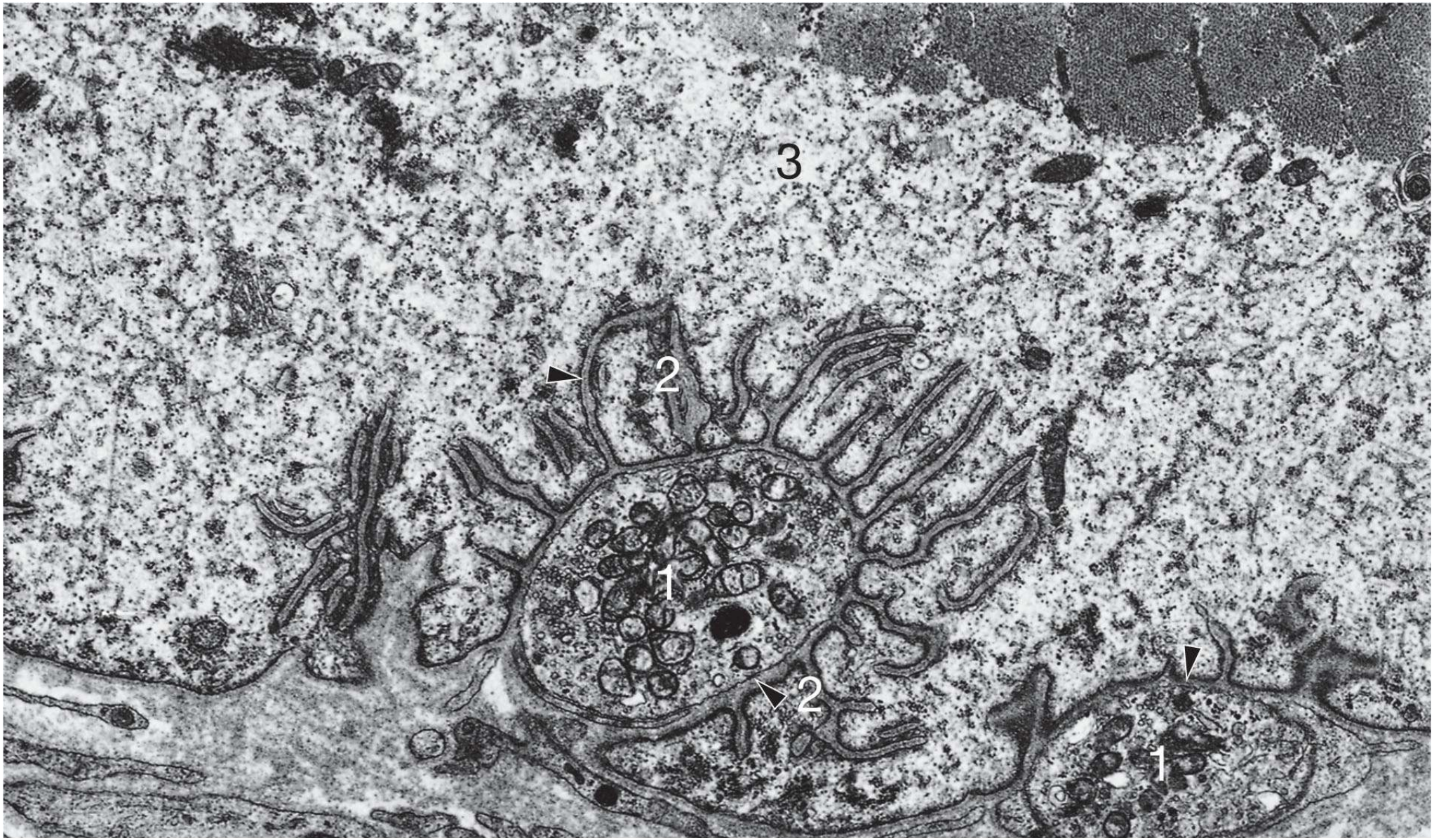
Prototypical Neuron – Synapse – Special Types



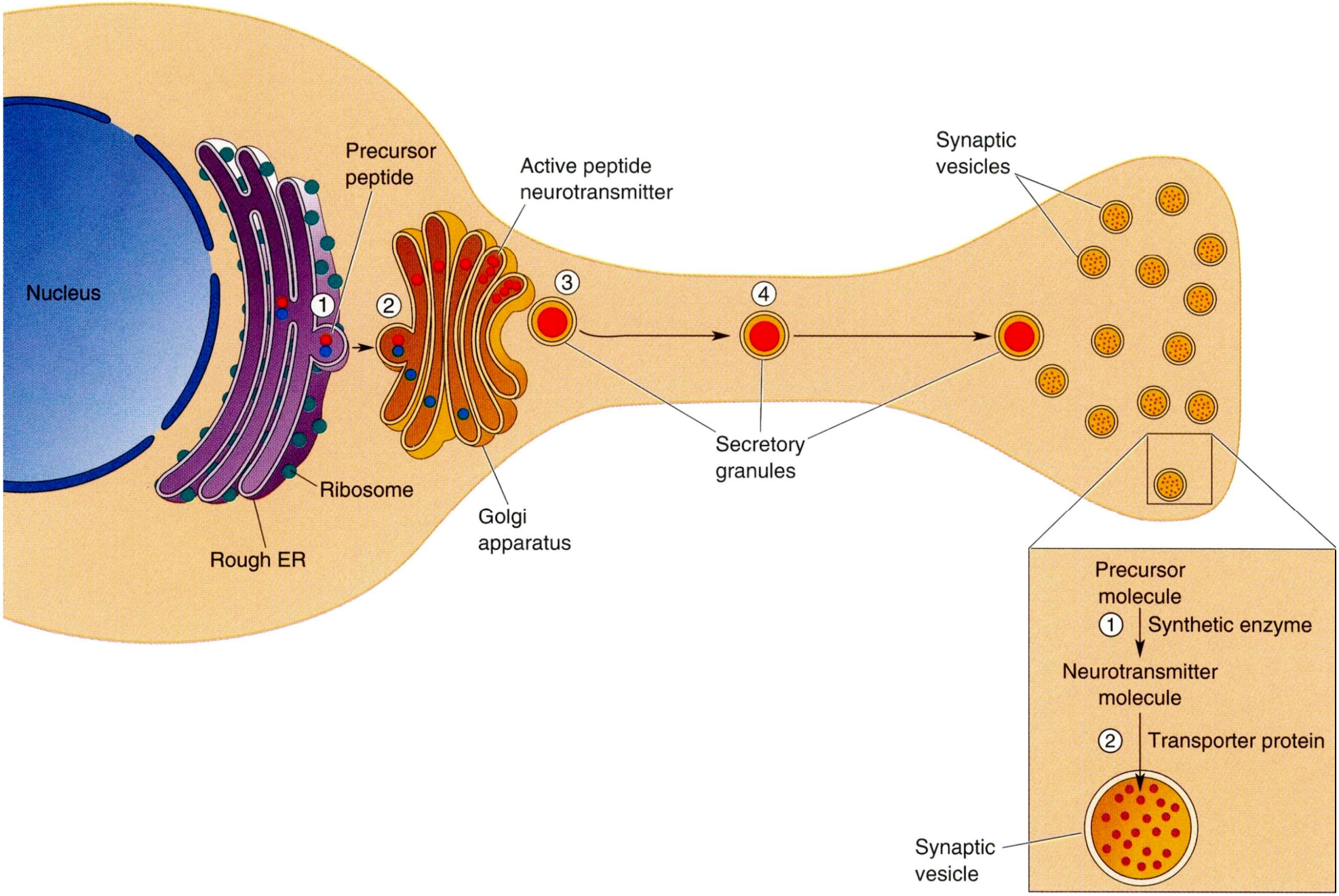
Motor End-Plate

Prototypical Neuron – Synapse – Special Types

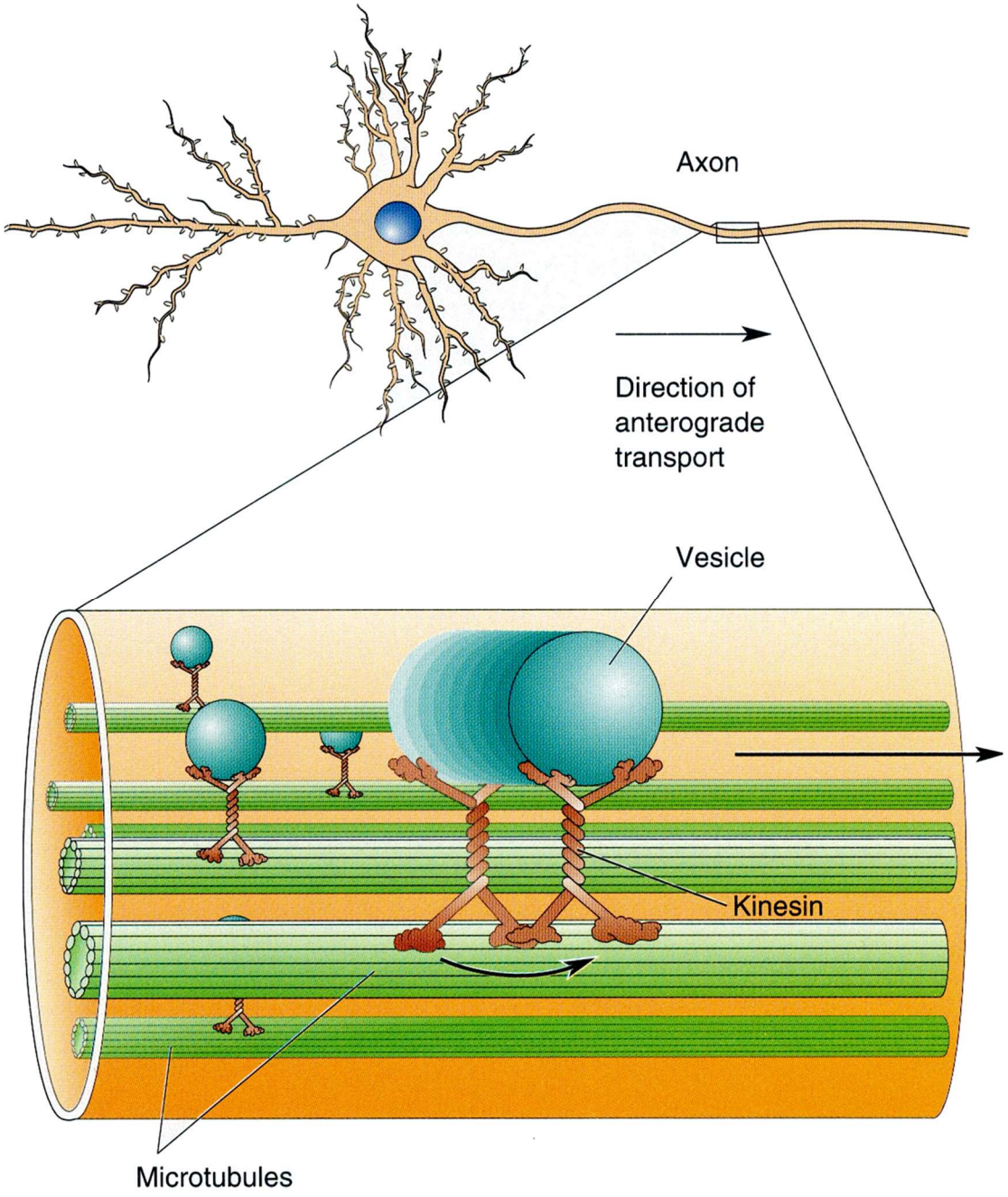
Motor End-Plate



Prototypical Neuron – Axoplasmic Transport



Prototypical Neuron – Axoplasmic Transport



<u>Anterograde Axoplasmatic Transport</u>:

(Perikaryon → Axon Terminal)

Protein Kinesin

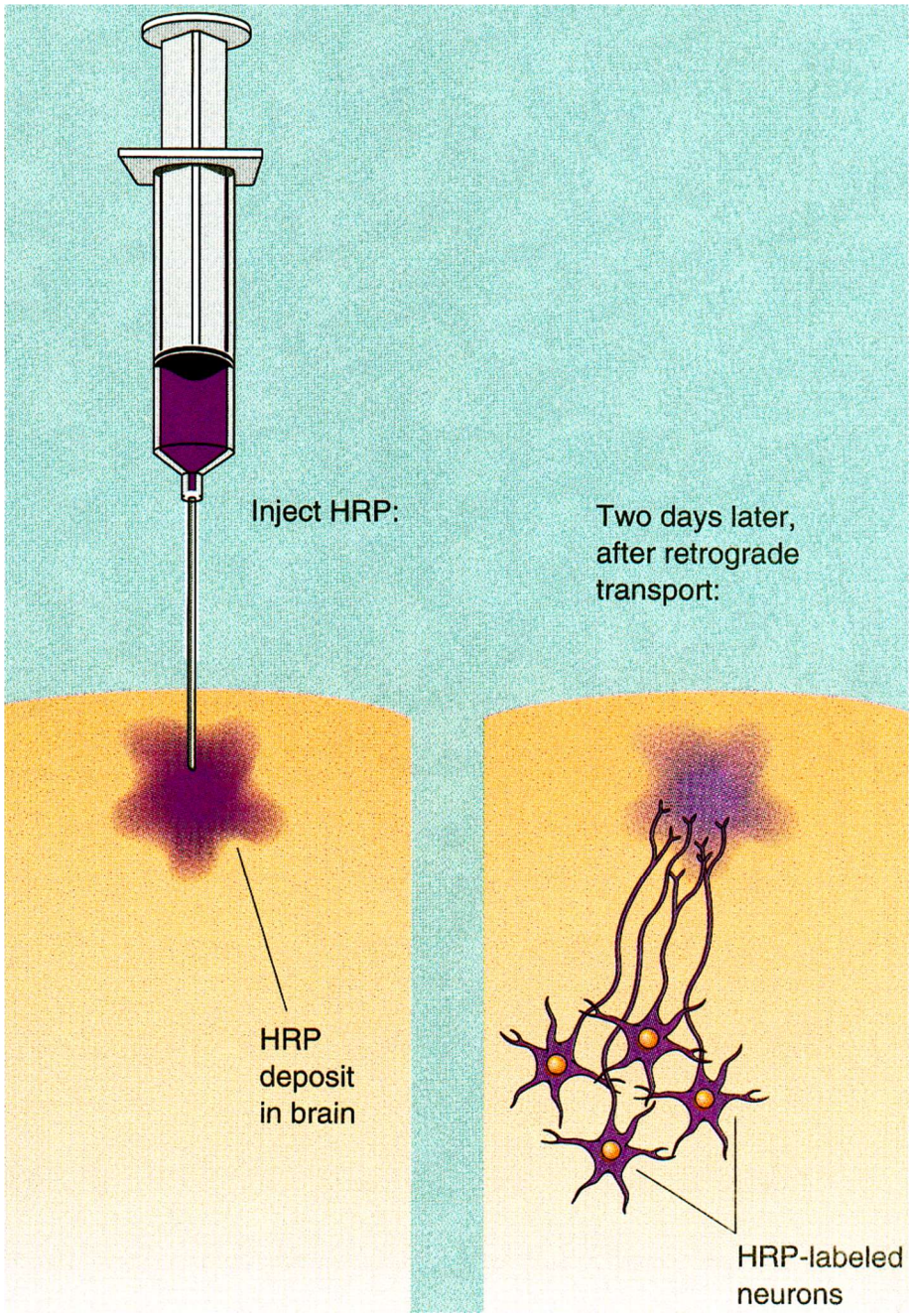
- **Fast Transport: Up to 1000 mm/Day**
- **Slow Transport: 1 – 10 mm/Day**

<u>Retrograde Axoplasmic Transport</u>:

(Axon Terminal → Perikaryon)

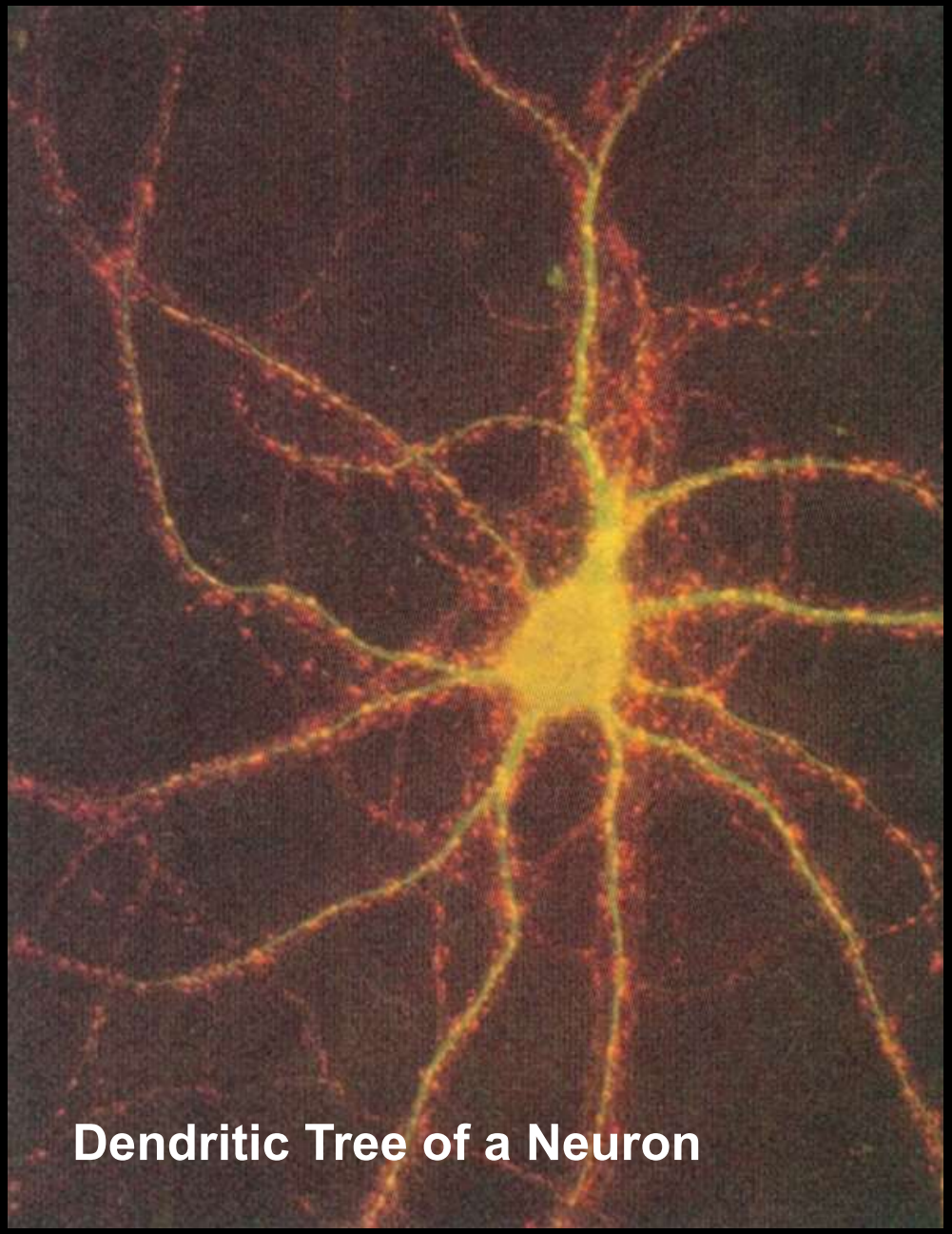
Protein Dynein

Tracing Connections in the Living Brain (Tract Tracing)

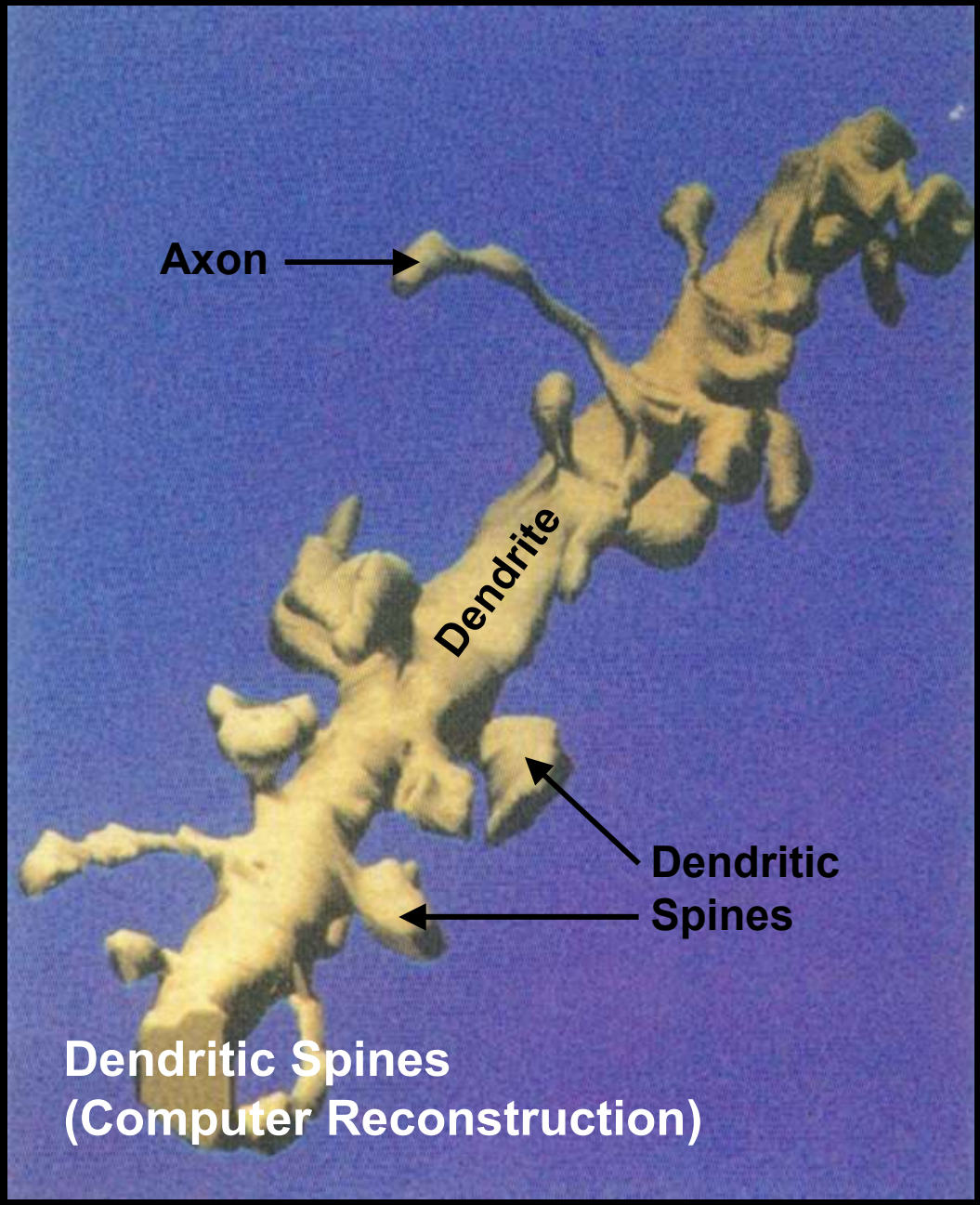


- **A Tracer (e.g., Horseradish Peroxidase = HRP) is Injected into the Cortex of a Living Animal (e.g., Rat, Mouse, Monkey).**
- **The Tracer is Taken up and Transported (Anterogradely or Retrogradely; Depending on the Type of Tracer) by Neuronal Processes (Mainly Axons).**
- **After Some Delay (Days – Weeks), the Animal is Sacrificed, the Brain is Sectioned, and the Tracer Detected with Histochemical or Immunohistochemical Techniques.**

Prototypical Neuron – Dendrites

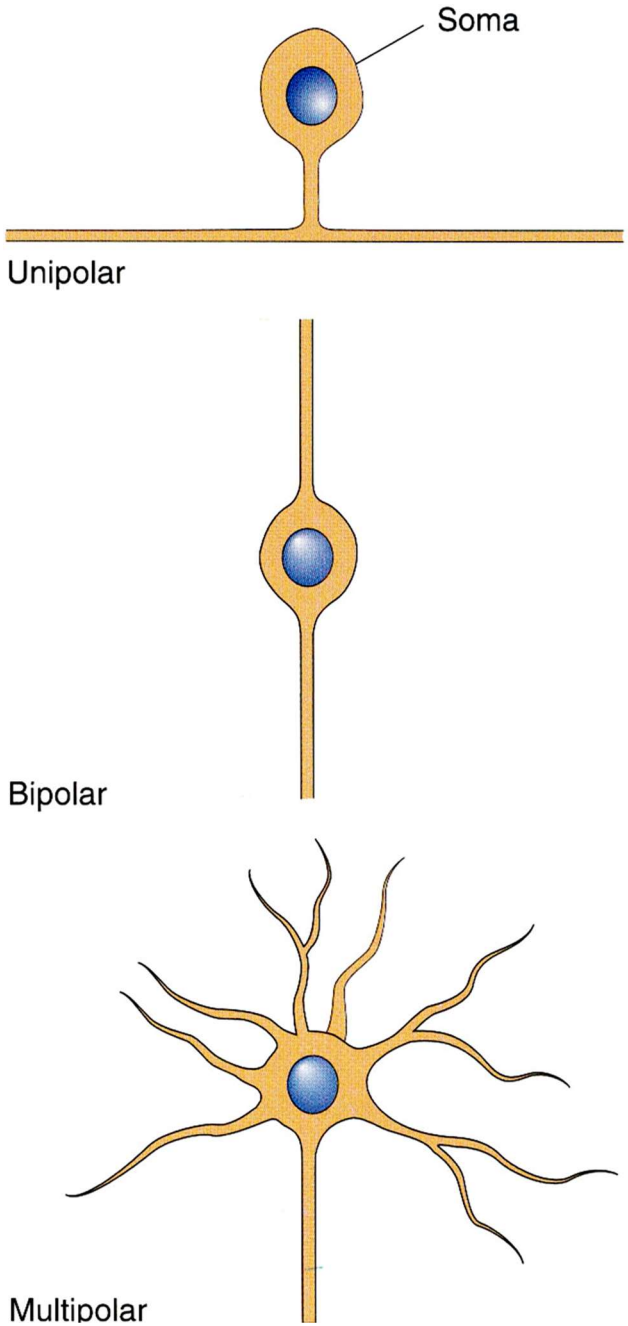


Dendritic Tree of a Neuron



Dendritic Spines
(Computer Reconstruction)

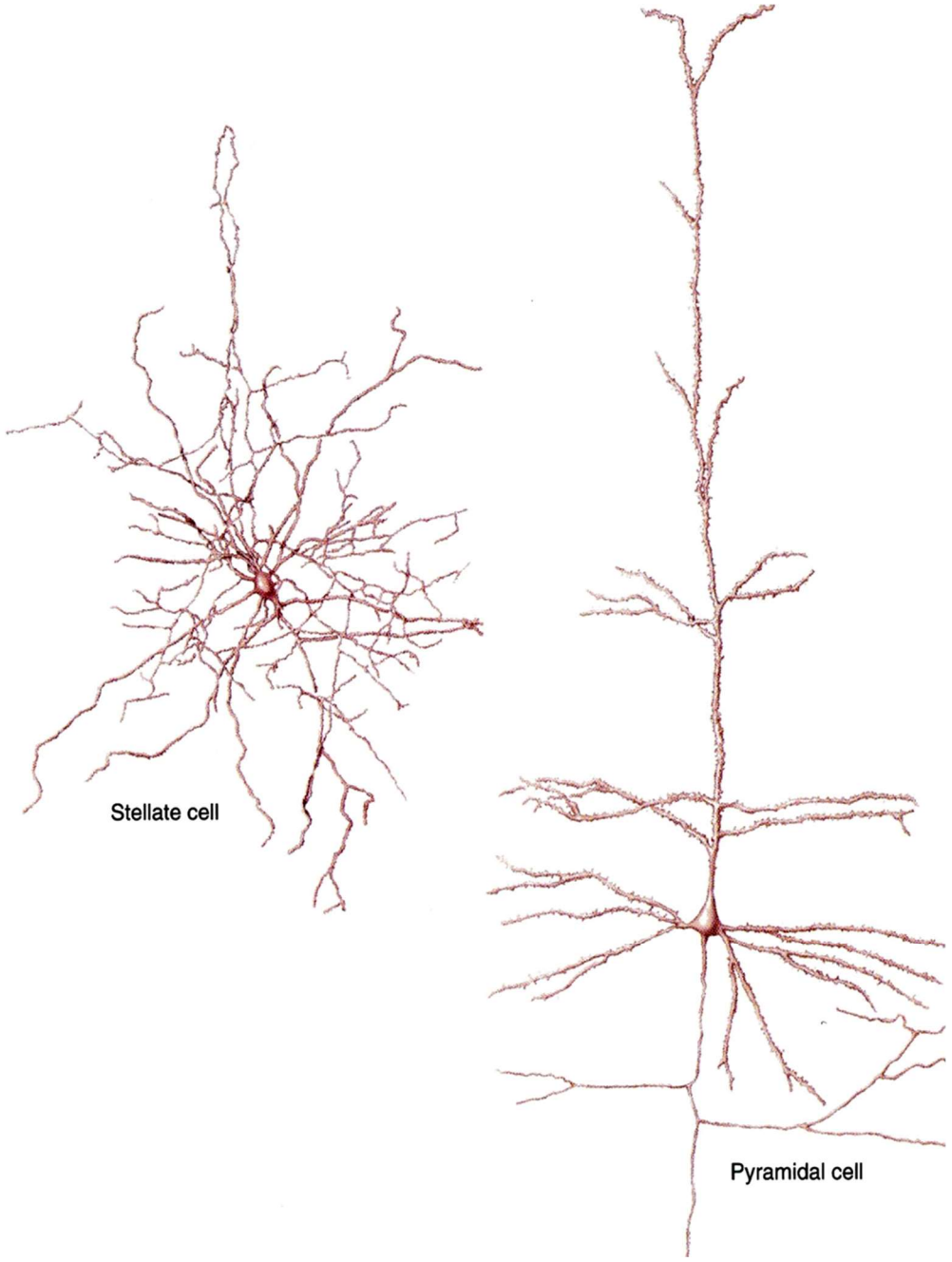
Classifying Neurons



Based on Number of Neurites:

- **Unipolar (One Neurite)**
- **Bipolar (Two Neurites)**
- **Multipolar (Three or More Neurites): Most Neurons in the Brain**

Classifying Neurons

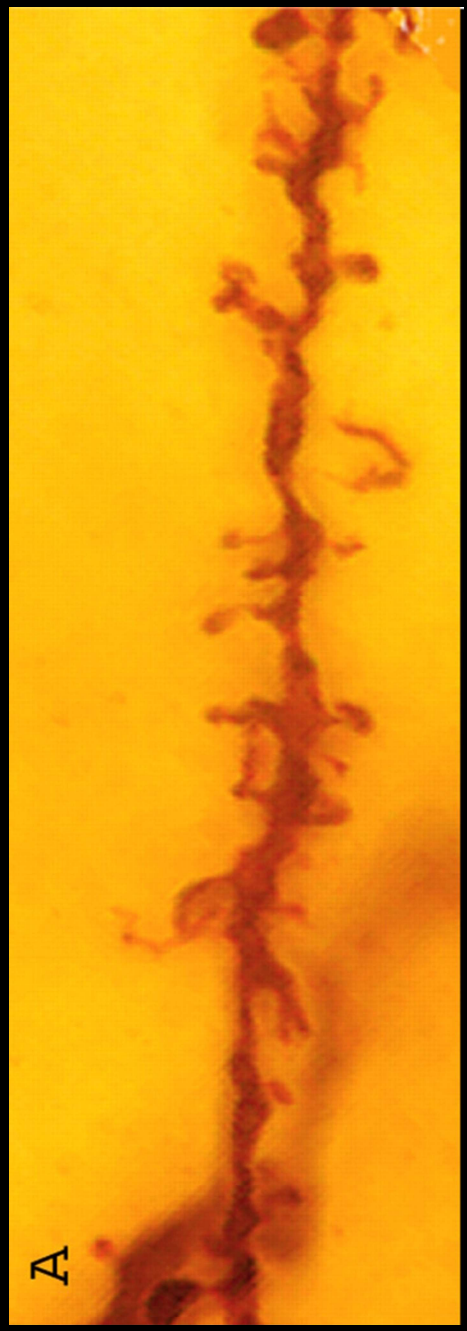


Based on Dendrites:

- **Descriptive Names Describing Shape of Dendritic Tree: e.g., Basket Cells, Chandelier Cells, etc.**
- **Pyramid-Shaped Dendritic Tree: Pyramidal Cells**
- **Star-Shaped Dendritic Tree: Stellate Cells**
- **Dendrites Have Spines: Spiny Neurons**
- **Dendrites Do not Have Spines: Aspinous Neurons**

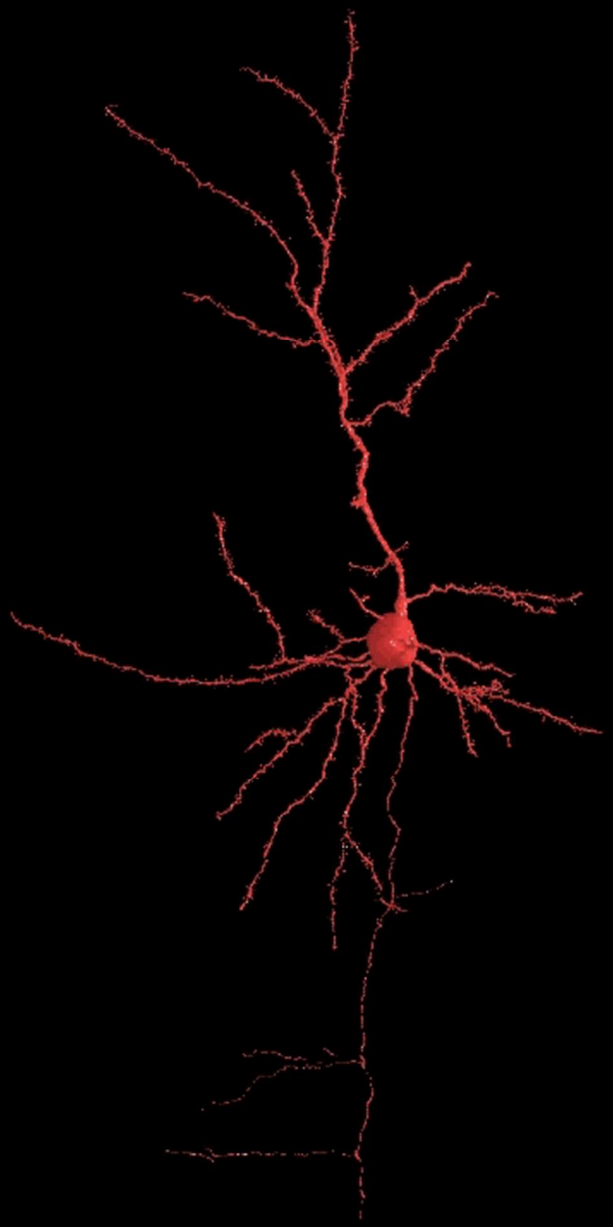
Pyramidal Cells Are Always Spiny
Stellate Cells Can Be Spiny or Aspinous

Pyramidal Cell

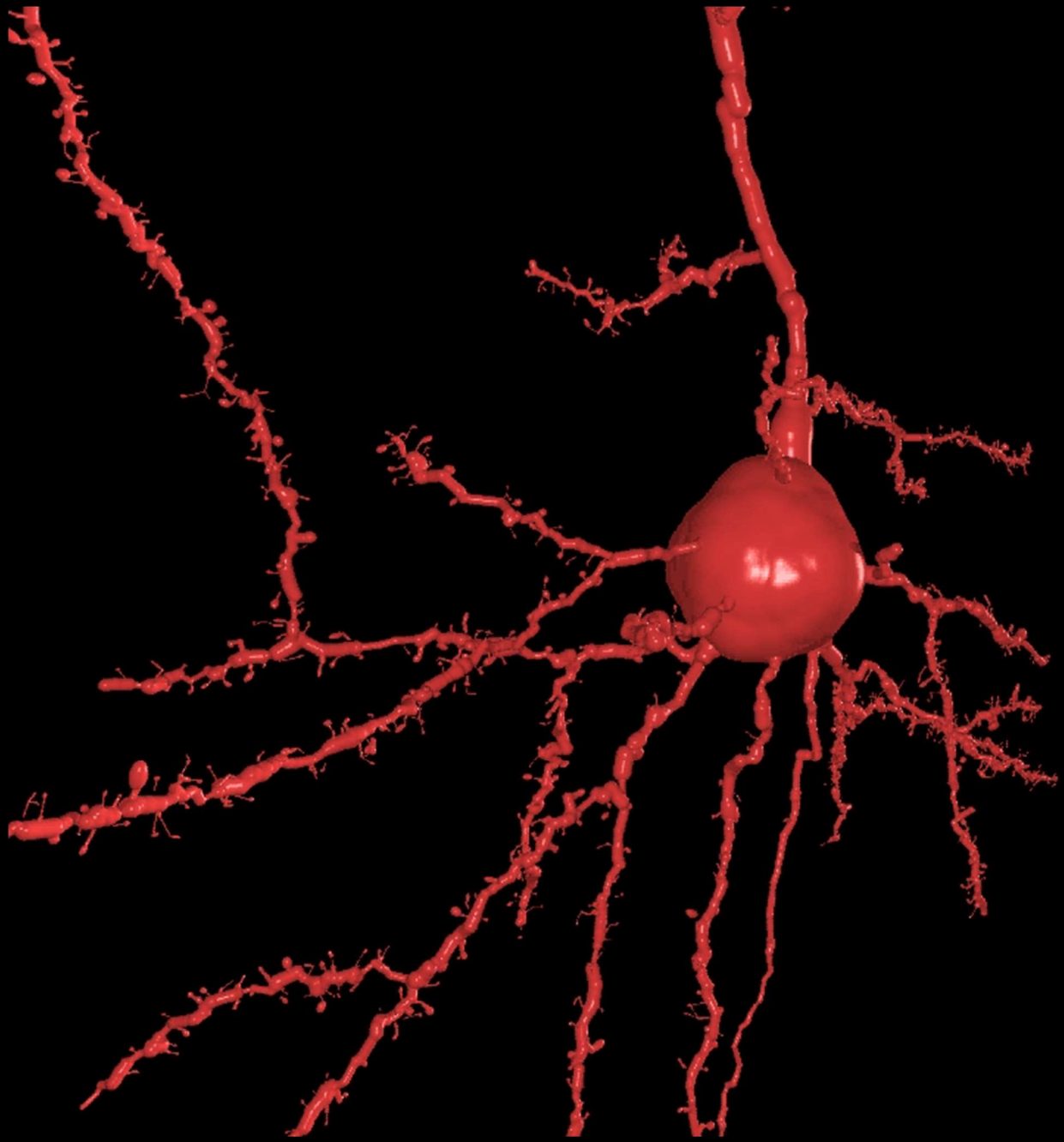


Garcia-Lopez et al.
Journal of Neuroscience
2006

Pyramidal Cell (3-D Reconstruction)



Pyramidal Cell (3-D Reconstruction)



Classifying Neurons

Based on Connections:

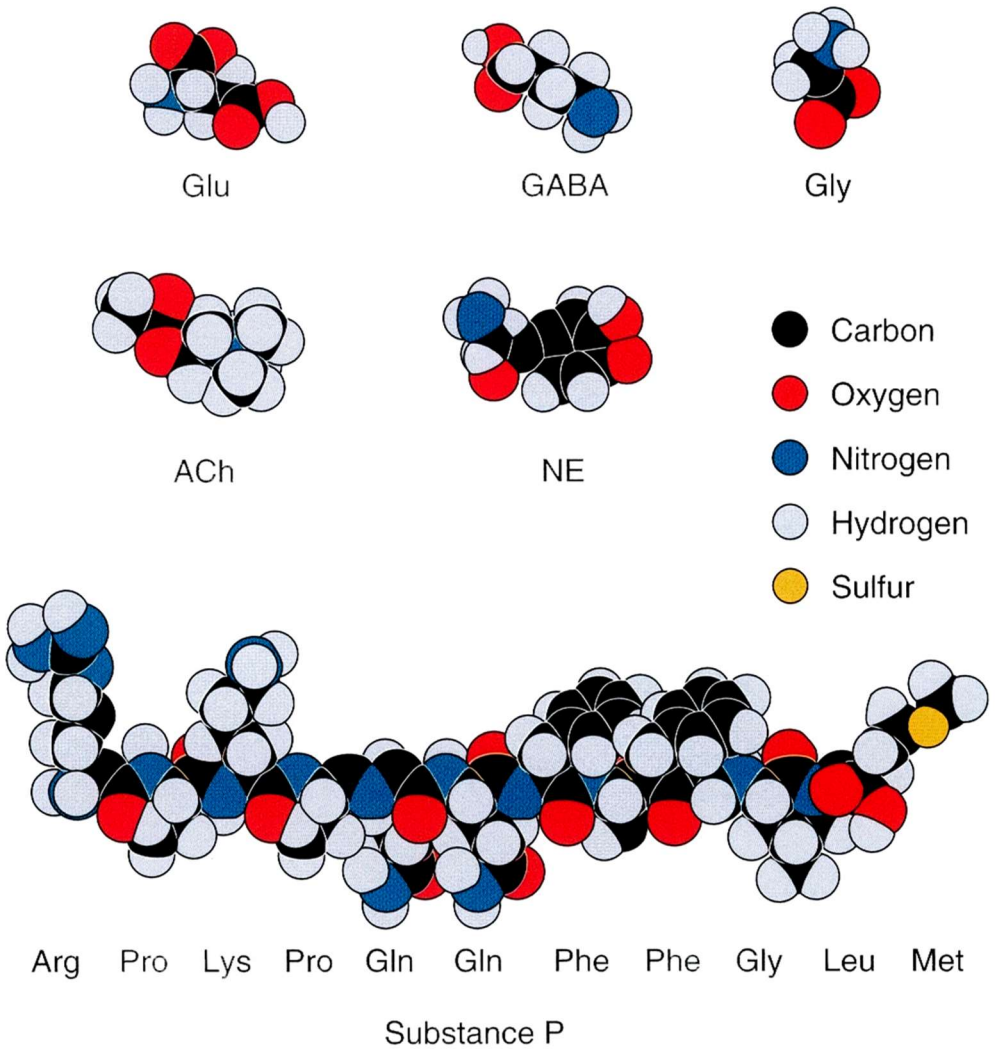
- **Neurites (Dendrites) Connected with Sensory Organs (e.g., Eye, Ear, Skin): Primary Sensory Neurons**
- **Neurites (Axons) Connected with Muscles: Motor Neurons**
- **Neurites (Axons, Dendrites) Connected with Other Neurons: Interneurons (Most Neurons)**

Based on Axon Length:

- **Long Axons that Extend from One Part of the Brain to the Other: Projection Neurons = Golgi Type I Neurons**
- **Short Axons that Do Not Extend Beyond the Vicinity of the Cell Body: Local Circuit Neurons = Golgi Type II Neurons**

Cerebral Cortex: **Pyramidal Cells are Projection Neurons (Golgi Type I)**
Stellate Cells are Local Circuit Neurons (Golgi Type II)

Classifying Neurons



Based on Neurotransmitters:

- **Acetylcholine (ACh): Cholinergic Neurons (e.g., Motoneurons)**
- **Noradrenaline (Norepinephrine = NE): Noradrenergic Neurons**
- **Glutamate (Glu): Glutamatergic Neurons**
- **Gamma Aminobutyric Acid (GABA): GABAergic Neurons**
- **Glycine (Gly): Glycinergic Neurons**

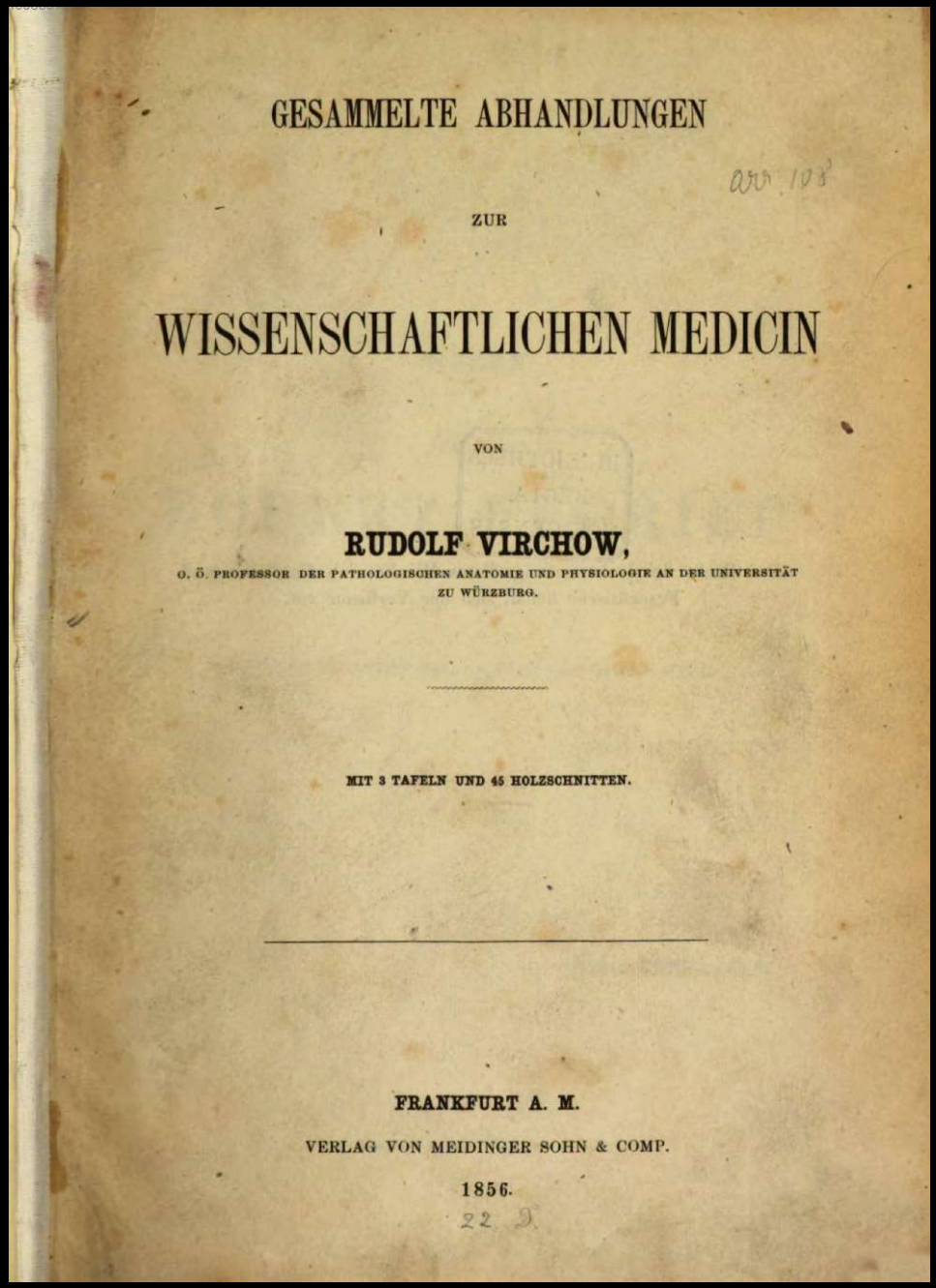
and others

Six Facts About Each Neuron

Each Neuron is a(n):

- **Anatomical Unit: Nucleus, Perikaryon, Dendrites, Axon**
- **Genetic Unit: Develops from an Independent Embryonic Cell (Neuroblast)**
- **Functional Unit: Smallest Information Processing Unit: Stimulus → Nerve Impulse (All Or None Law)**
- **Polarized Unit: Conducts Nerve Impulses in One Direction: Dendrite → Perikaryon → Axon → Synapse**
- **Pathologic Unit: If Severely Enough Injured, the Entire Neuron Will Die as a Cellular Unit.**
- **Regenerative Unit: May Grow a New Axon if the Axon is Severed. Effective Axon Regeneration is Possible only in the Peripheral Nervous System, Not in the Central Nervous System.**

Glia – A Bit of History



GESAMMELTE ABHANDLUNGEN

ZUR

WISSENSCHAFTLICHEN MEDICIN

VON

RUDOLF VIRCHOW,

O. Ö. PROFESSOR DER PATHOLOGISCHEN ANATOMIE UND PHYSIOLOGIE AN DER UNIVERSITÄT ZU WÜRZBURG.

MIT 3 TAFELN UND 45 HOLZSCHNITTEN.

FRANKFURT A. M.

VERLAG VON MEIDINGER SOHN & COMP.

1856.

Virchow
Gesammelte Abhandlungen zur wissenschaftlichen Medicin
Meidinger 1856

Glia – A Bit of History

zu verzögern, wie seine Referate in Canstatt's Jahresber. f. 1847. II. S. 44 u. f. 1849. II. S. 28 darthun, ja schliesslich hat er sich nicht entblödet, die Vermuthung aufzustellen, dass ich Körnchen mit Kernen, feine Nervenfasern mit Bindegewebe verwechselt habe (Zeitschr. f. rat. Med. VII. S. 410). Ich habe auf diese Zumuthung schon geantwortet (Archiv III. S. 245) und bin jetzt um so mehr gerechtfertigt, als ein Beobachter nach dem anderen sich für meine Auffassung erklärt. Gehören die feinen Fasern der Rindenschicht an den Ventrikeln dem Bindegewebe an, so kann wohl kein Zweifel darüber sein, dass vielmehr *Henle* Bindegewebe mit Nerven verwechselte, da er die Epithelien direkt auf Nervenfasern aufsitzen liess. Nach meinen Untersuchungen besteht daher das Ependym nicht bloss aus einem Epithel, sondern wesentlich aus einer mit Epithel bekleideten Bindegewebsschicht, und obwohl diese sich ohne Schwierigkeit von der Oberfläche abpräpariren lässt, so bildet sie doch keine isolirte Haut im engeren Sinne des Wortes, sondern nur die über die Oberfläche hervortretende Schicht der Zwischen-Bindesubstanz der Hirnsubstanz (Archiv VI. S. 138). Diese Bindesubstanz bildet in dem Gehirn, dem Rückenmark und den höheren Sinnesnerven eine Art von Kitt *(Neuroglia)*, in welche die nervösen Elemente eingesenkt sind und welche die Hauptablagerungsstätte für Corpora amylacea (die im Texte erwähnten hellen Bläschen) ist. Unter-

Virchow Gesammelte Abhandlungen zur wissenschaftlichen Medicin Meidinger 1856

Glia – A Bit of History

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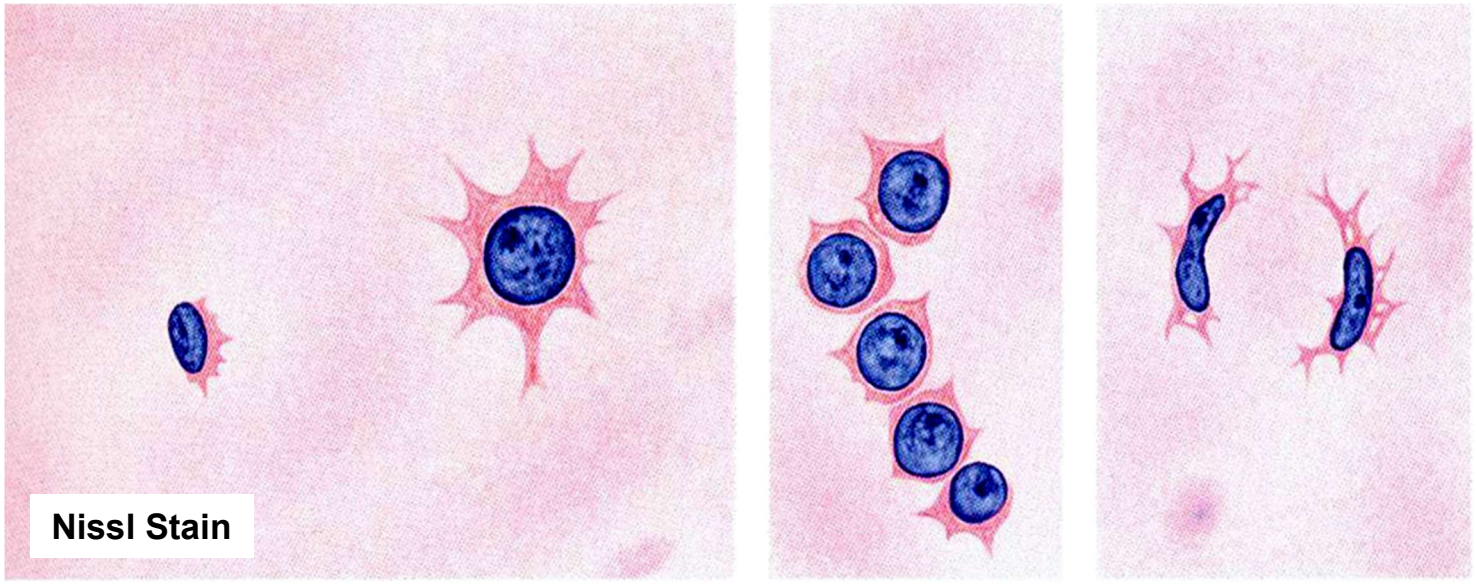
This connective substance forms in the brain, in the spinal cord, and in the higher sensory nerves a sort of putty *(neuroglia)*, in which the nervous elements are embedded …

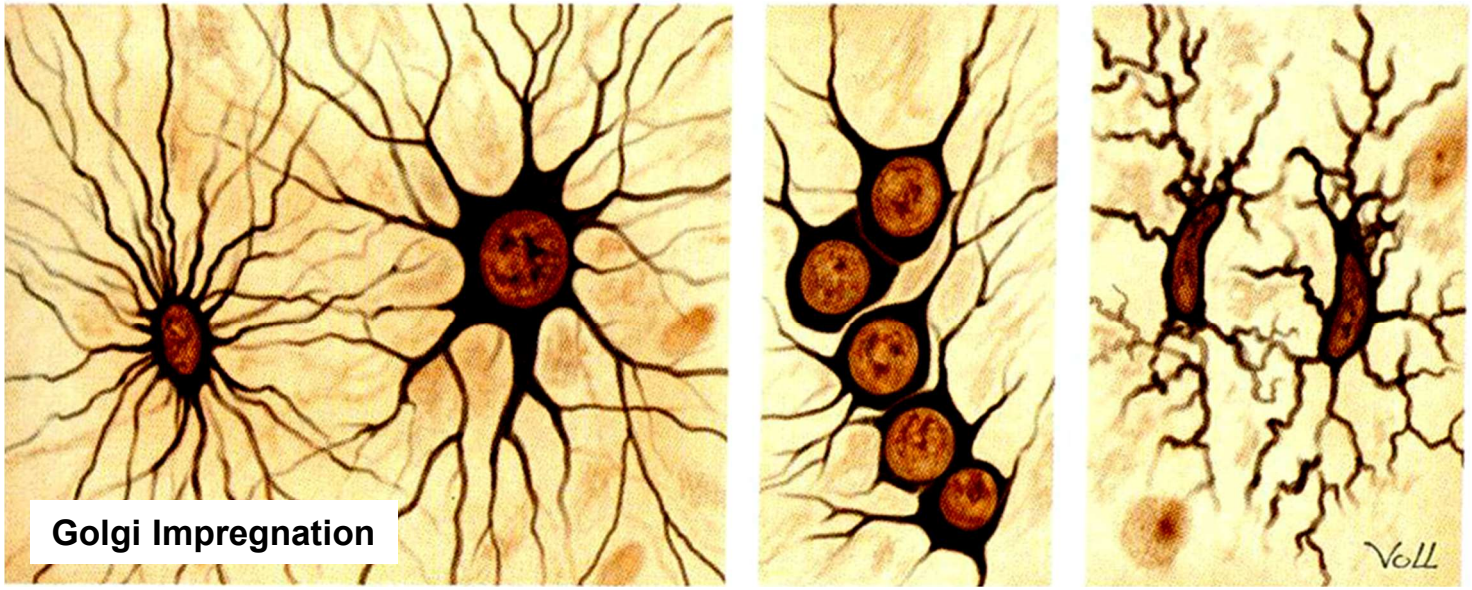
(translated in Somjen Glia 1988)

Virchow Gesammelte Abhandlungen zur wissenschaftlichen Medicin Meidinger 1856

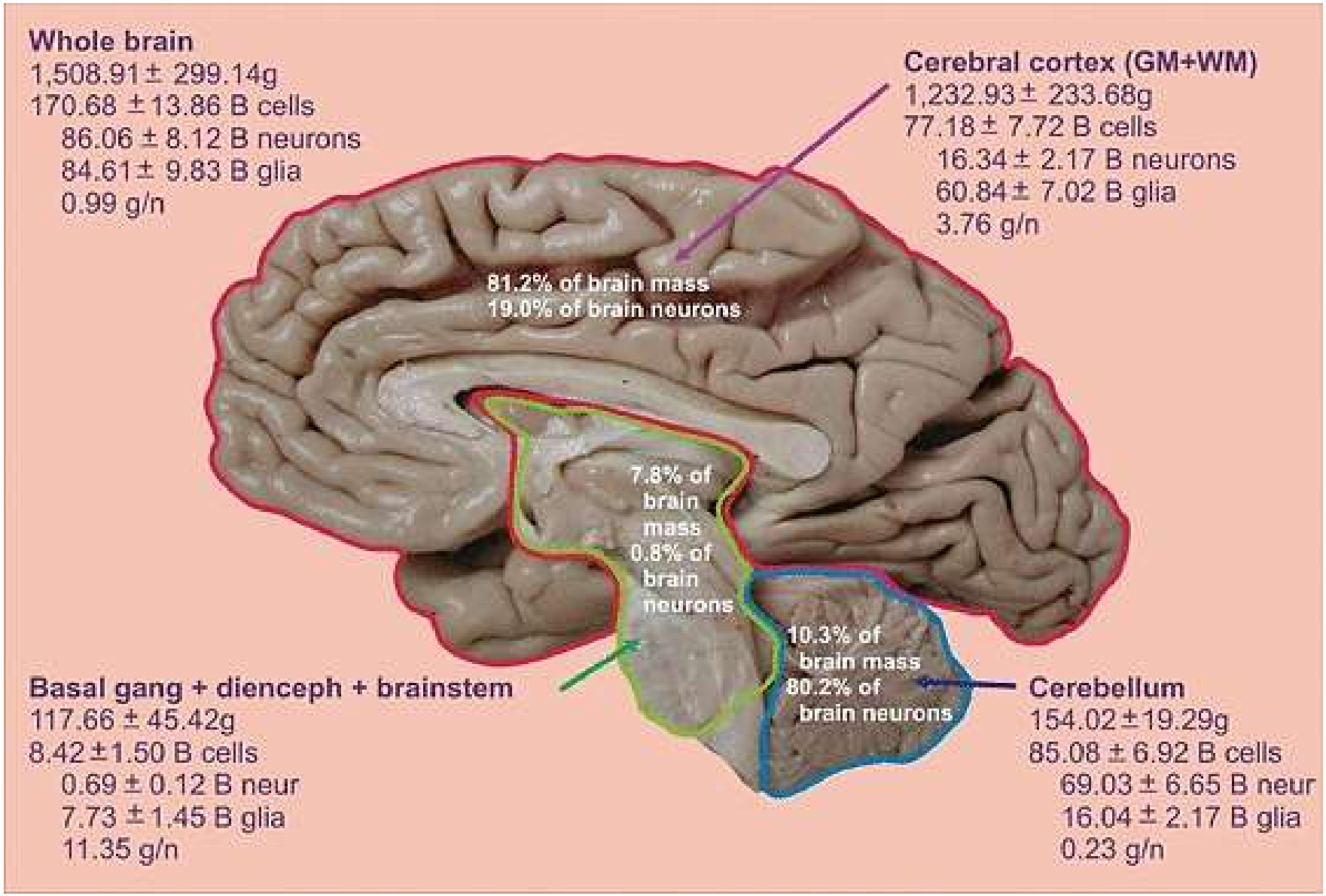
Glia Cells



fibrillärer Astrozyt | protoplasmatischer Astrozyt | Oligo-dendrozyten | Mikroglia

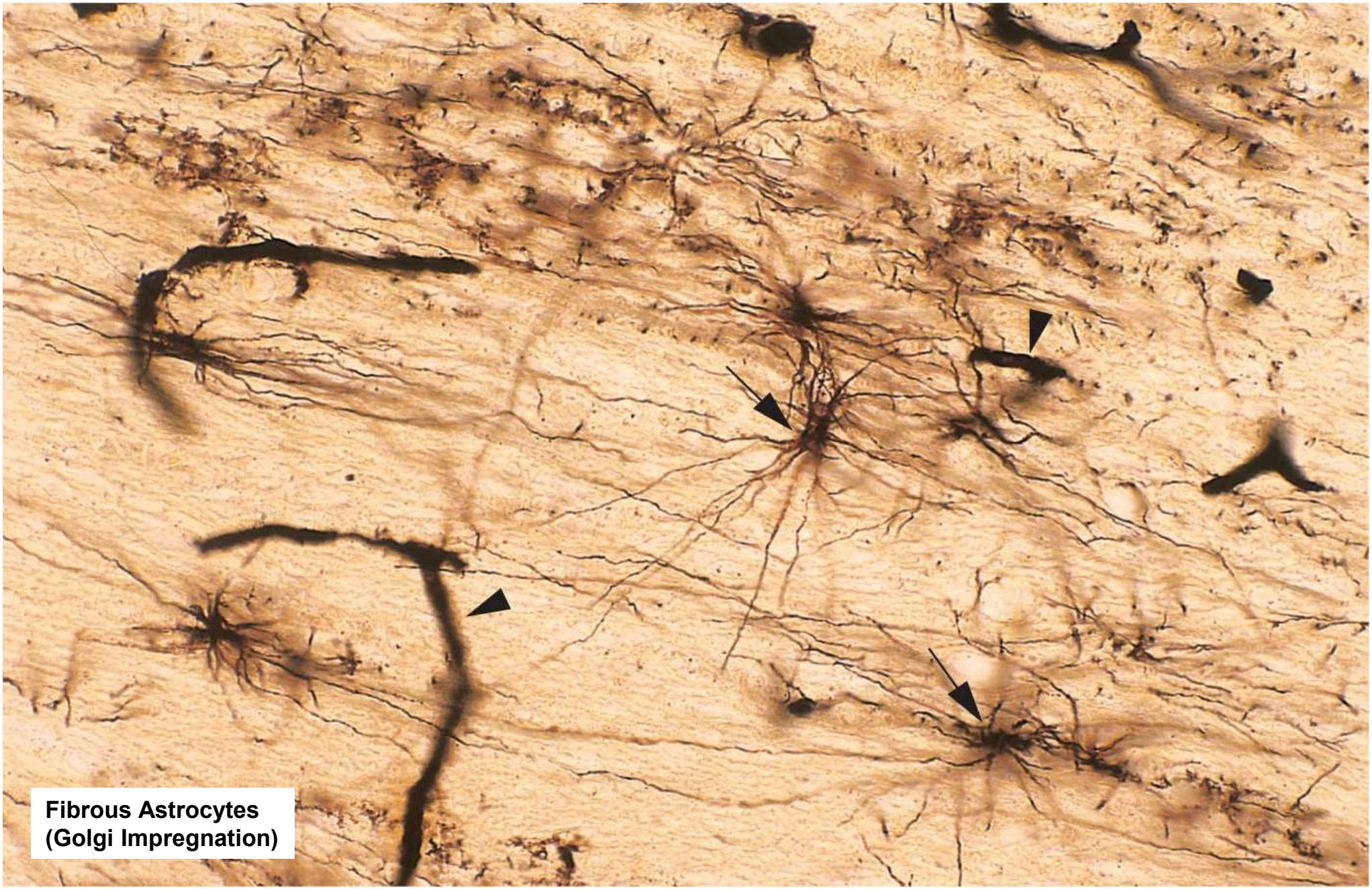


Neuron and Glia Composition of the Human Brain



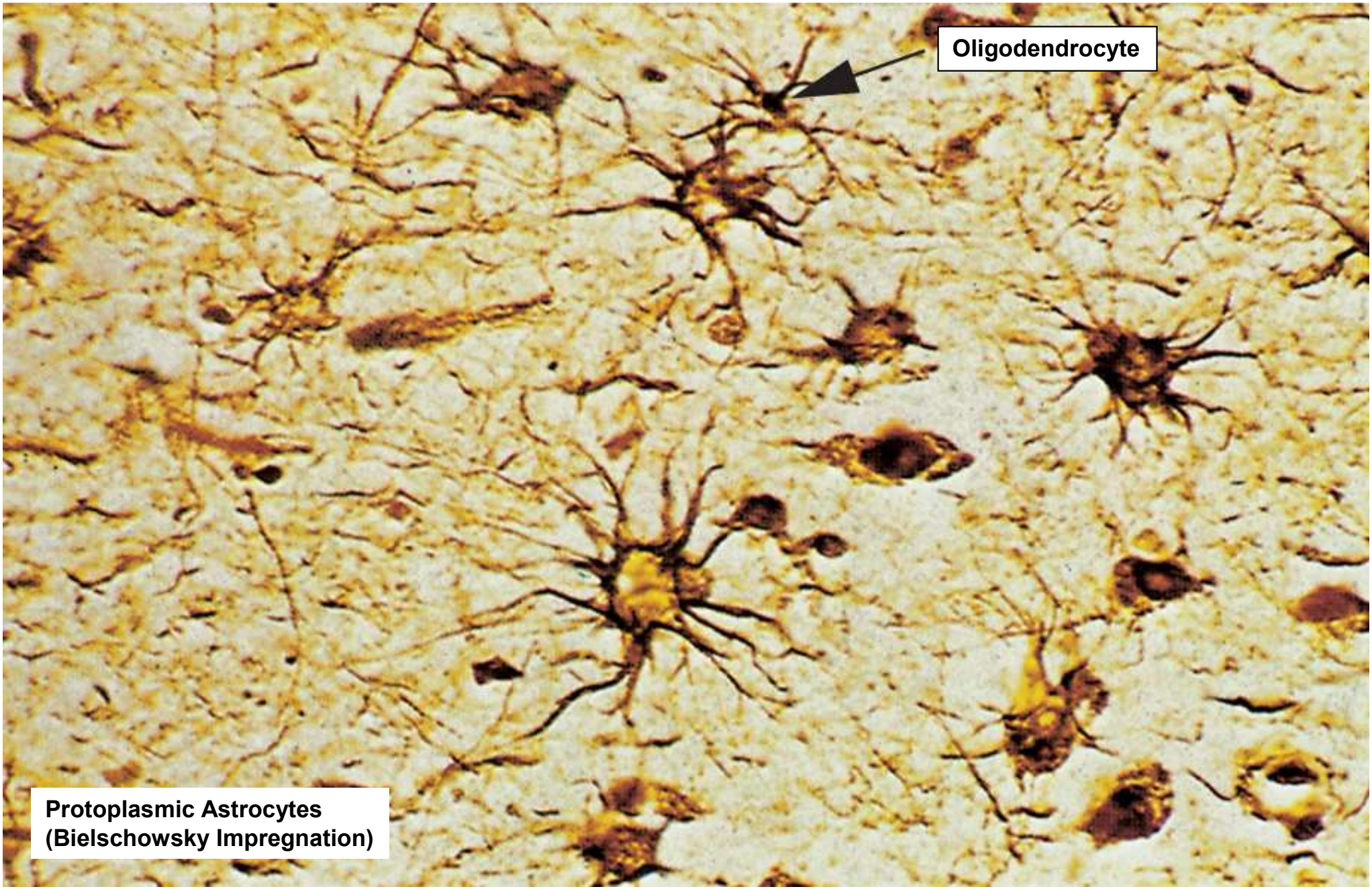
Lent et al.
European Journal of Neuroscience 2012

Astrocytes



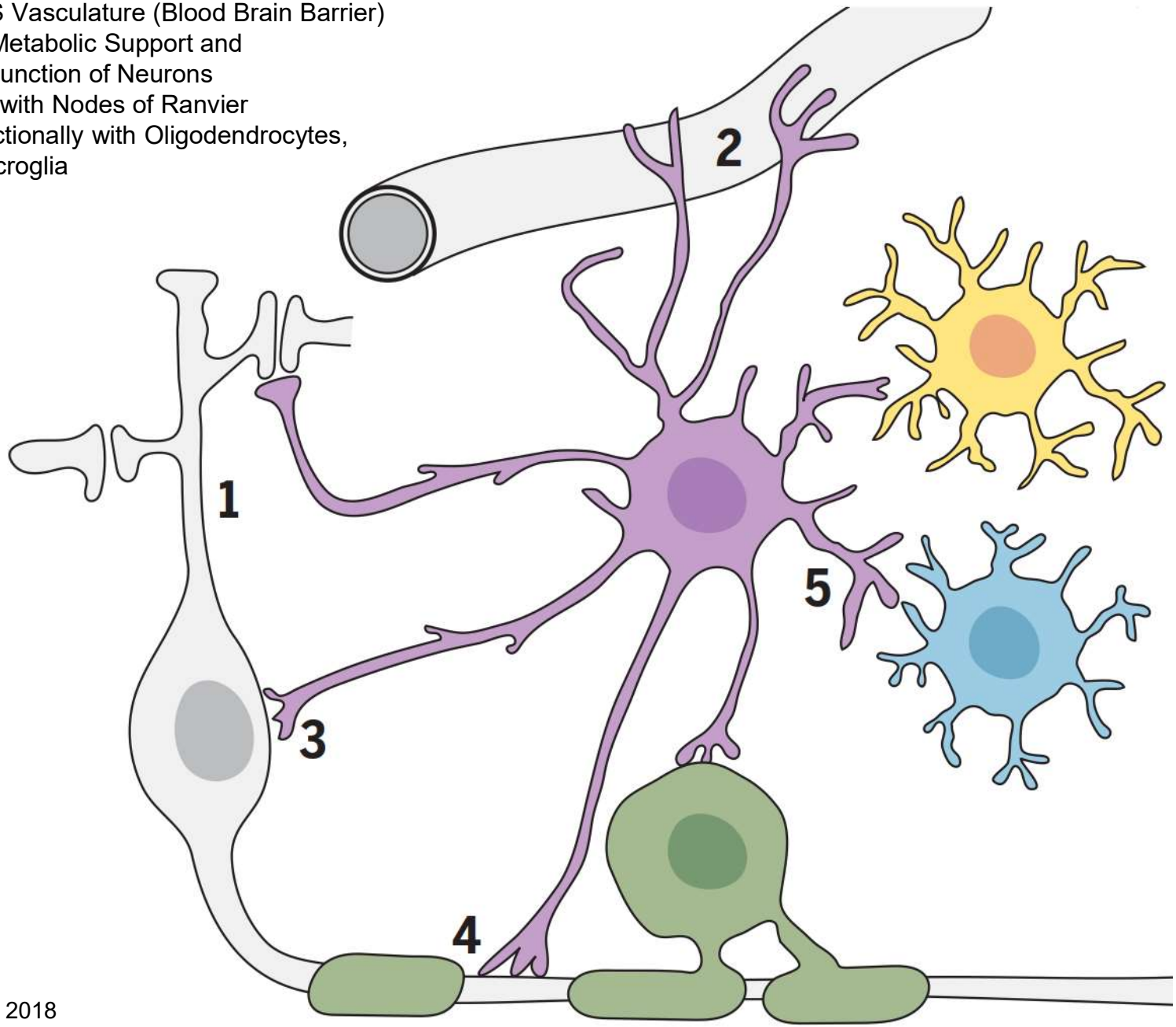
Fibrous Astrocytes
(Golgi Impregnation)

Astrocytes


Oligodendrocyte
Protoplasmic Astrocytes
(Bielschowsky Impregnation)

Astrocytes (Purple)

1 Regulate Synapse Formation, Elimination, and Function
2 Ensheath CNS Vasculature (Blood Brain Barrier)
3 Contribute to Metabolic Support and Homeostatic Function of Neurons
4 Make Contact with Nodes of Ranvier
5 Interact Bidirectionally with Oligodendrocytes, OPCs, and Microglia

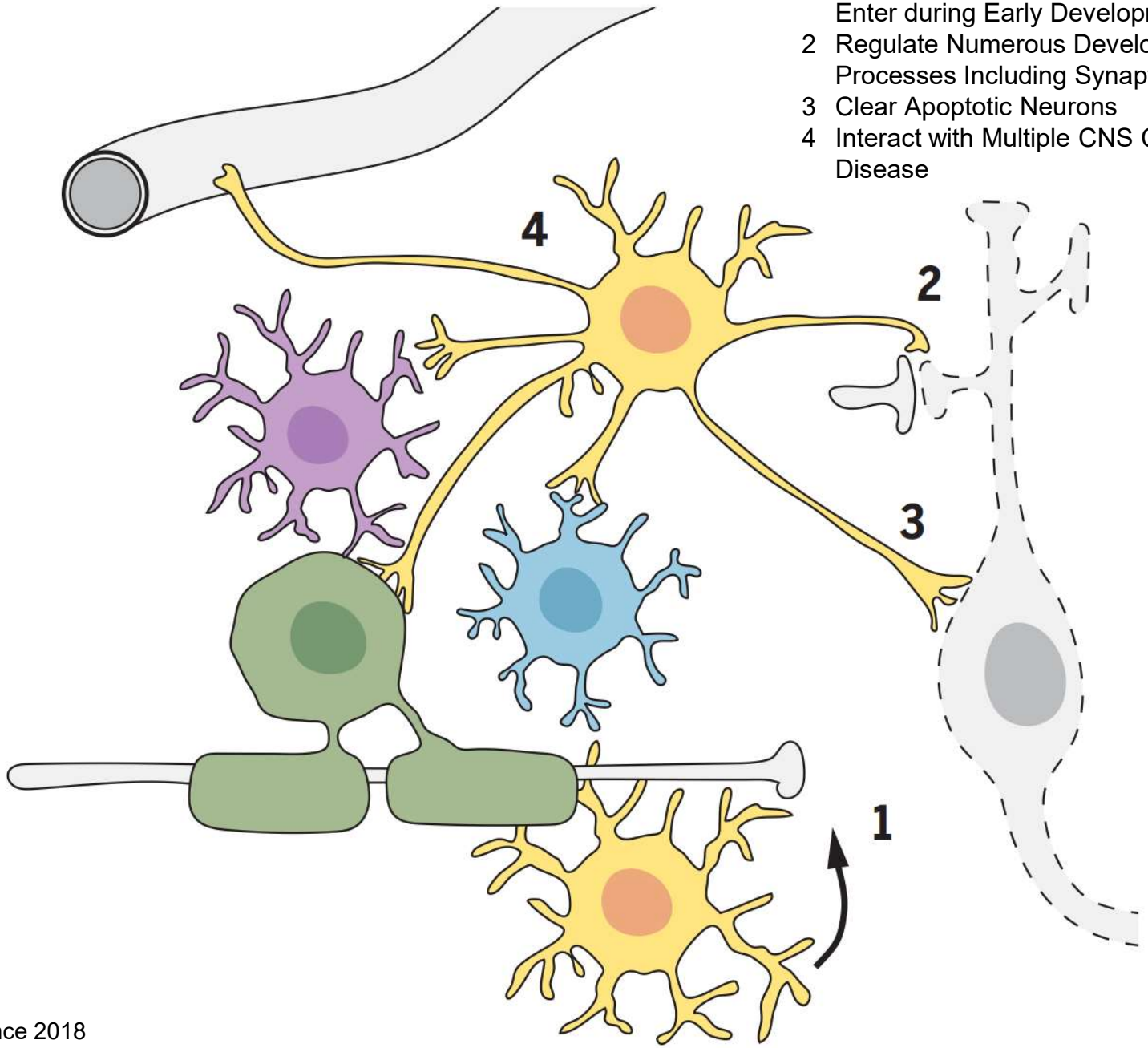


Allen et al. Science 2018

Microglia

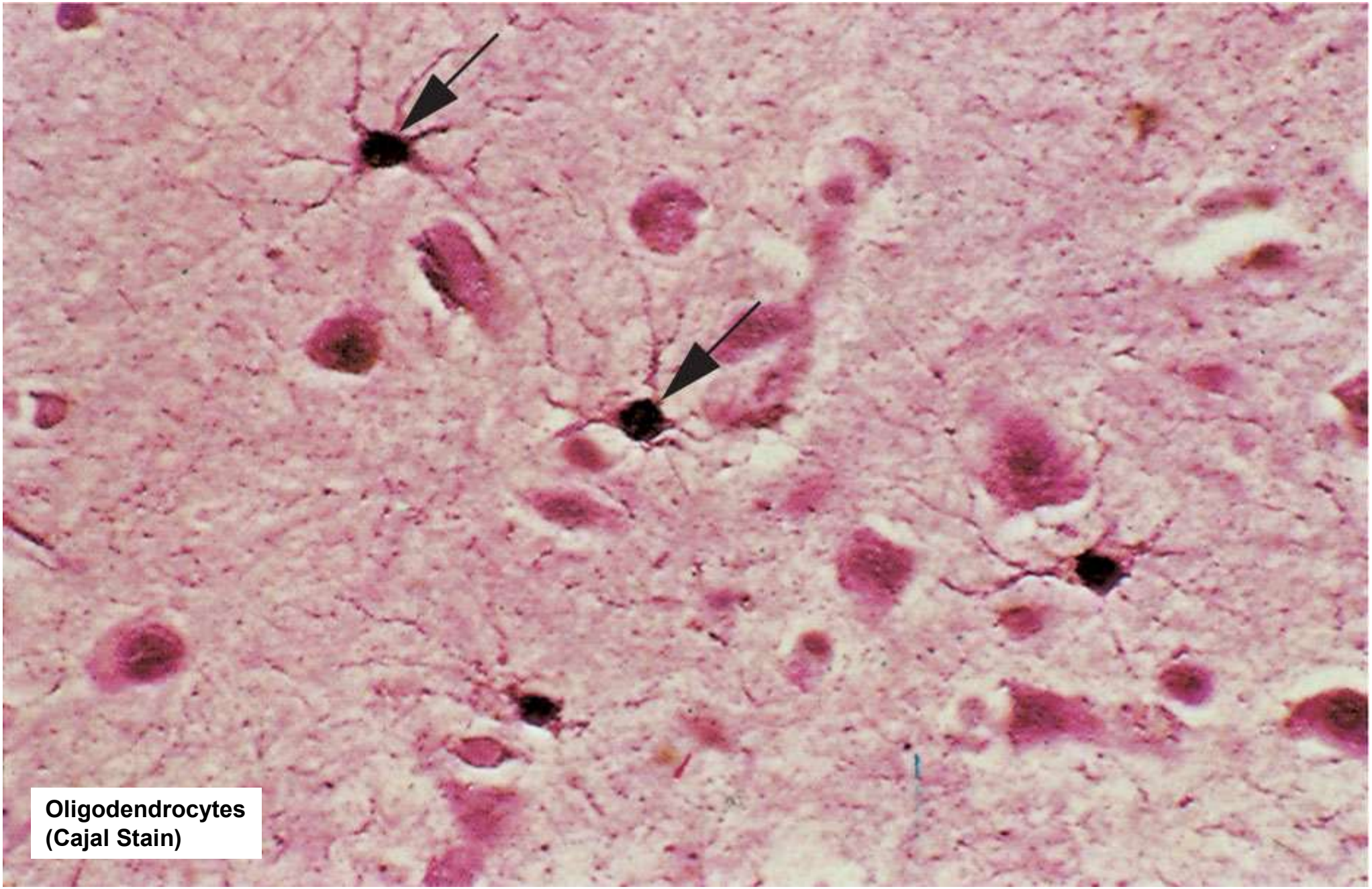
Microglia (Yellow)

1 Resident Immune Cells of the Brain,
Enter during Early Development from the Periphery
2 Regulate Numerous Developmental and Functional
Processes Including Synaptic Pruning
3 Clear Apoptotic Neurons
4 Interact with Multiple CNS Cell Types in Health and
Disease



Allen et al. Science 2018

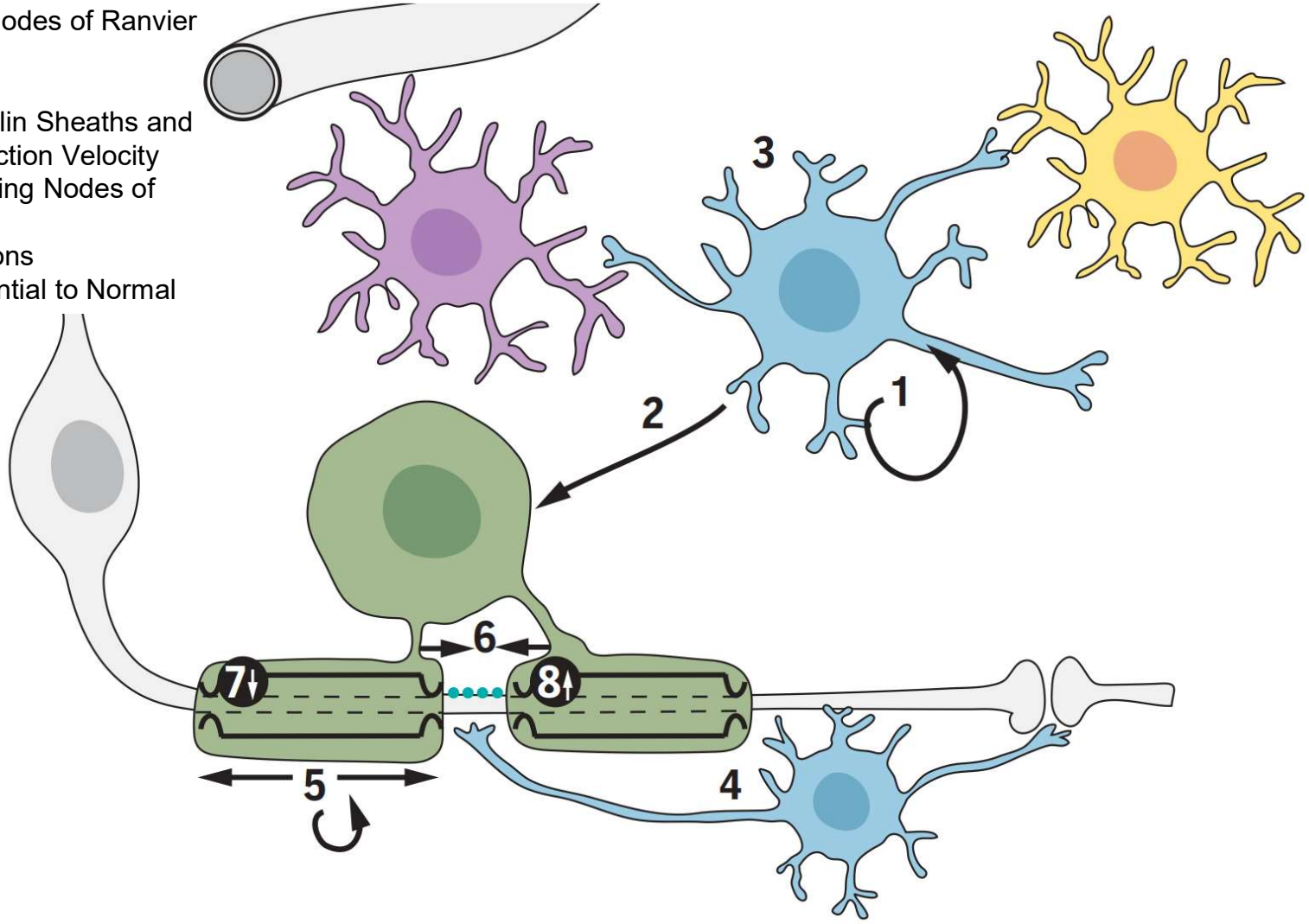
Oligodendrocytes



Oligodendrocyte Precursor Cells (OPCs, Blue) and Mature Oligodendrocytes (Dark Green)

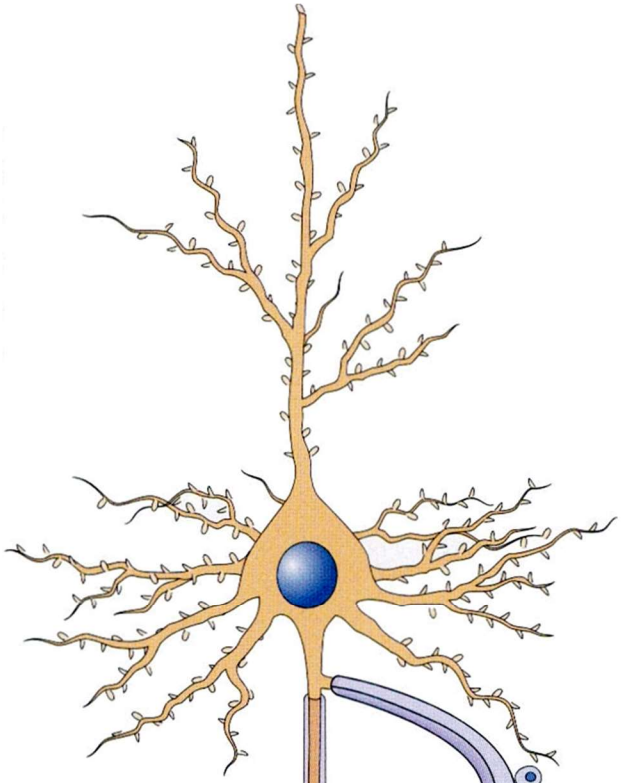
1 **OPCs** are the Most Proliferative Cells of the CNS
2 Generate Mature Oligodendrocytes throughout Life
3 Interact with Many Other Cells of the CNS Particularly in Disease
4 Extend Processes that Contact Nodes of Ranvier and Regulate Synaptic Function

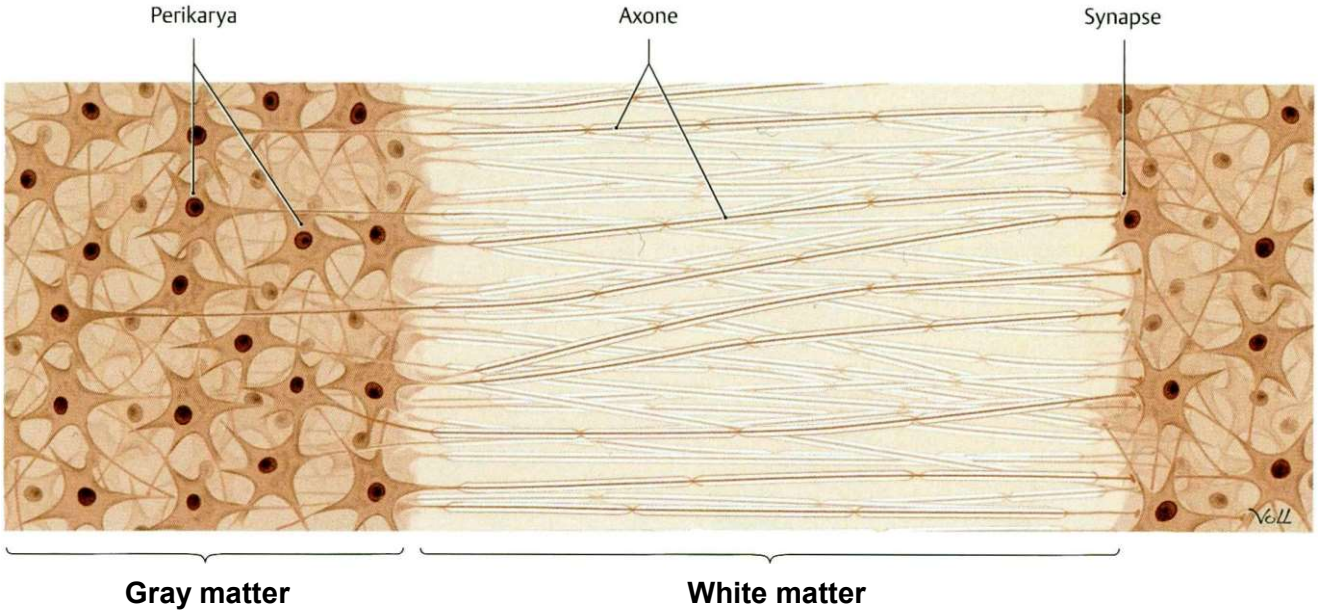
5 **Oligodendrocytes** Produce Myelin Sheaths and Regulate Action Potential Conduction Velocity
6 Organize Axonal Domains Including Nodes of Ranvier
7 Provide Metabolic Support to Axons
8 Facilitate Ion Homeostasis, Essential to Normal Action Potential Conduction

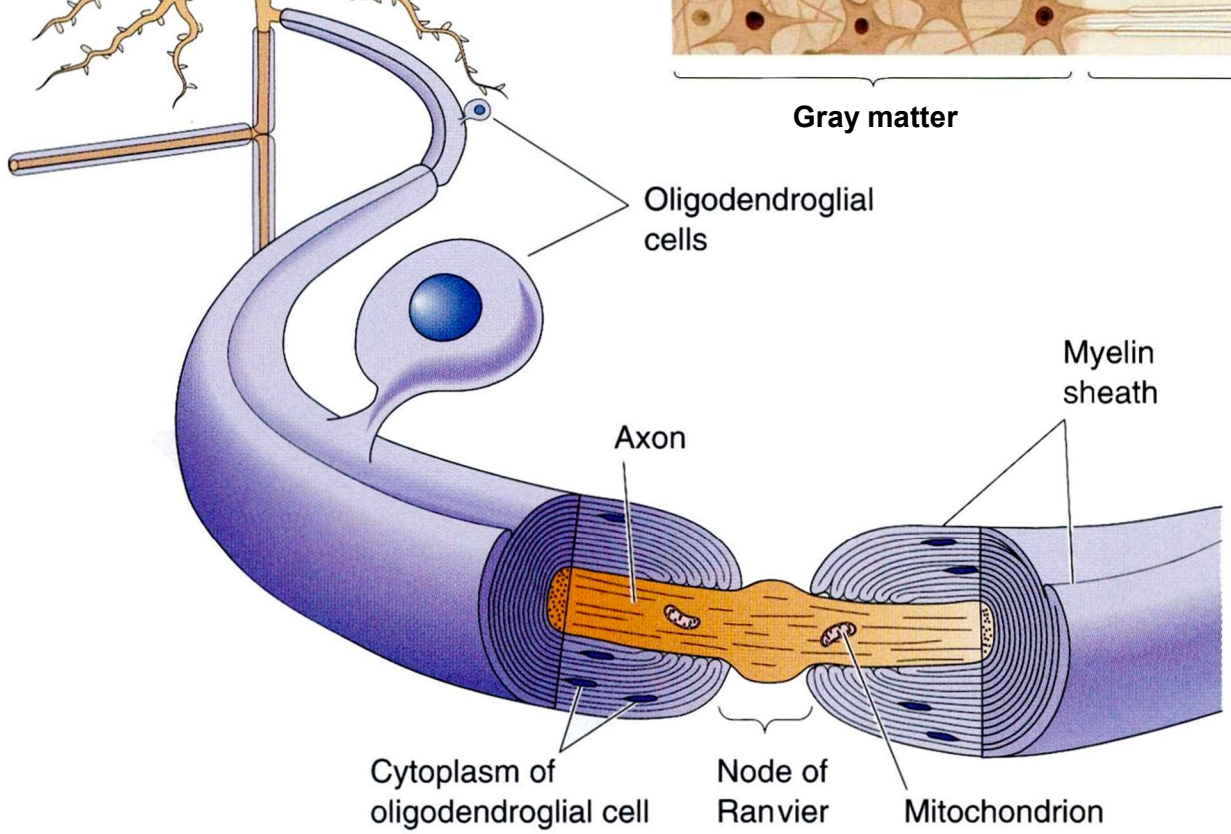


Allen et al. Science 2018

Oligodendrocytes – Myelin Sheaths

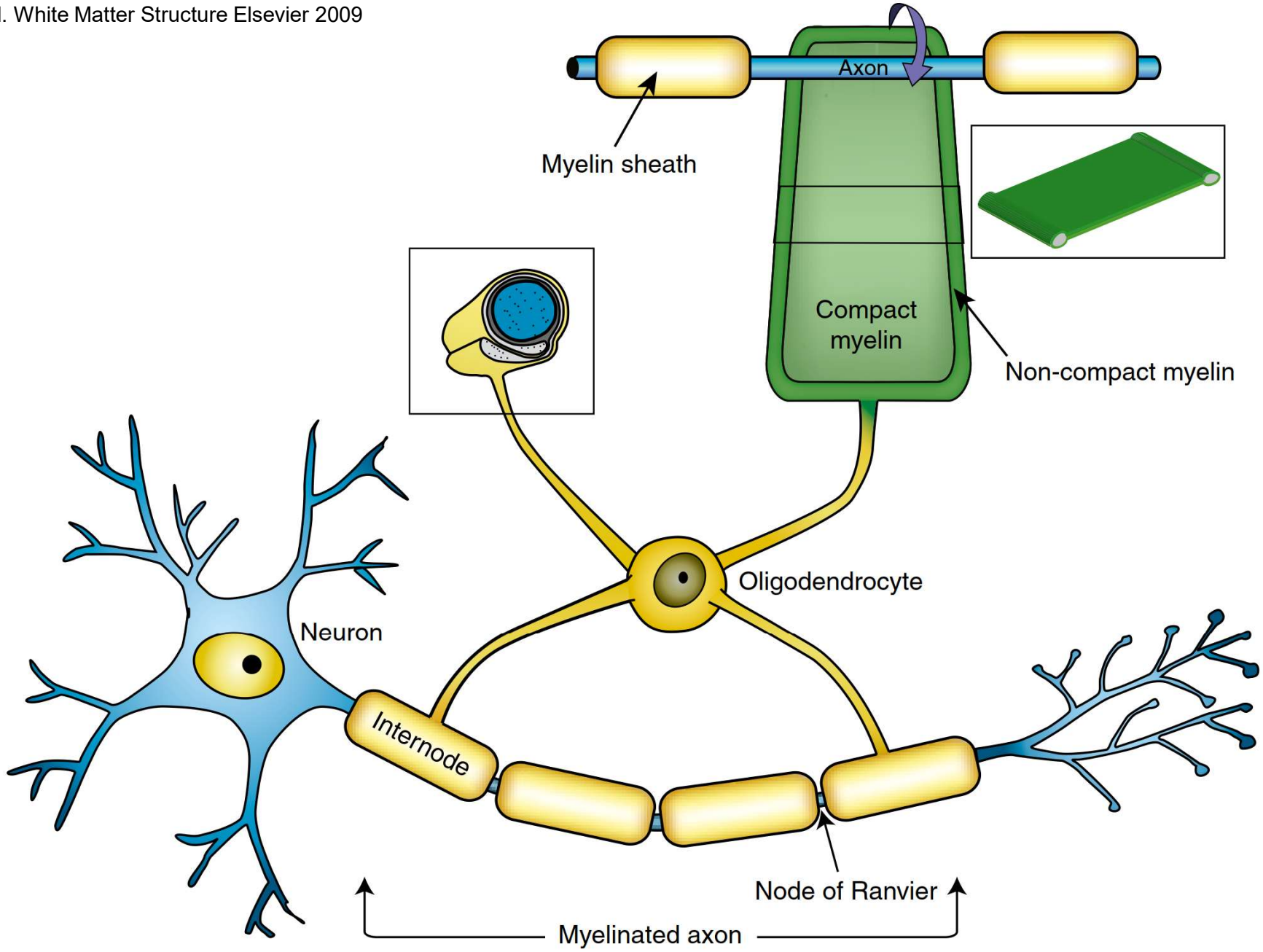




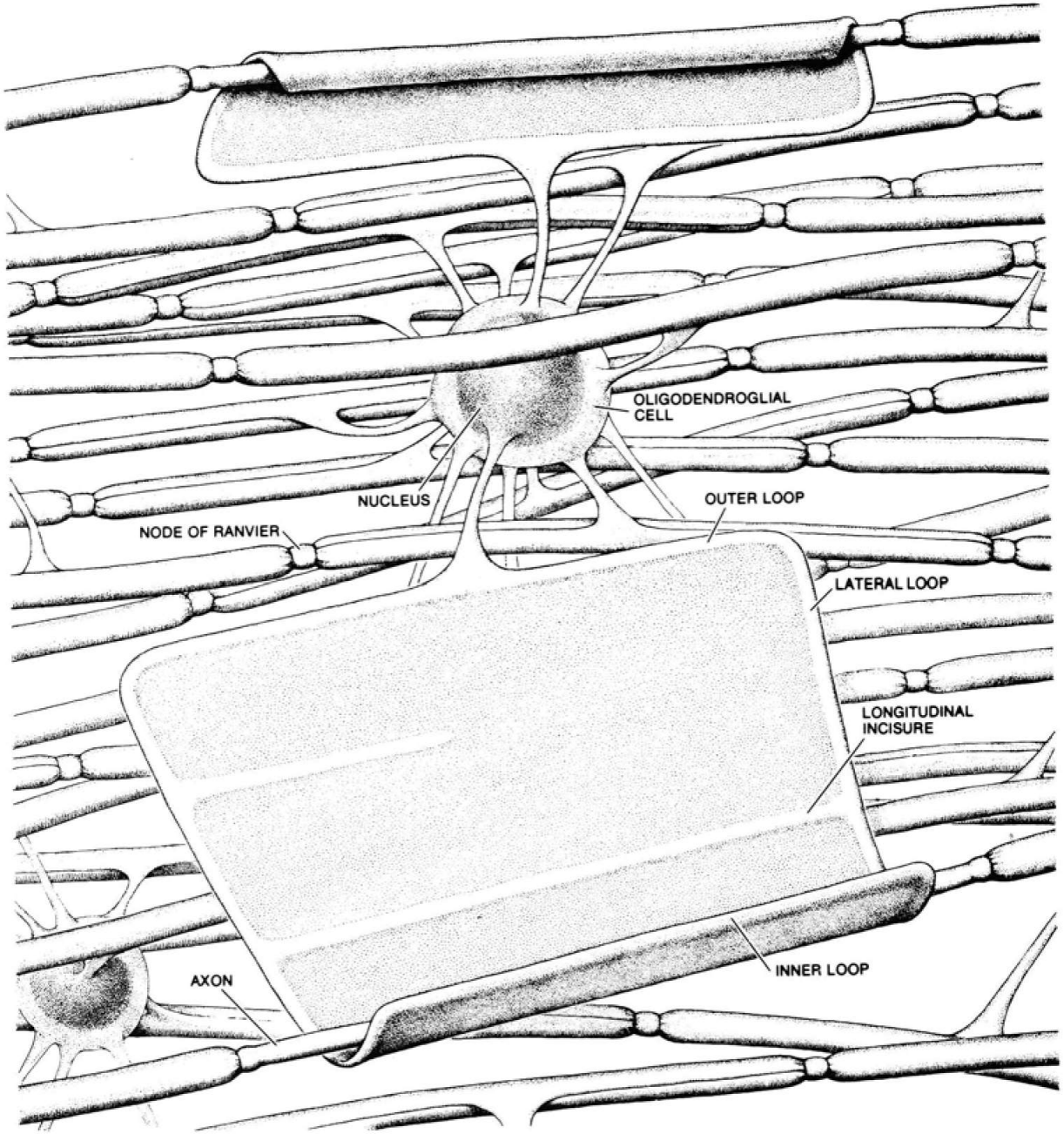


Oligodendrocytes – Myelin Sheaths

Edgar et al. White Matter Structure Elsevier 2009

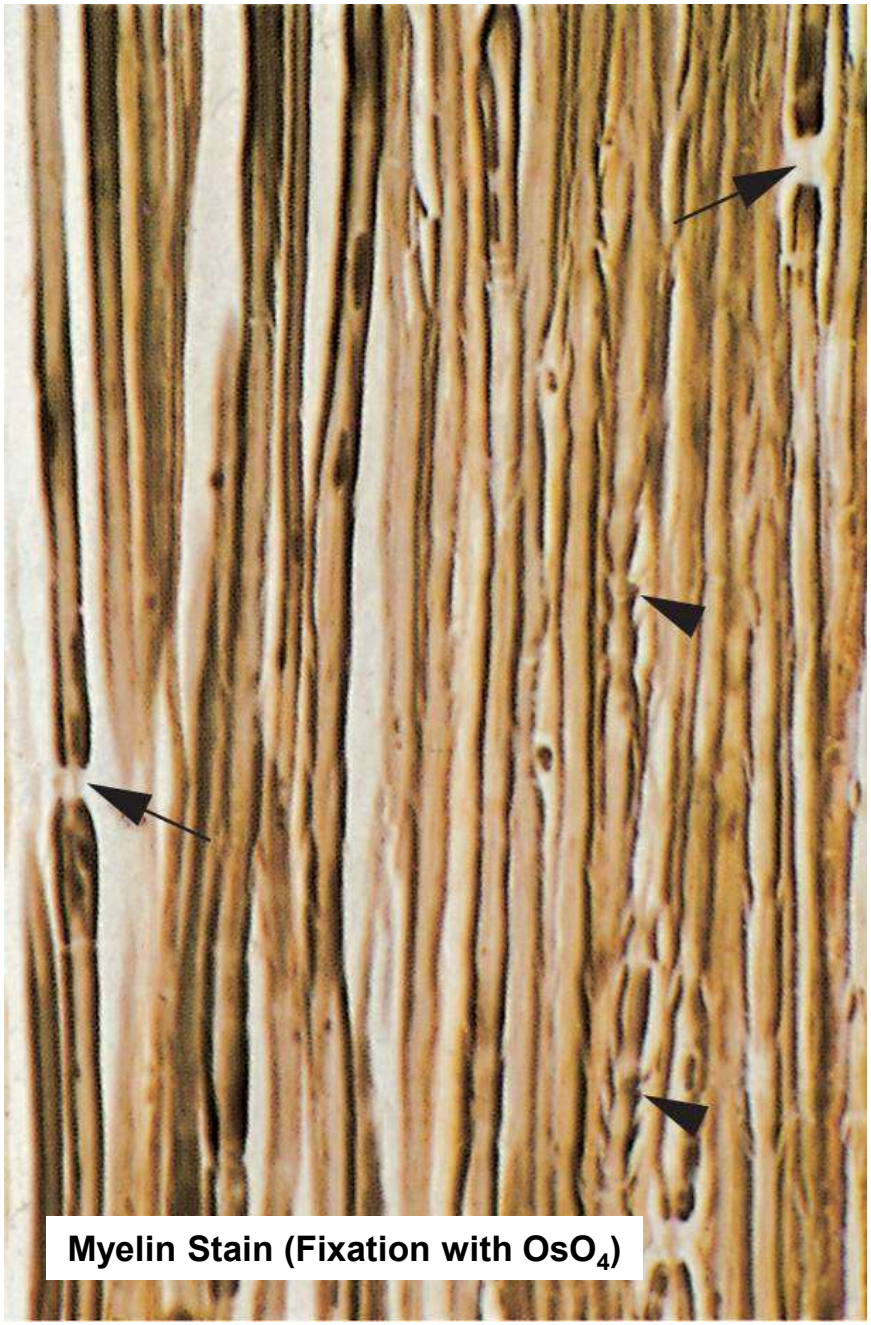


Oligodendrocytes – Myelin Sheaths

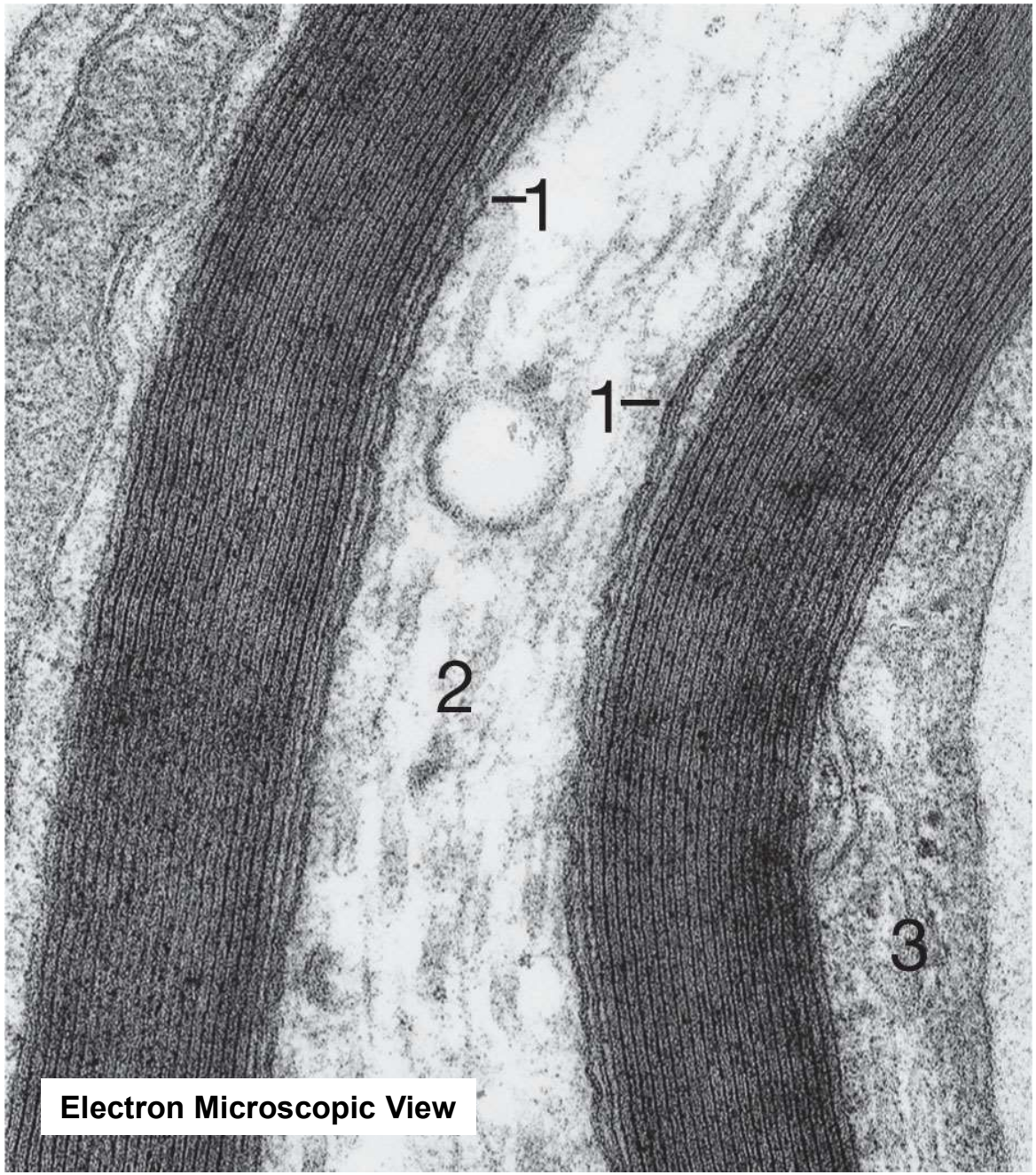


Morell Myelin
Plenum Press 1984

Oligodendrocytes – Myelin Sheaths

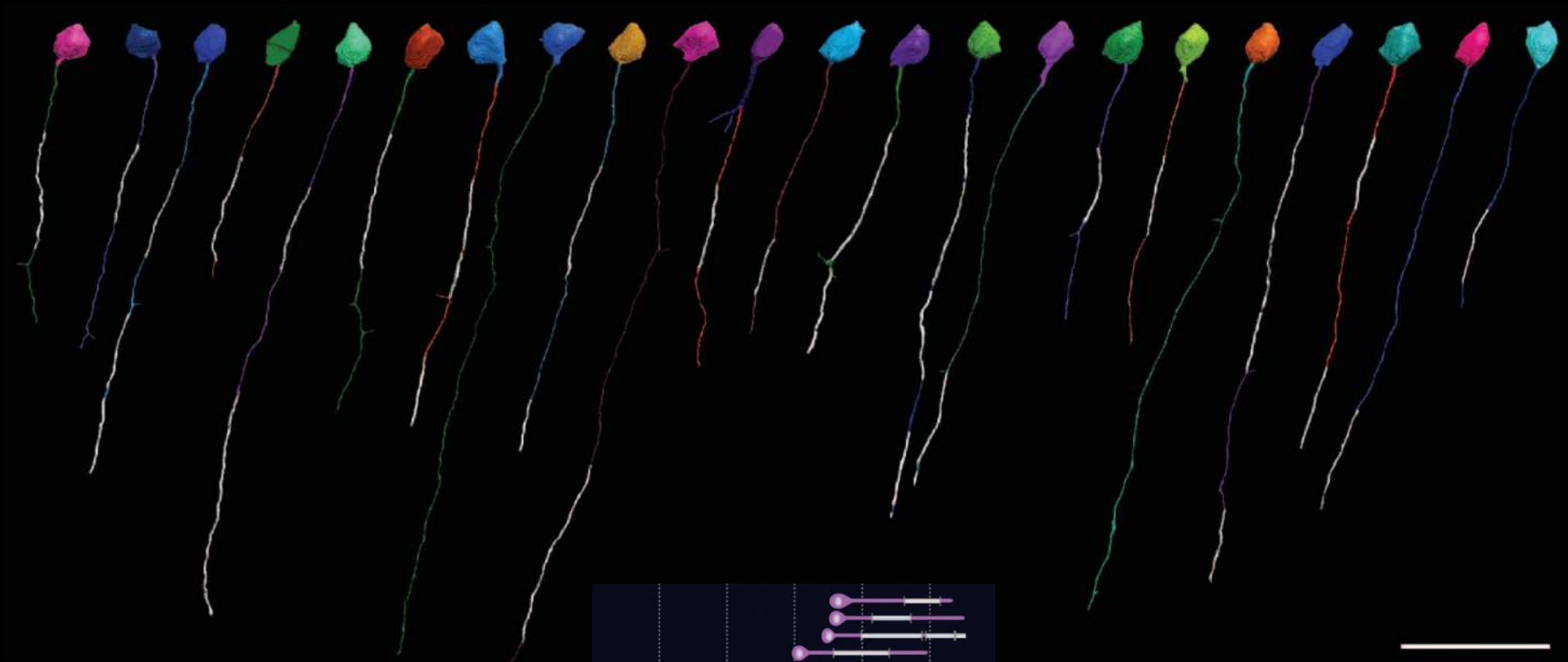


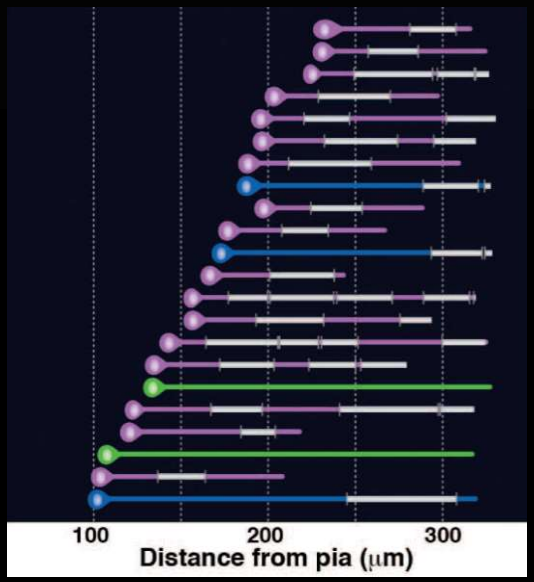
Myelin Stain (Fixation with OsO_4)



Electron Microscopic View

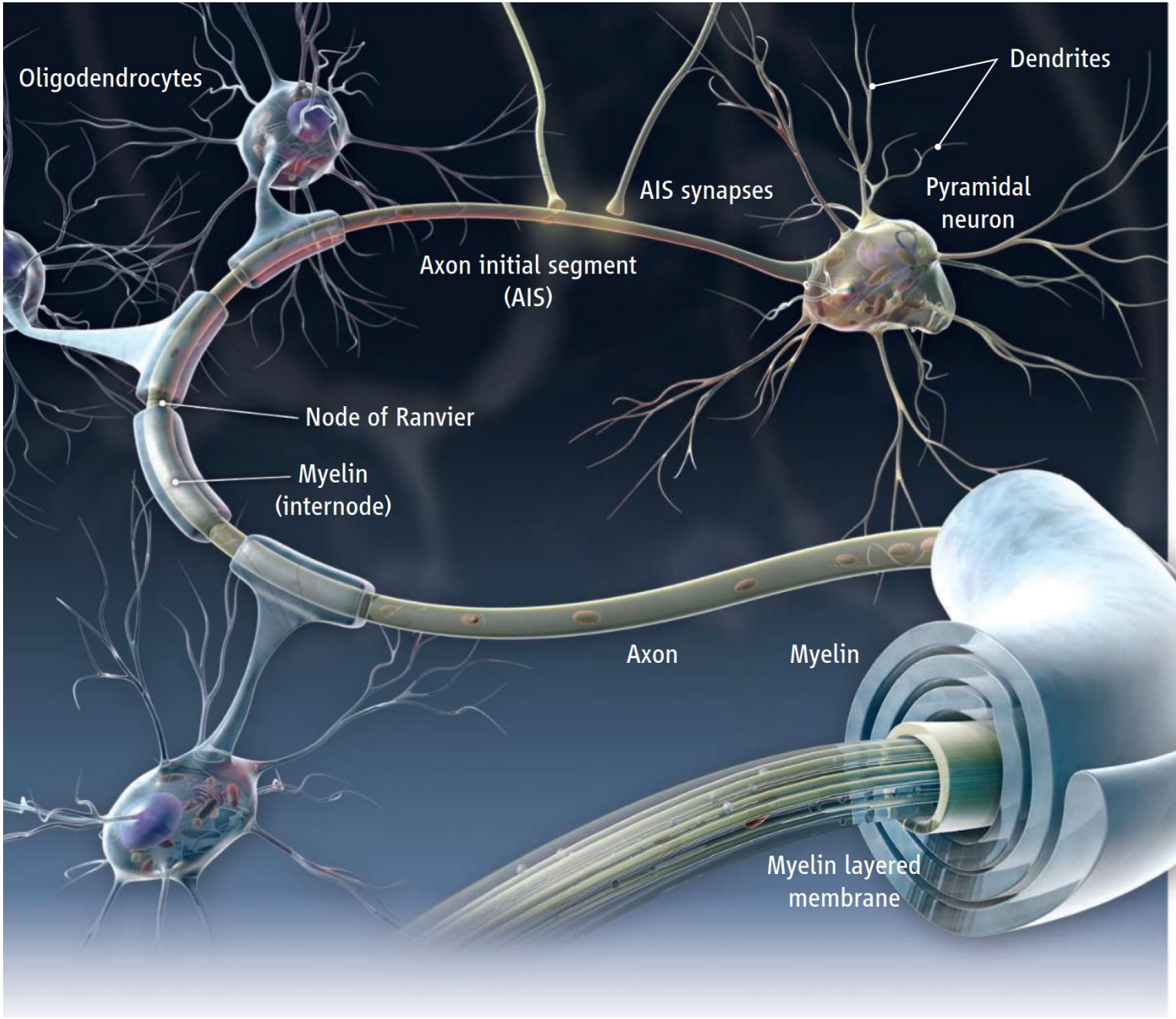
Myelination is Discontinuous





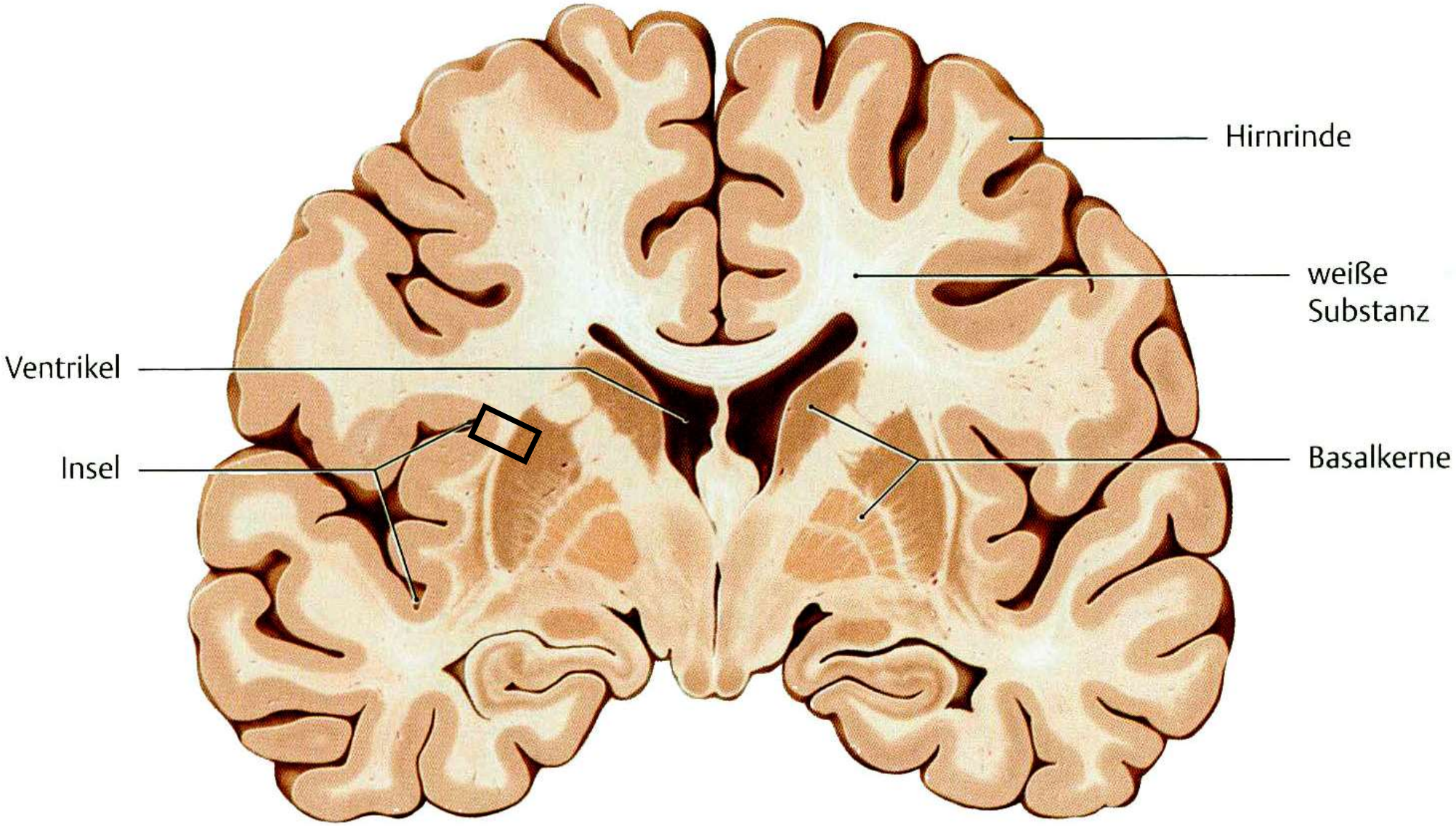
Tomassy et al. Science 2014

Myelination is Discontinuous



Fields Science 2014

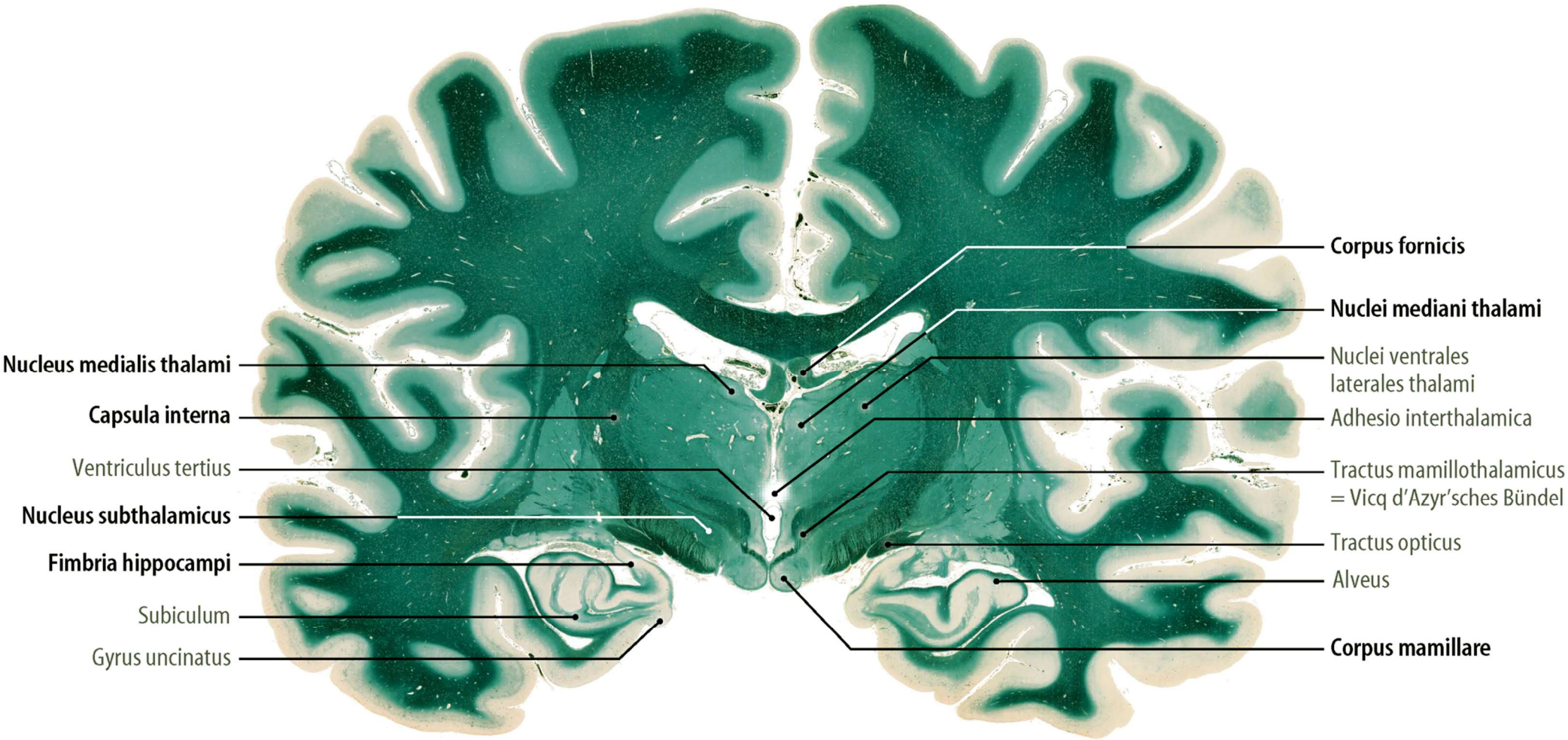
Gray Matter – White Matter – Ventricles



Gray Matter (Superficial and Deep) – White Matter – Ventricles

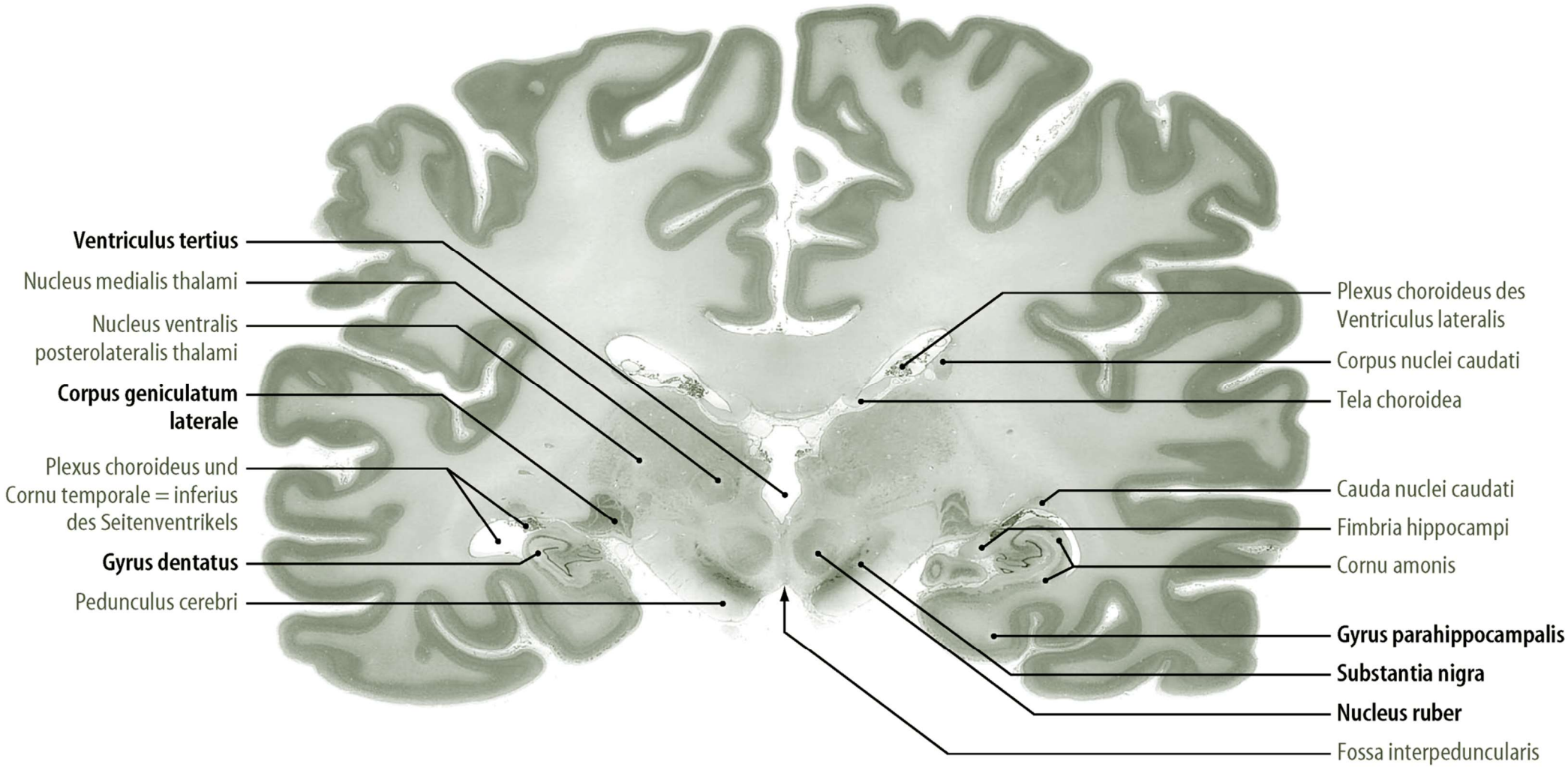
Cortex **Nuclei**

Myelin Stain (Naked Eye View)



Gray Matter is Light – White Matter is Dark

Cell Body Stain (Naked Eye View)



Gray Matter is Dark – White Matter is Light