Neurulation

Readings:

- Chapter 5
- Chapter 10
  - P. 208-214
  - P. 218-219 (Peripheral Nerve)
  - p. 239-240 (Cranial Nerve)

Neurulation

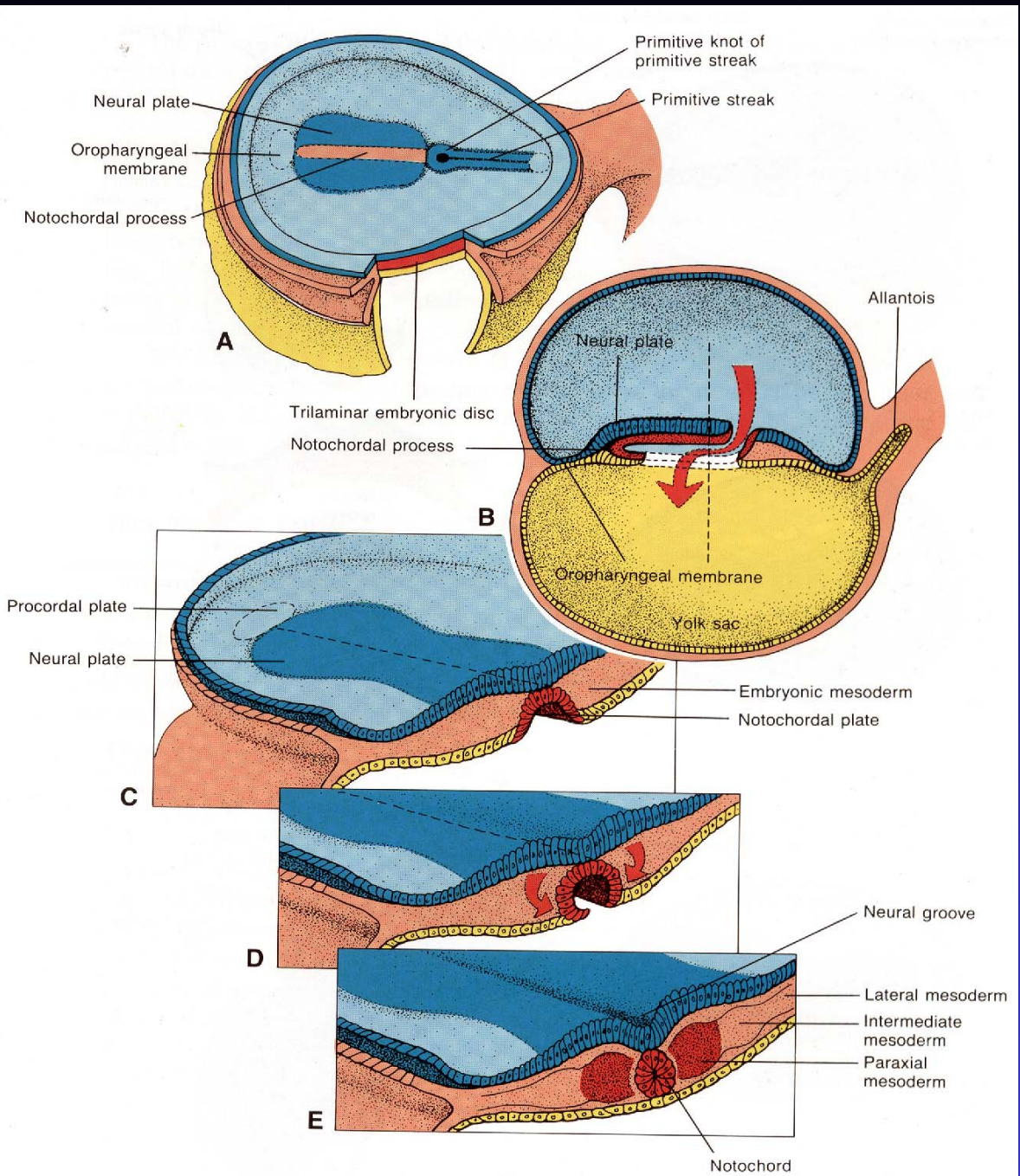
Induced by Notochord – Noggin/Chordin

Neural Plate → Neural Groove → Neural Tube

Regionalization – Subdivisions of the Central Nervous System (CNS)

Noggin, chordin → Anterior Neural Tissues Forebrain

FGF8 – Fibroblast Growth Factor 8 → Posterior neural tissues, i.e. spinal cord



Middle of third week: Neural Plate

Notochord induces overlying ectoderm → neural plate –

Thickening of cell layer

Anterior Inducer: Noggin/ Chordin

Posterior Inducer: FGF-8,

Neural Plate → Neural Tube

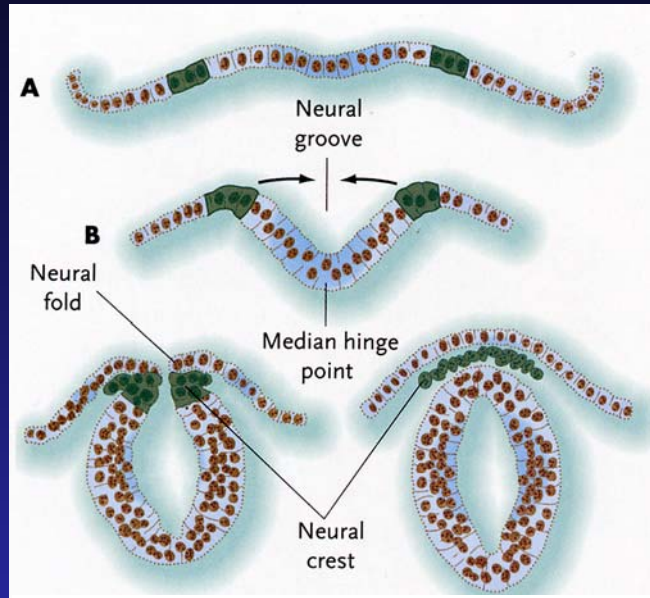
Four Stages of Neural Tube formation:

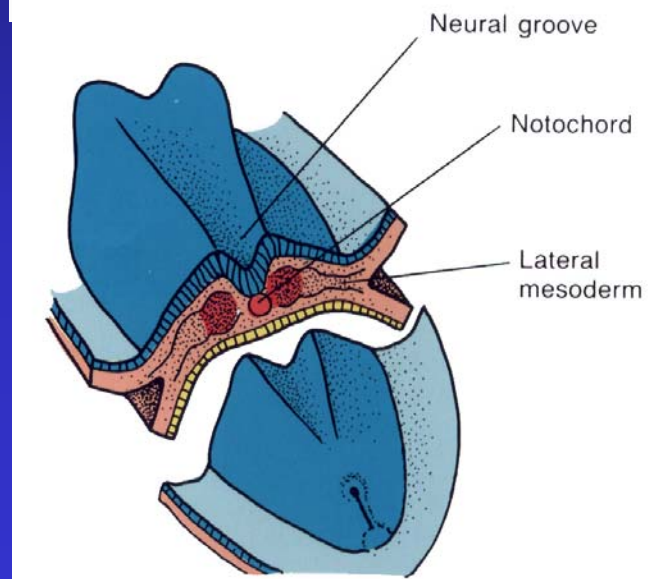
1) Thickening of the Neural Plate

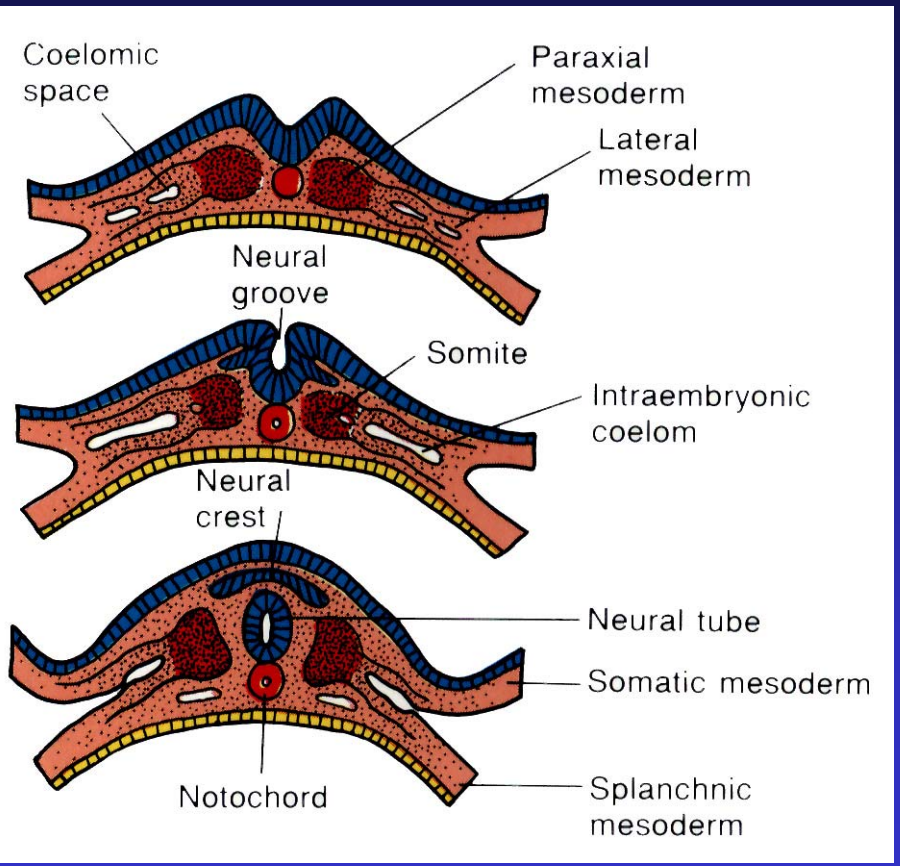
2) Establishing the contours of the Neural Plate: Cell shape changes and rearrangement of cells

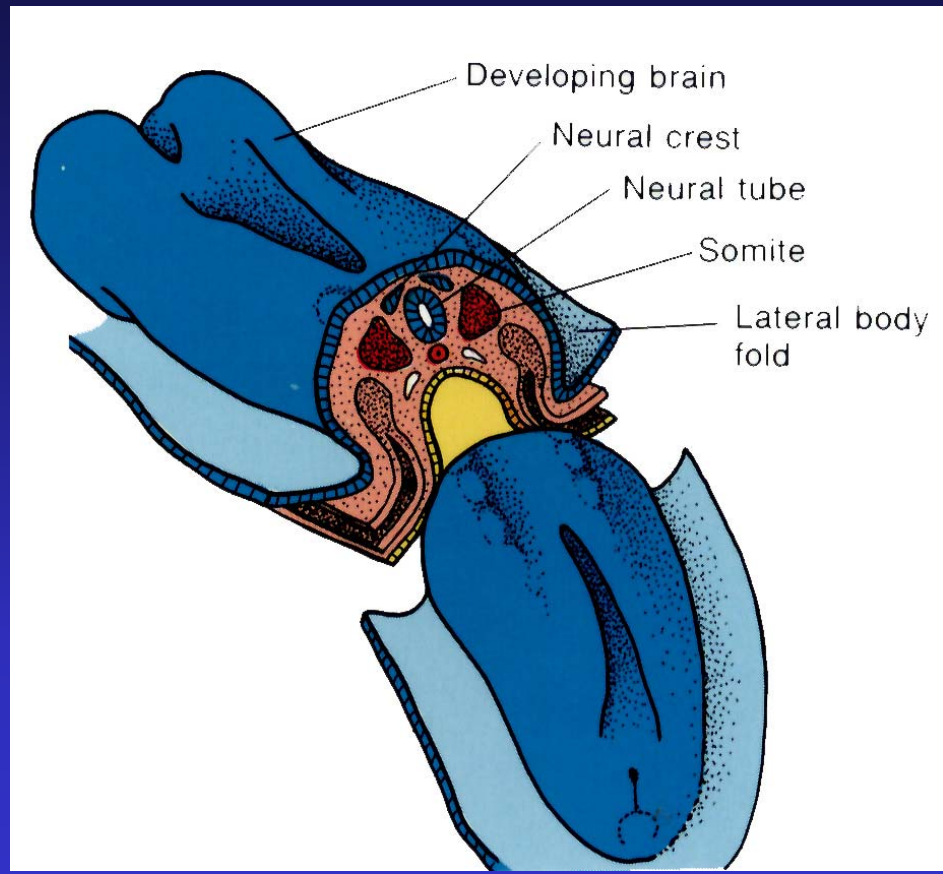
3) Lateral Neural Folds elevate to form the Neural Groove – medial hinge acts as an anchor, Cell shape changes apically, expanding lateral epidermis forces elevation

4) Apposition and fusion of the Neural Folds to form the Neural Tube

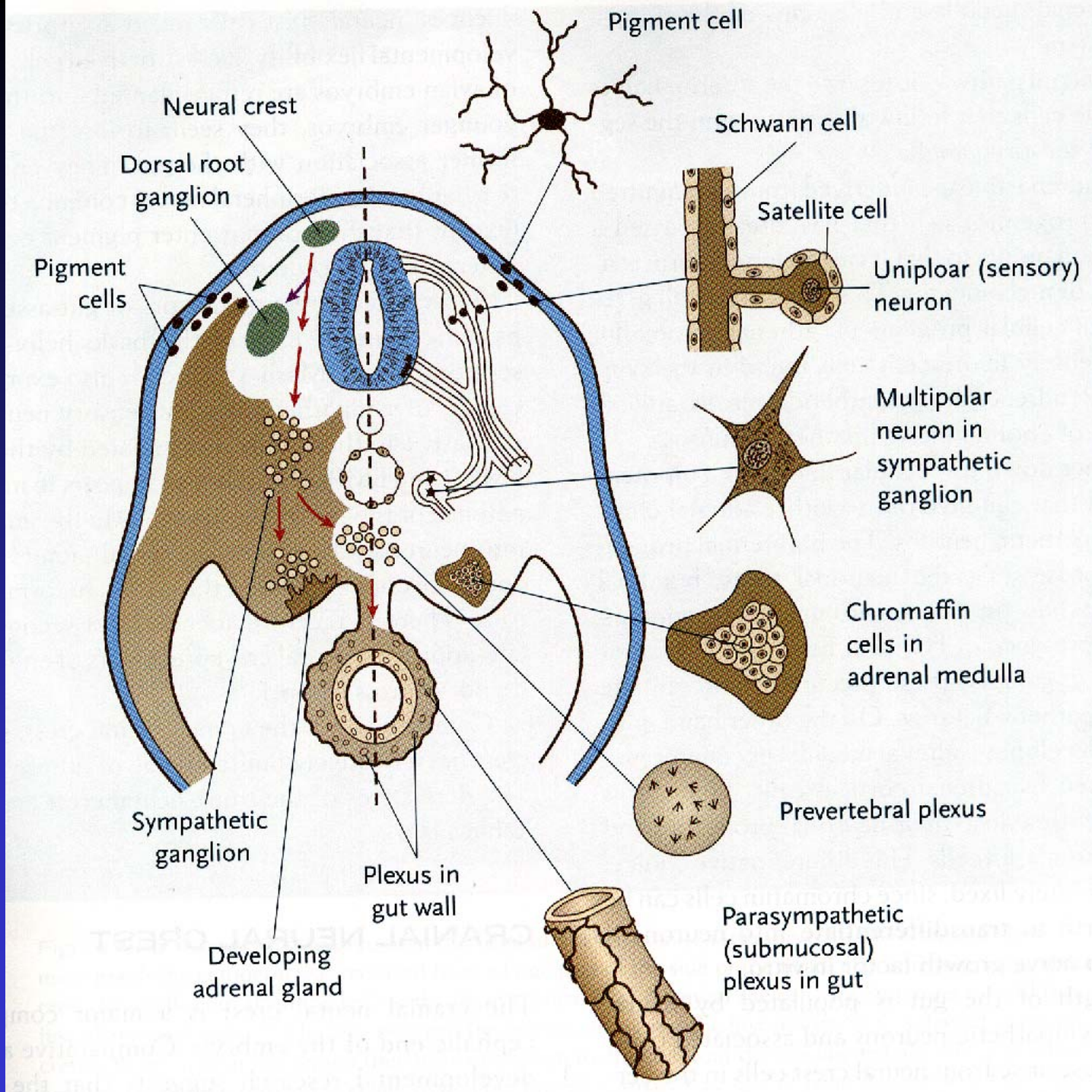




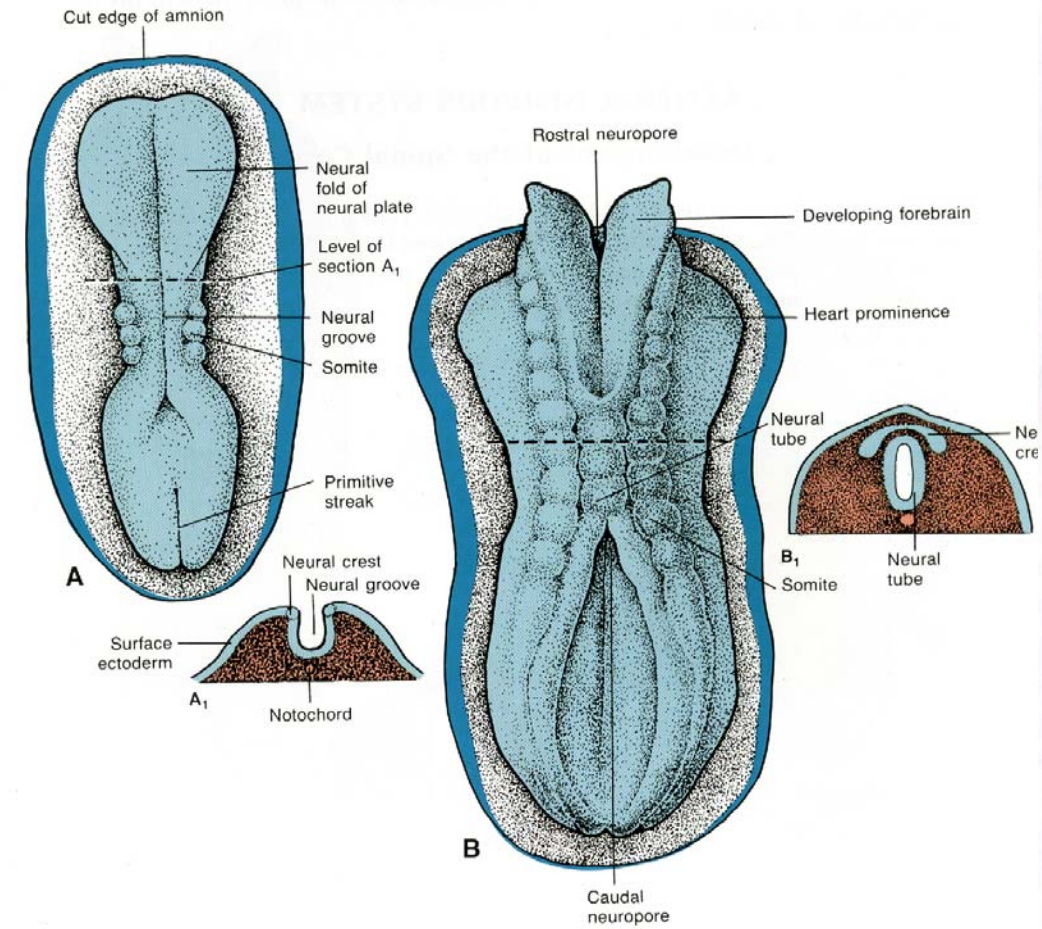

Coelomic space
Paraxial mesoderm
Lateral mesoderm
Neural groove
Somite
Intraembryonic coelom
Neural crest
Neural tube
Somatic mesoderm
Notochord
Splanchnic mesoderm

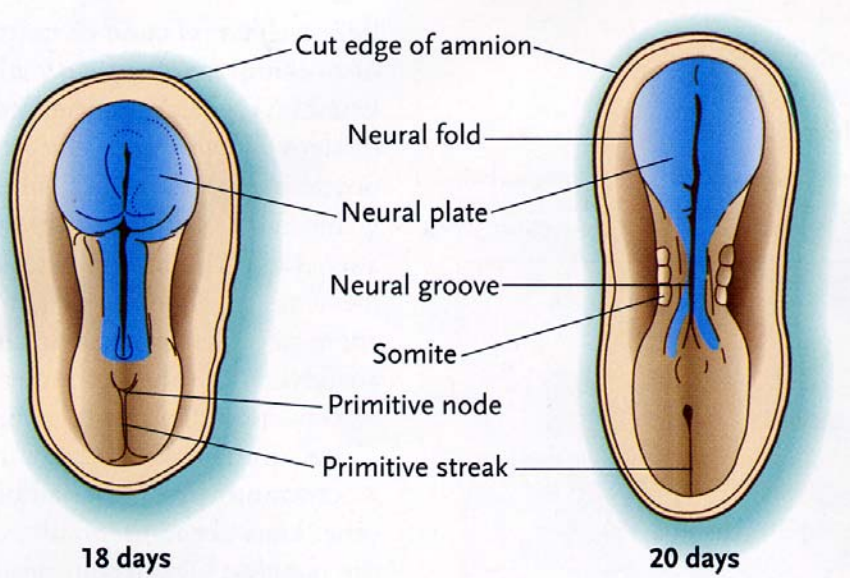

Developing brain
Neural crest
Neural tube
Somite
Lateral body fold

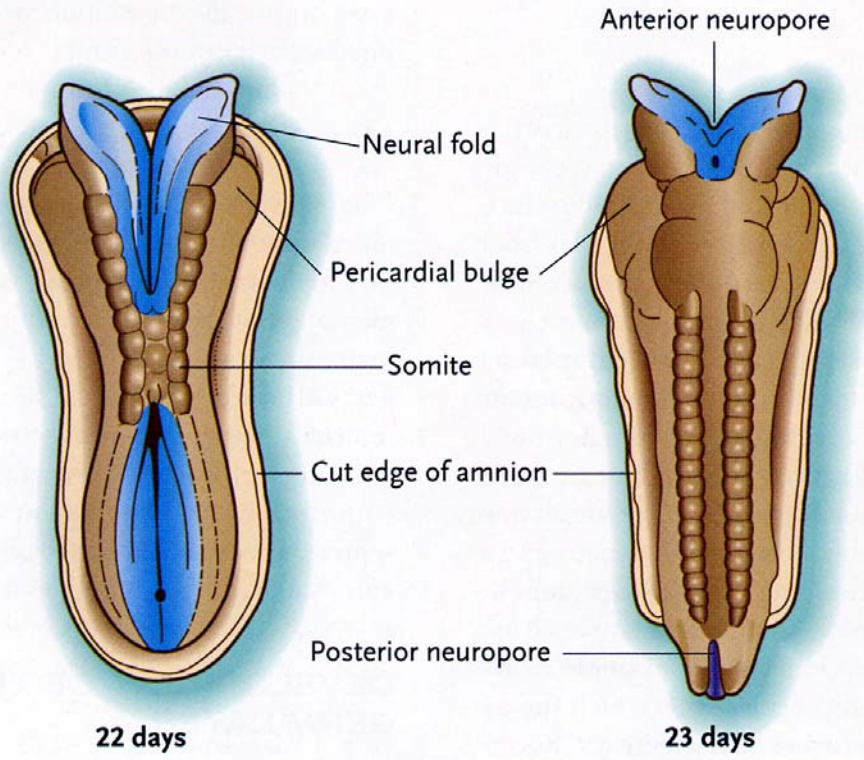
Neural Crest



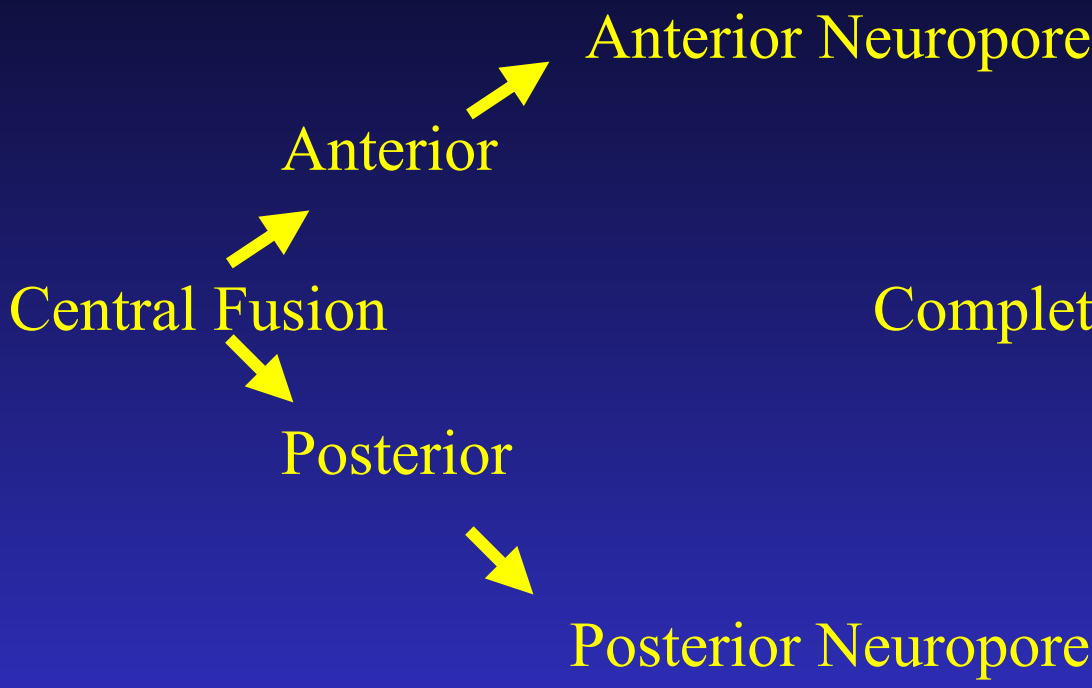
Early CNS Development







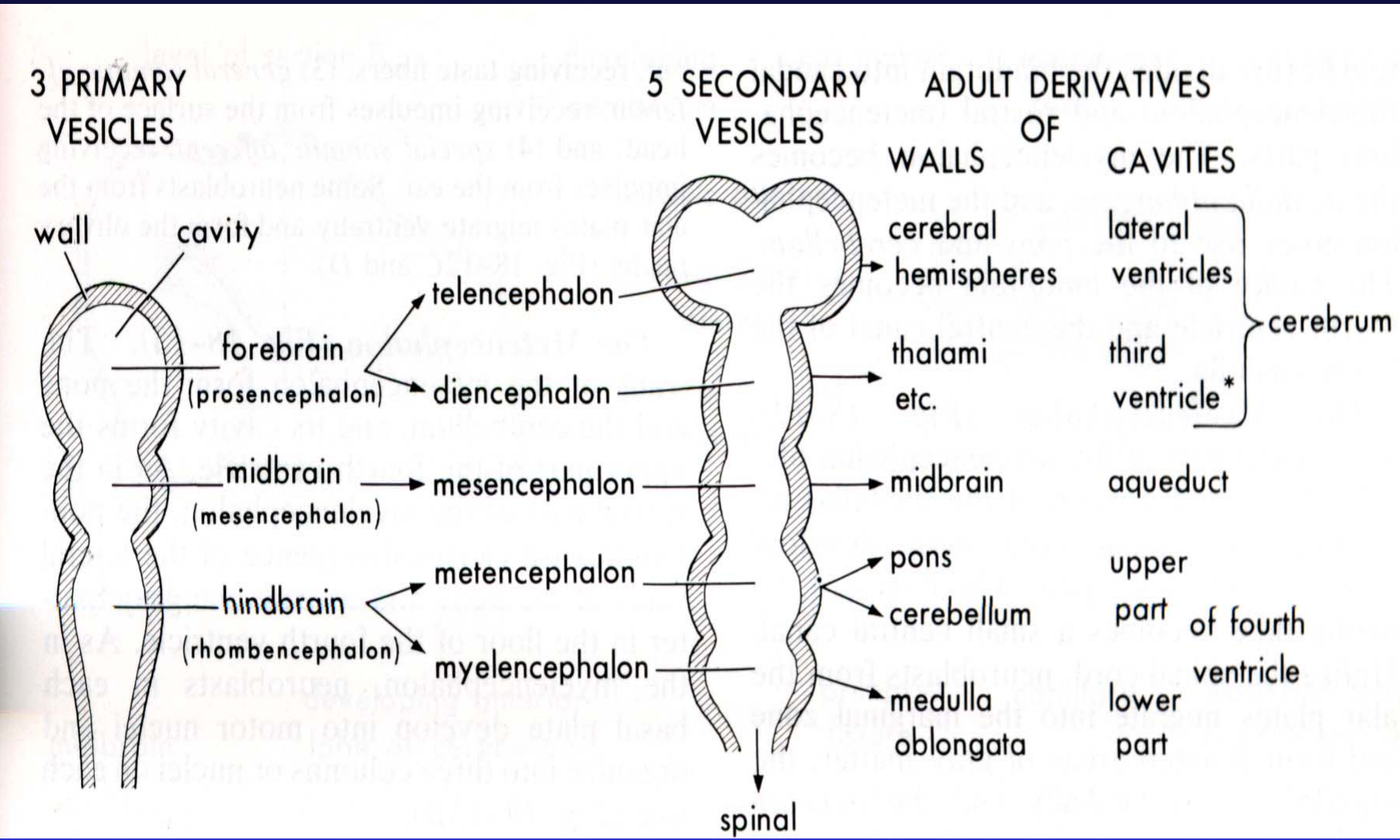
Neural Tube Formation

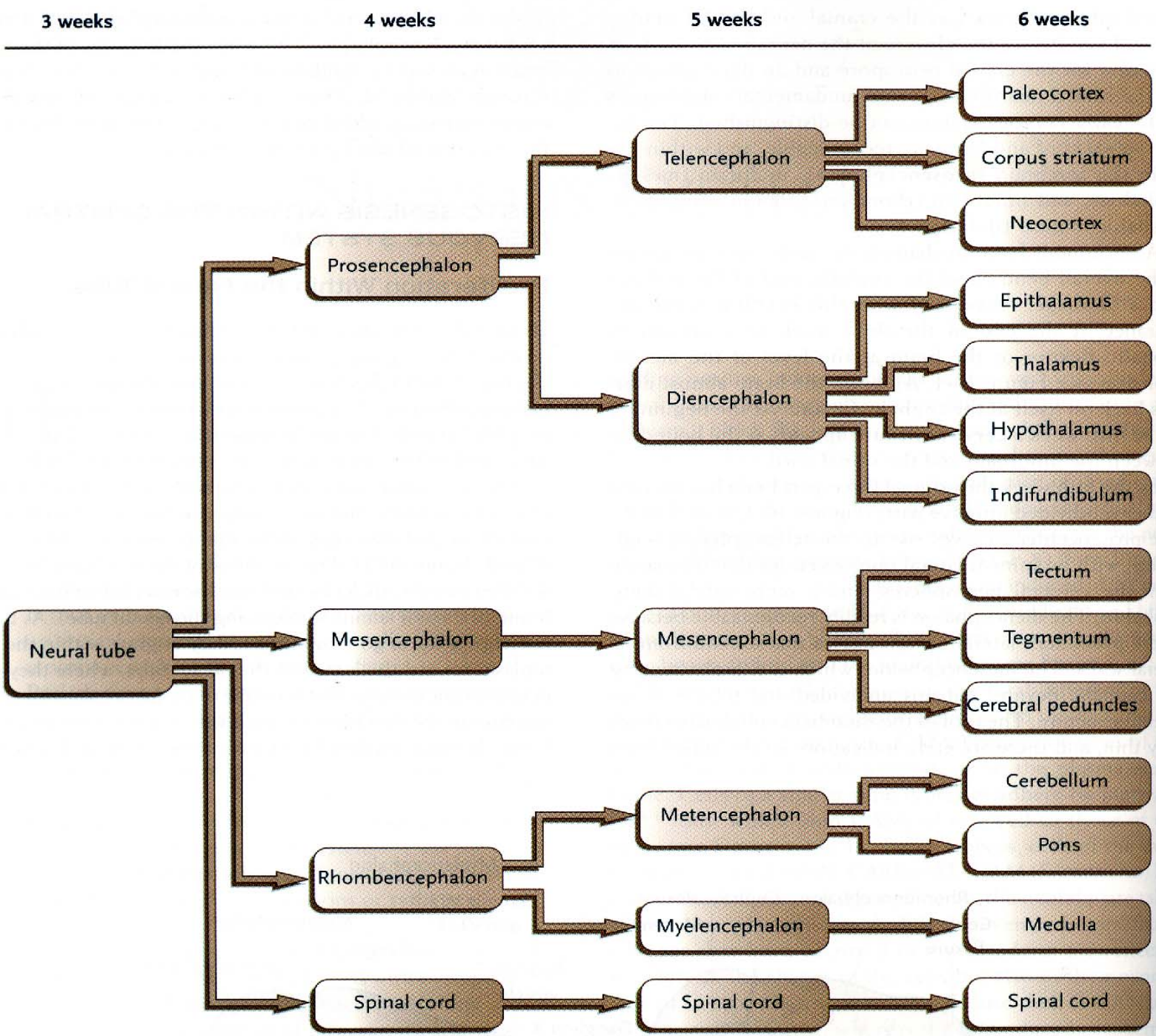


Completion – Closure of Neuropores

Secondary Neurulation – Posterior to the neuropore –
Mesenchymal condensation to form a rod that undergoes cavitation – secondary fusion with primary neural tube.

Segmentation of the Neural Tube




3 weeks
4 weeks
5 weeks
6 weeks
Neural tube
Prosencephalon
Mesencephalon
Rhombencephalon
Spinal cord
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
Spinal cord
Paleocortex
Corpus striatum
Neocortex
Epithalamus
Thalamus
Hypothalamus
Indifundibulum
Tectum
Tegmentum
Cerebral peduncles
Cerebellum
Pons
Medulla
Spinal cord

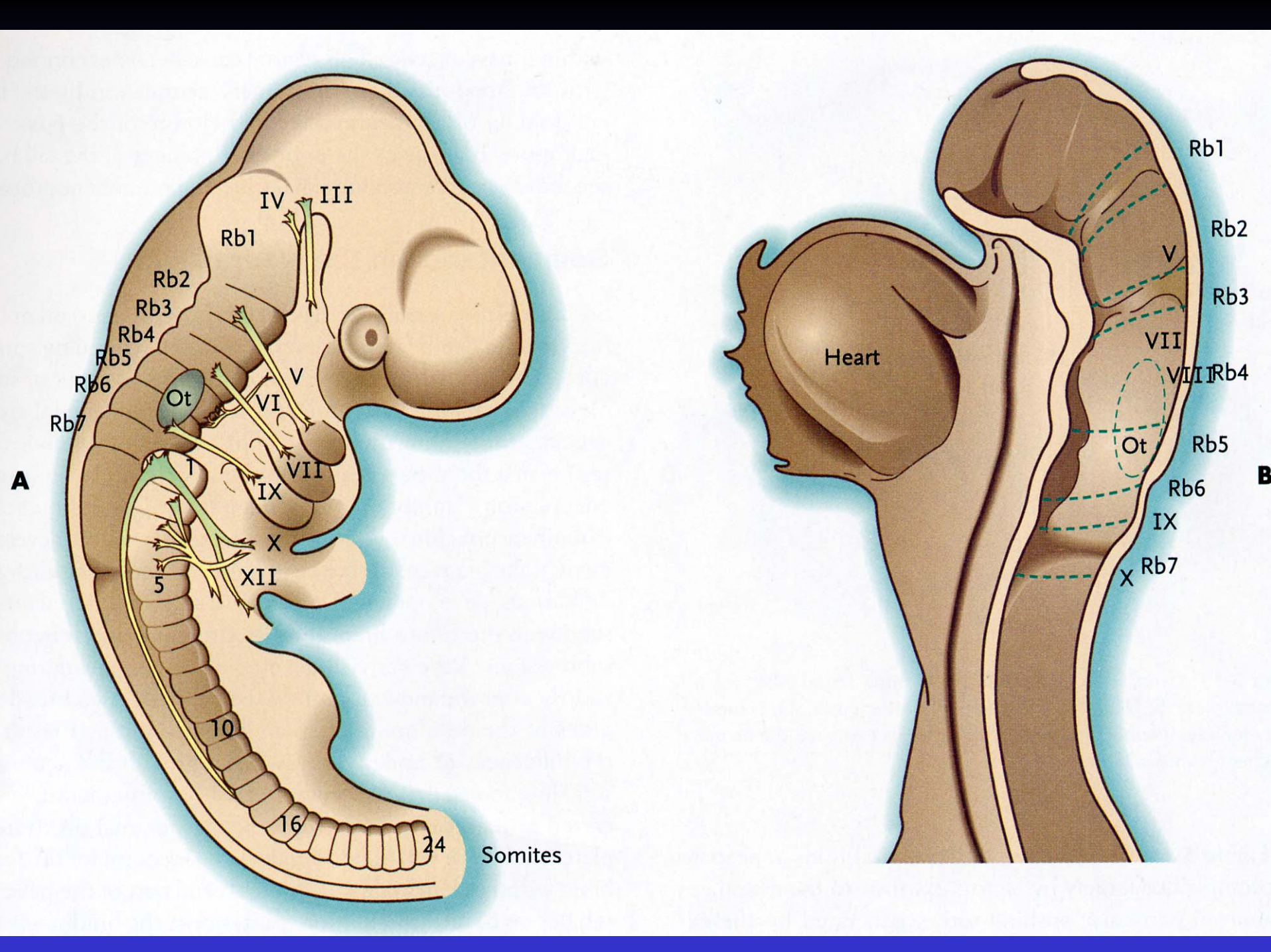
Segmentation of the Rhombencephalon

Neuromeres – Transient regularly spaced segments, also called Rhombomeres

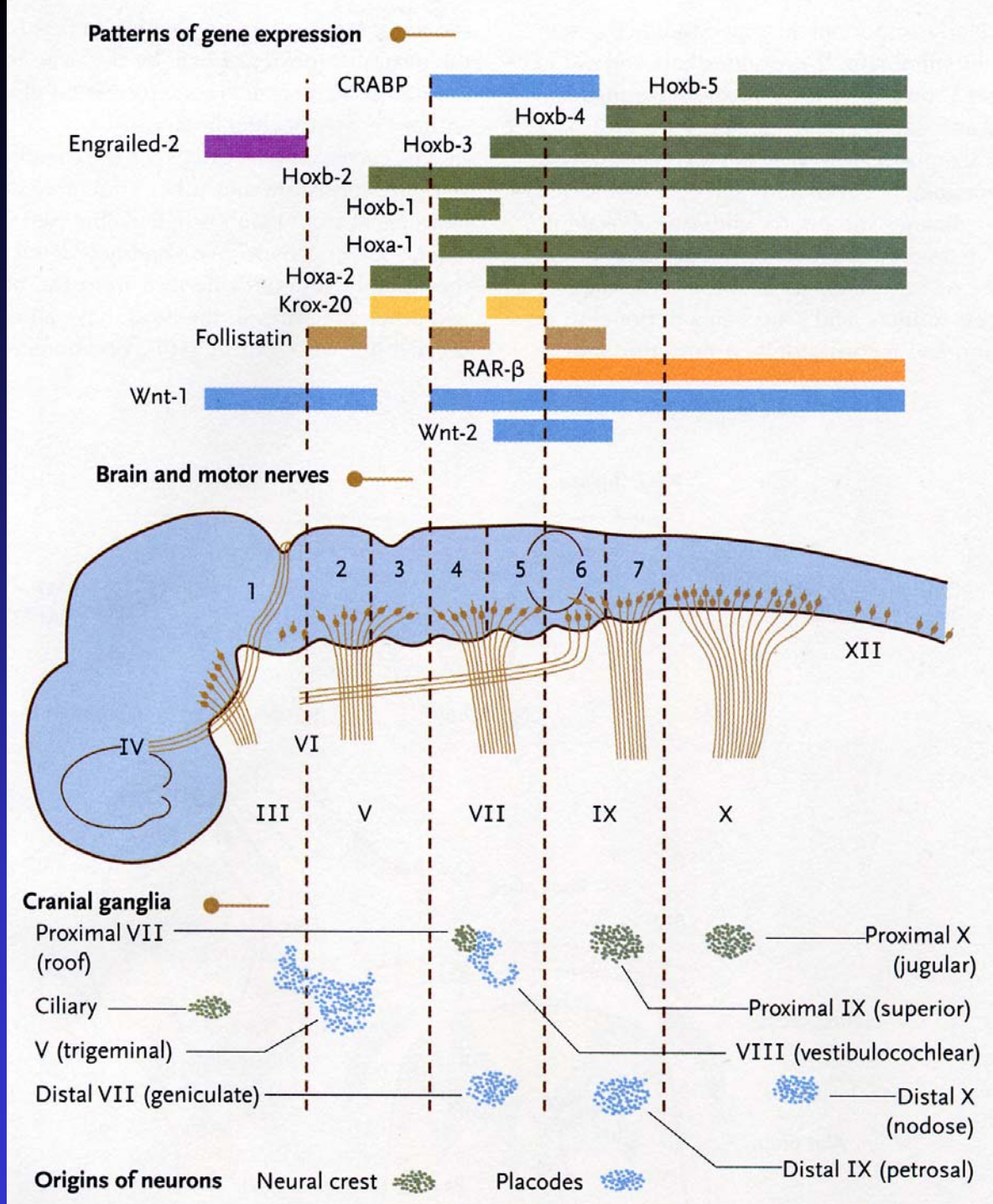
7 pairs – each an isolated compartment

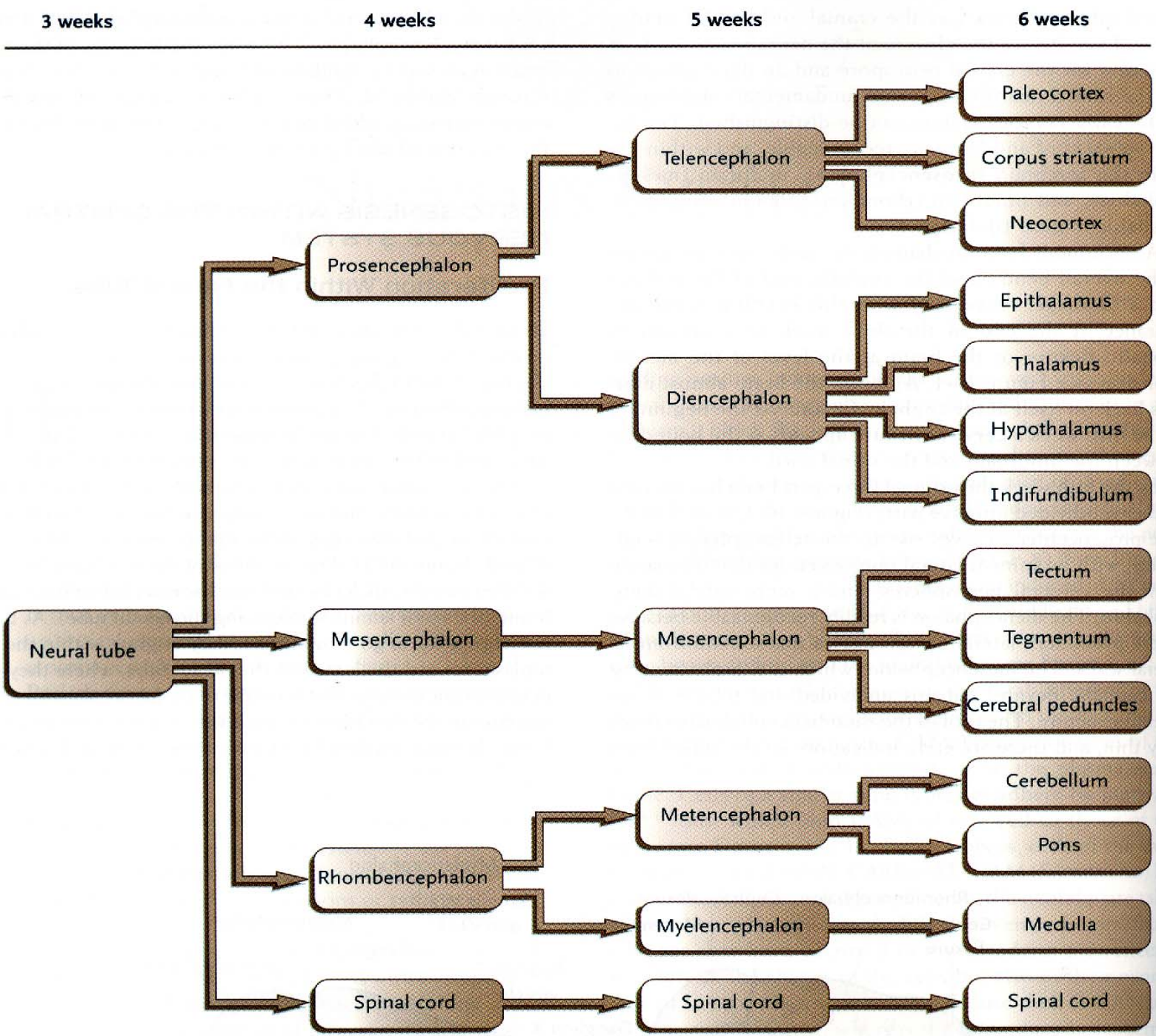
Alternating cell adhesive characteristics; alternating rhombomeres intermingle freely

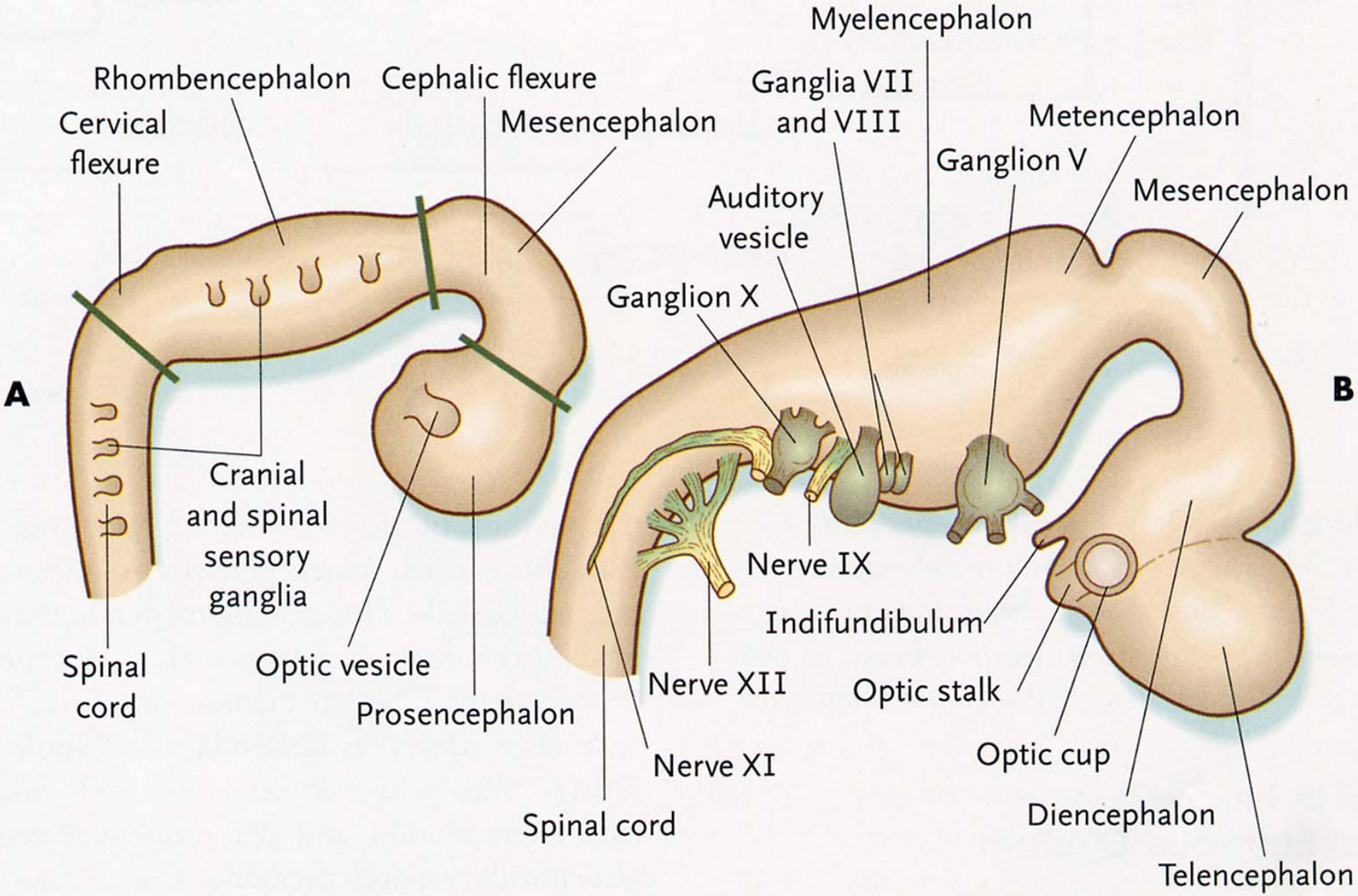
Segmental organization gives rise to specific cranial nerves


A
IV
III
Rb1
Rb2
Rb3
Rb4
Rb5
Rb6
Rb7
Ot
V
VI
VII
IX
X
XII
1
5
10
16
24
Somites
B
Heart
Rb1
Rb2
V
Rb3
VII
VIII
Rb4
Ot
Rb5
Rb6
IX
X
Rb7

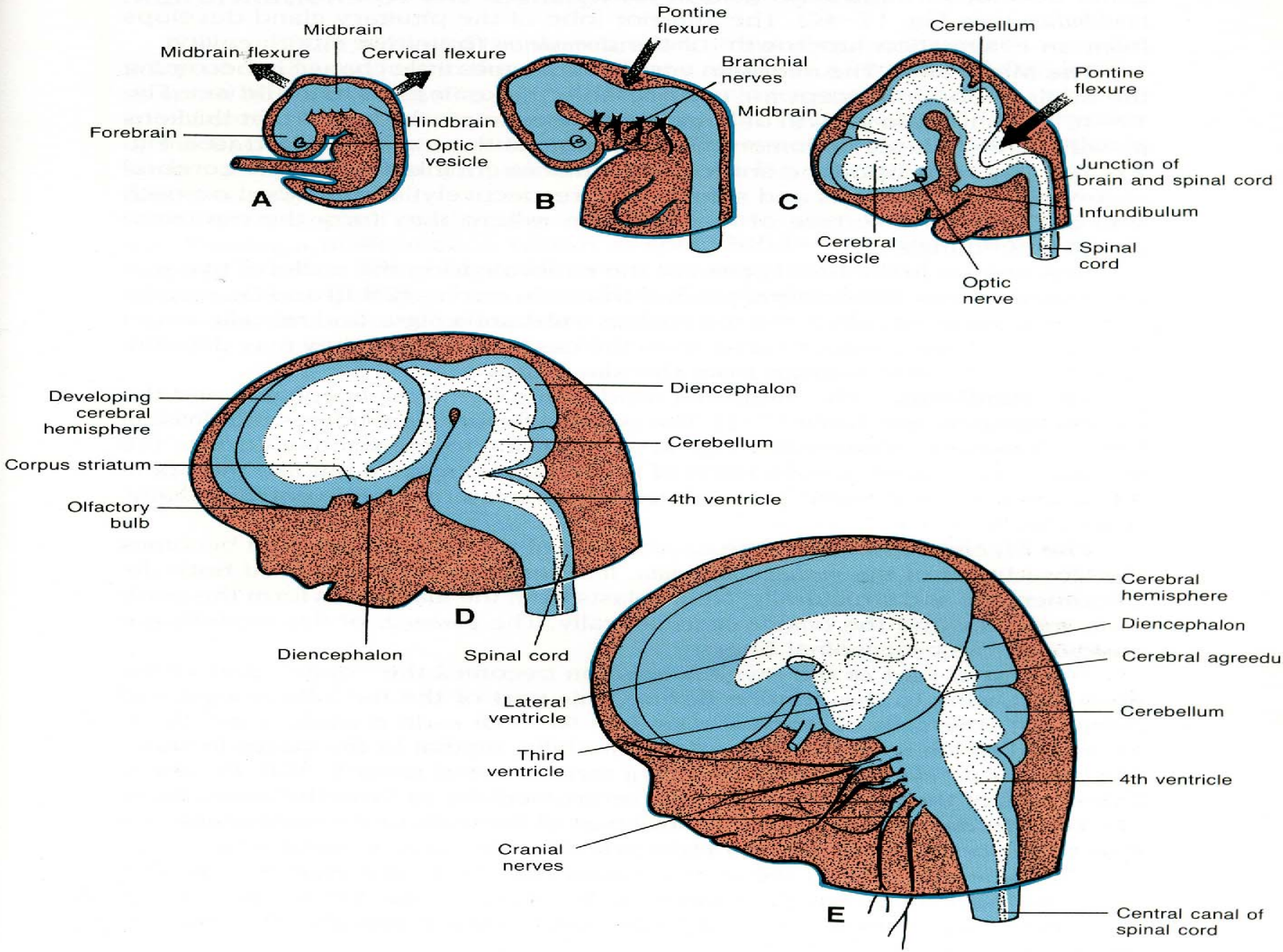
Specification and Position-Specific Gene Expression

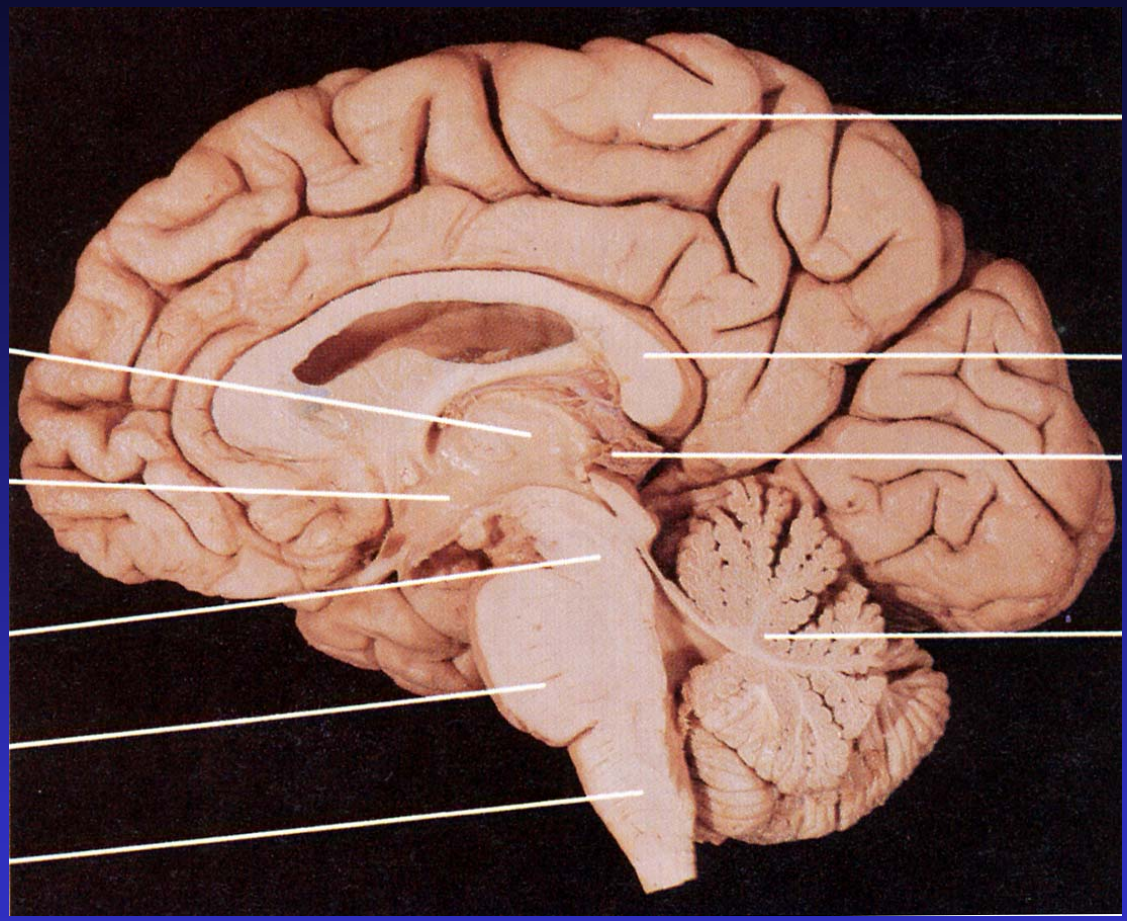



3 weeks
4 weeks
5 weeks
6 weeks
Neural tube
Prosencephalon
Mesencephalon
Rhombencephalon
Spinal cord
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
Spinal cord
Paleocortex
Corpus striatum
Neocortex
Epithalamus
Thalamus
Hypothalamus
Indifundibulum
Tectum
Tegmentum
Cerebral peduncles
Cerebellum
Pons
Medulla
Spinal cord

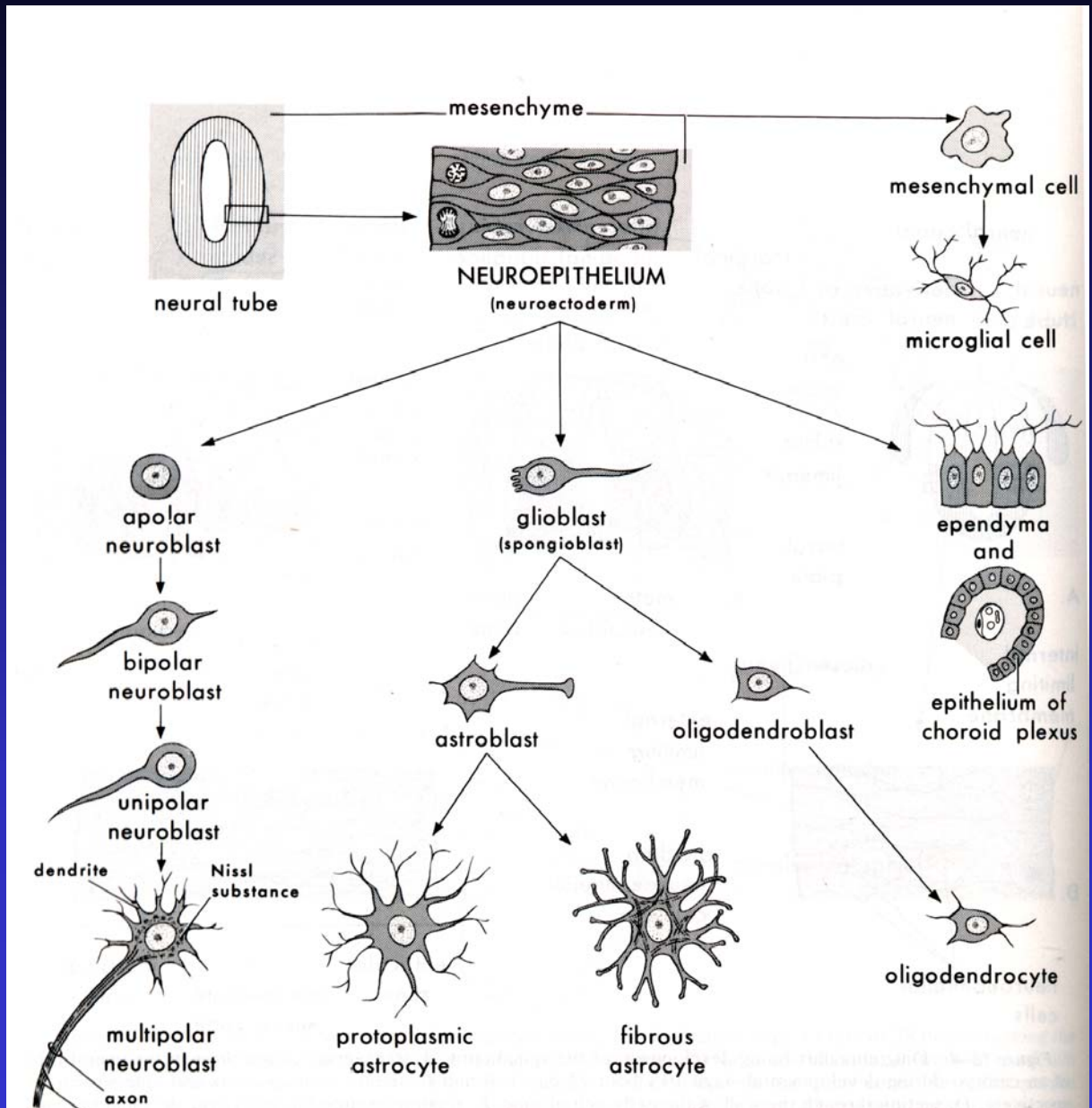


Cephalic flexure, Cervical flexure, Pontine flexure


Midbrain
Midbrain flexure
Cervical flexure
Forebrain
Hindbrain
Optic vesicle
A
Pontine flexure
Branchial nerves
B
Cerebellum
Pontine flexure
Midbrain
Junction of brain and spinal cord
Infundibulum
Cerebral vesicle
Spinal cord
Optic nerve
C
Developing cerebral hemisphere
Diencephalon
Cerebellum
Corpus striatum
4th ventricle
Olfactory bulb
Diencephalon
Spinal cord
D
Cerebral hemisphere
Diencephalon
Cerebral agreedu
Lateral ventricle
Cerebellum
Third ventricle
4th ventricle
Cranial nerves
Central canal of spinal cord
E


Cerebrum
Thalamus
CorpusCallosum
Hypothalamus
Pineal Body
Midbrain
Cerebellum
Pons
Medulla
oblongata

Histogenesis of CNS cells



Cell Types

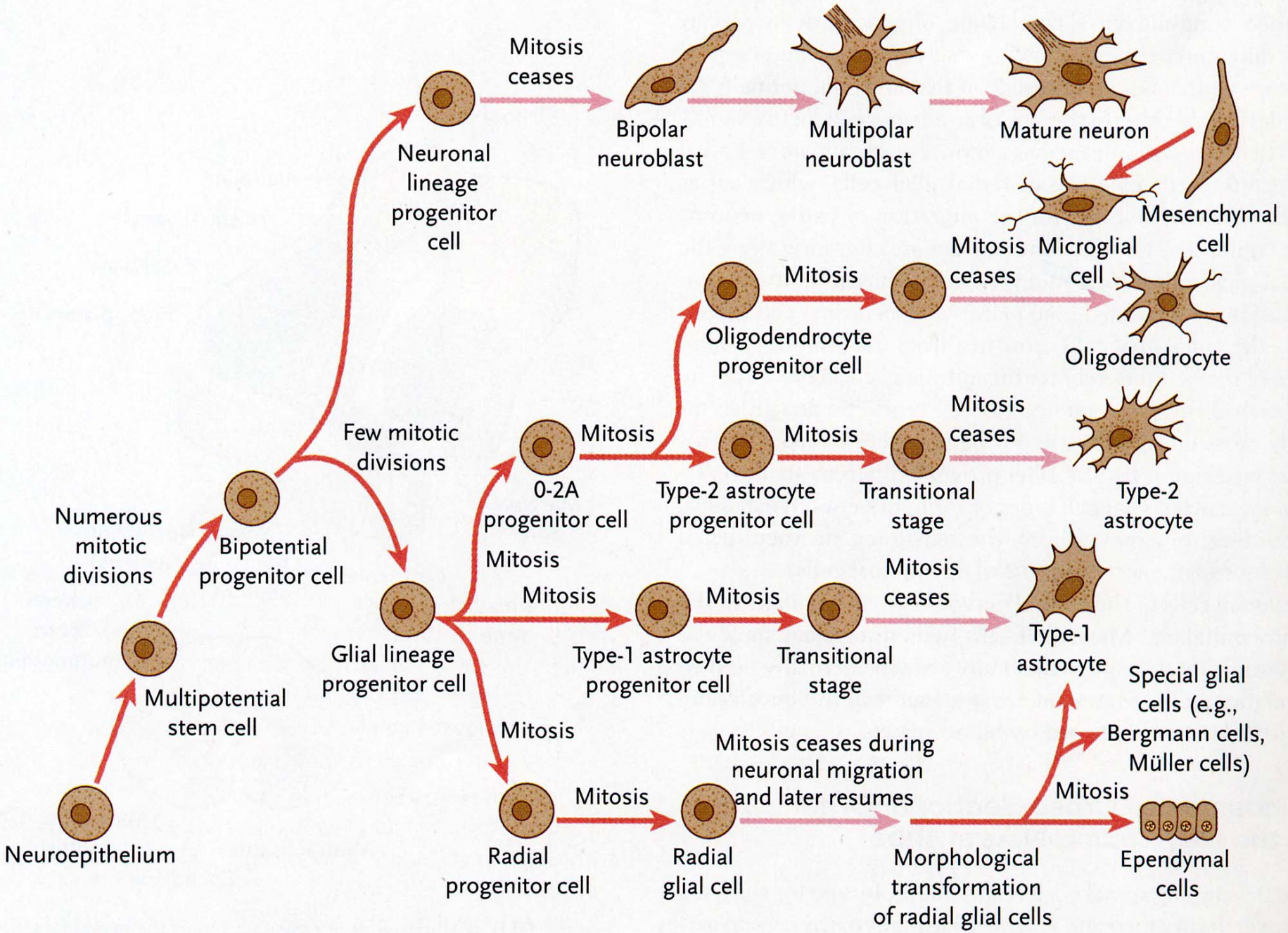
Neuroepithelium – Multipotential Stem Cell

Bipotential Progenitor Cell

Neuronal vs. Glial Cell Lineage

Neuronal Lineage (neurofilament expression):
Bipolar neuroblast, Multipolar neuroblast, Neuron

Glial Lineage (glia fibrillary acidic protein, GFAP):
Radial glia, Type-1 Astrocyte, Type-2 Astrocyte, Oligodendrocyte


Mitosis ceases
Bipolar neuroblast
Multipolar neuroblast
Mature neuron
Neuronal lineage progenitor cell
Mesenchymal cell
Mitosis ceases
Microglial cell
Mitosis
Oligodendrocyte progenitor cell
Oligodendrocyte
Mitosis ceases
Few mitotic divisions
Mitosis
Mitosis
0-2A progenitor cell
Type-2 astrocyte progenitor cell
Transitional stage
Type-2 astrocyte
Numerous mitotic divisions
Bipotential progenitor cell
Mitosis
Mitosis
Mitosis
Mitosis ceases
Glial lineage progenitor cell
Type-1 astrocyte progenitor cell
Transitional stage
Type-1 astrocyte
Multipotential stem cell
Special glial cells (e.g., Bergmann cells, Müller cells)
Mitosis
Mitosis ceases during neuronal migration and later resumes
Mitosis
Neuroepithelium
Radial progenitor cell
Radial glial cell
Morphological transformation of radial glial cells
Ependymal cells

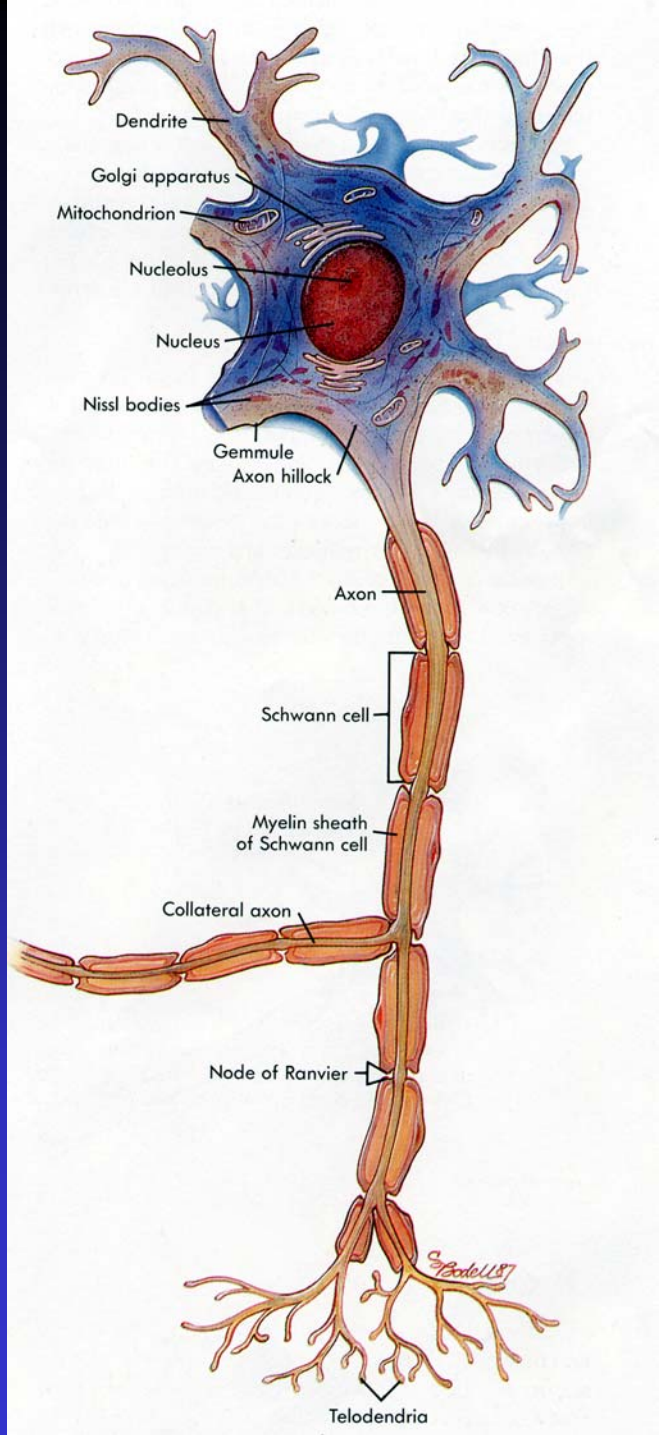
Dendrite

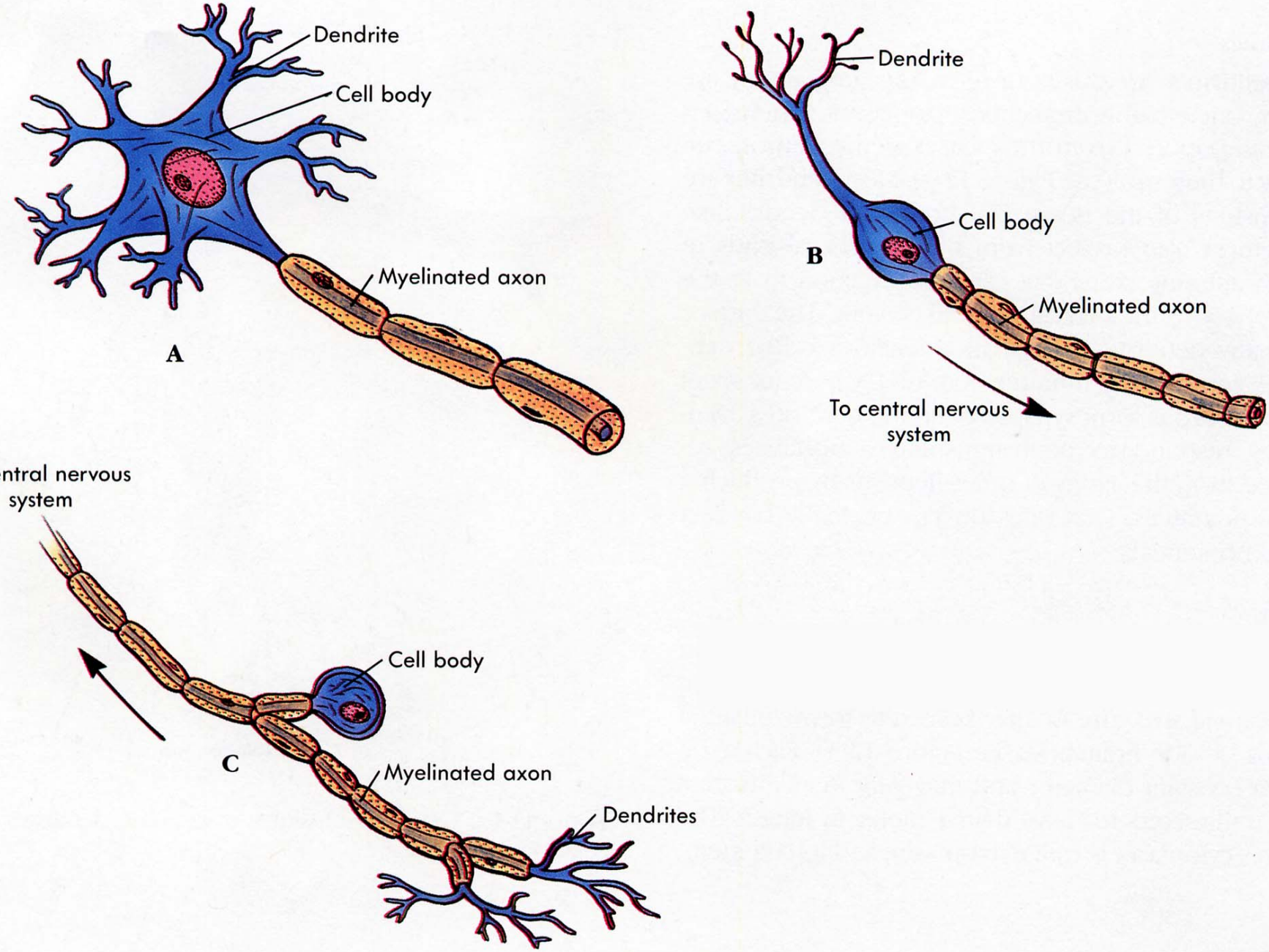
Cell Body

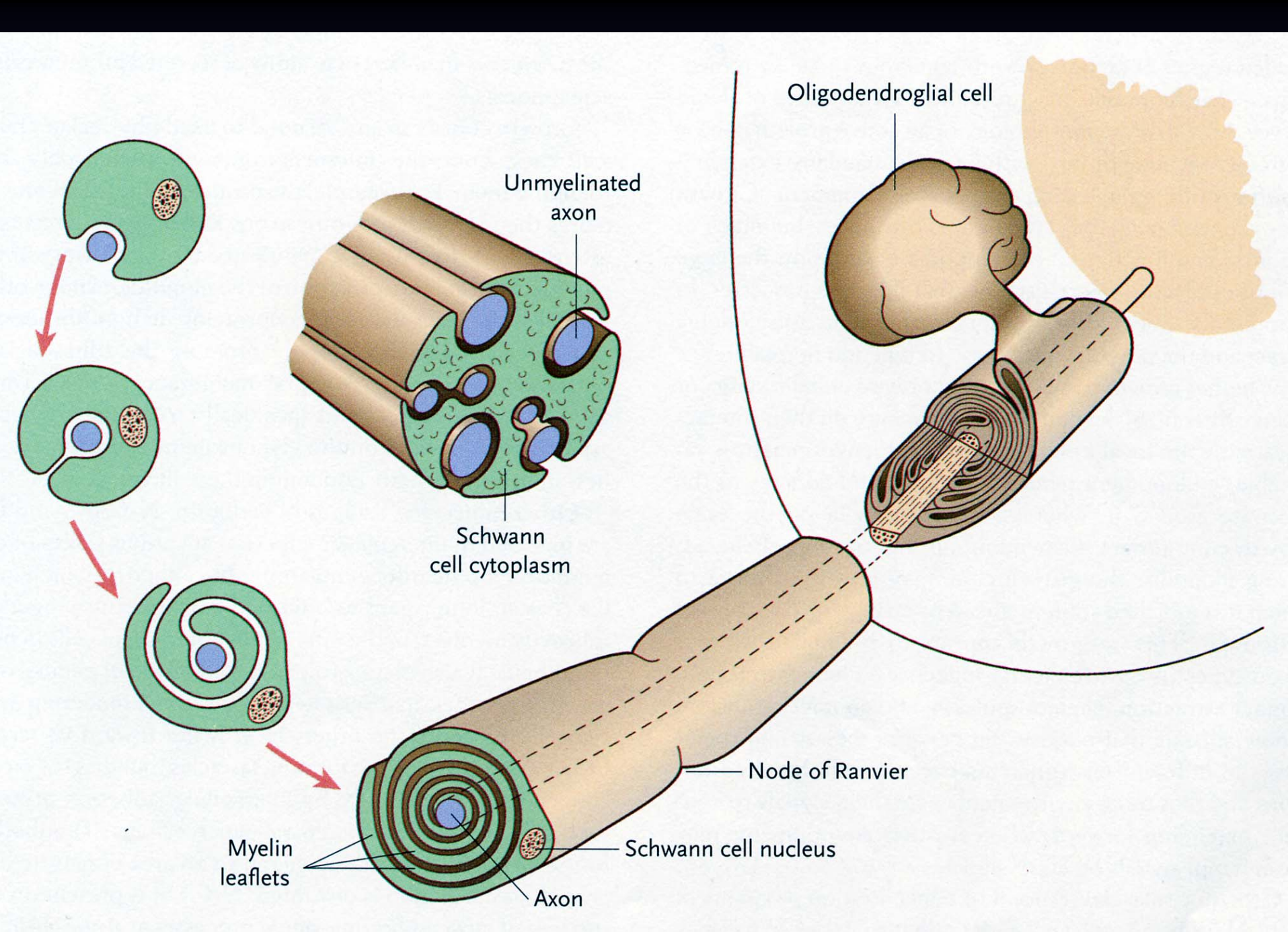
Axon

Schwann Cell

Myelin Sheath

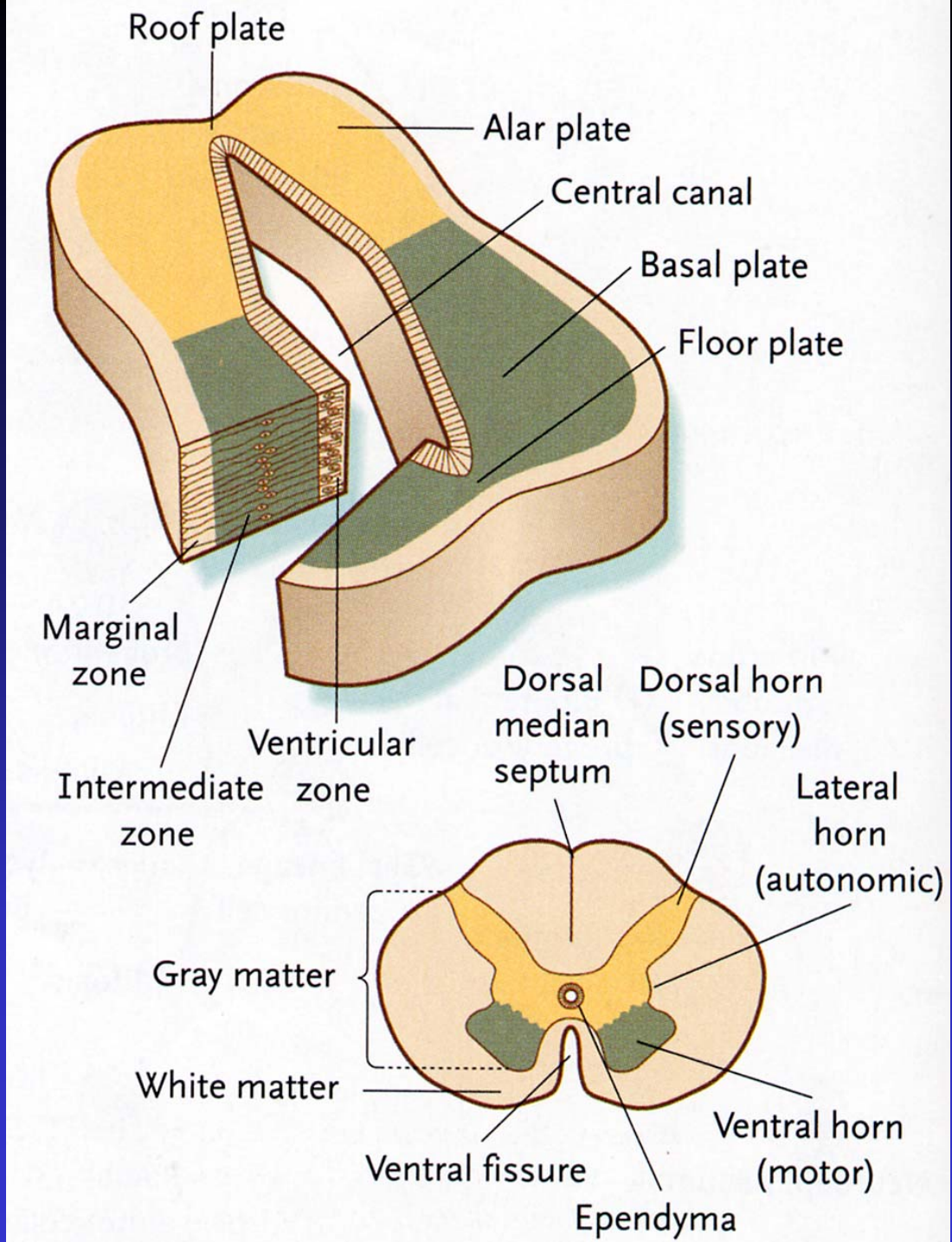



Dendrite
Cell body
Myelinated axon
A
Dendrite
Cell body
B
Myelinated axon
To central nervous system
To central nervous system
Cell body
C
Myelinated axon
Dendrites


Oligodendroglial cell
Unmyelinated axon
Schwann cell cytoplasm
Node of Ranvier
Myelin leaflets
Schwann cell nucleus
Axon

Spinal Cord

- Central Canal – Lumen
- Ventricular Zone – Cells lining the Central Canal becomes Gray matter
- Intermediate Zone
- Marginal Zone – neuronal cell processes; no cell bodies, becomes White matter



6 Parts of the Spinal Cord

2 Alar Plates (Left and Right)

Sulcus Limitans separates Alar and Basal plates

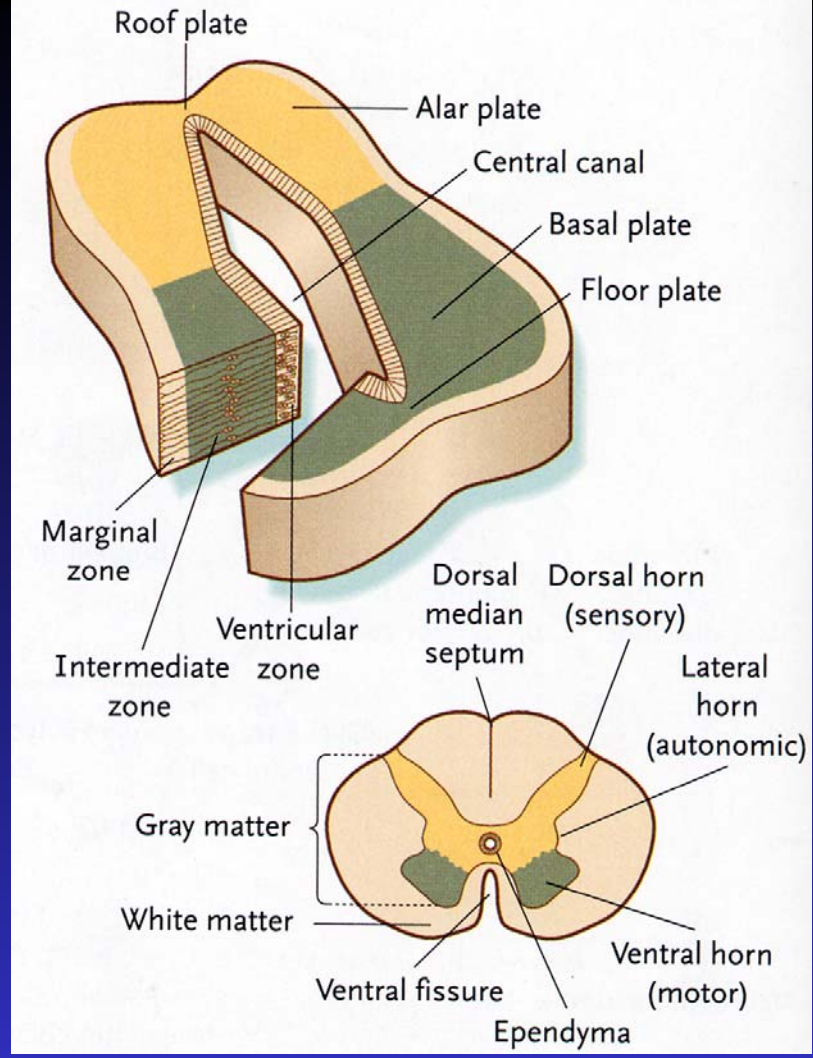
2 Basal Plates (Left and Right)

Roof Plate connecting Alar plates

Floor Plate connecting Basal plates

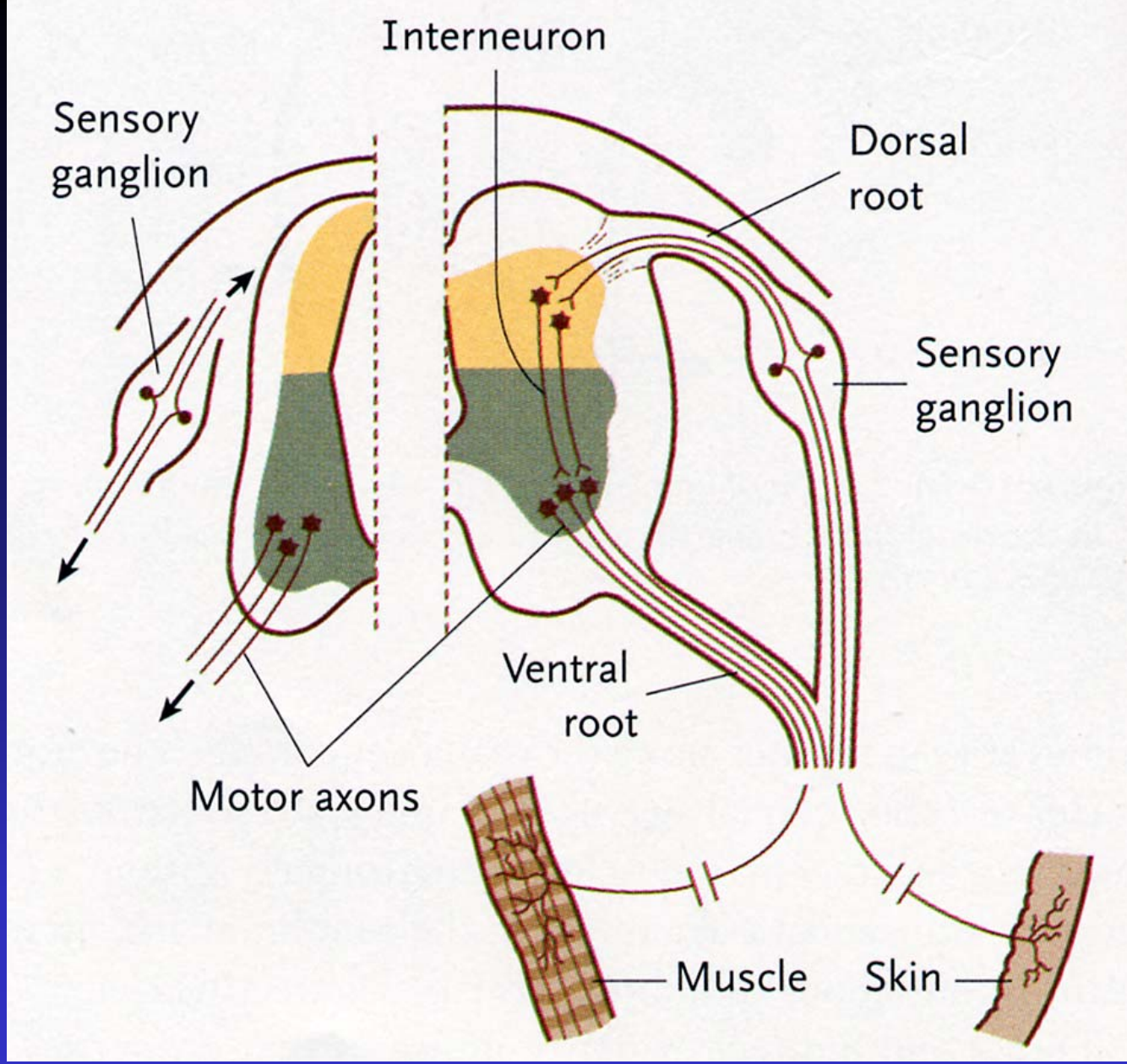
Basal plates → Motor – Ventral Horn

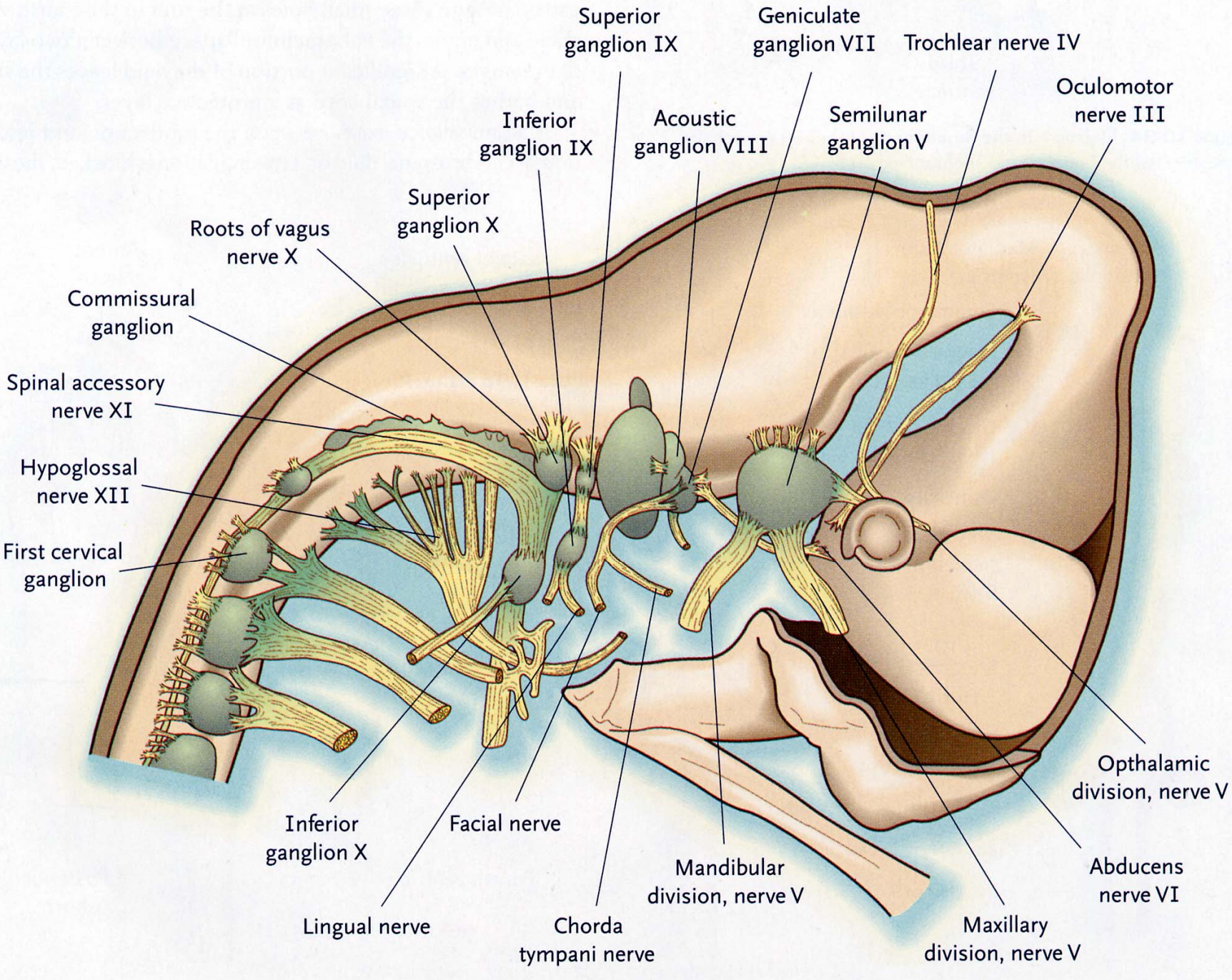
Alar plates → Sensory – Dorsal Horn



Nerves

- Motor
- Sensory
- Autonomic
  - Sympathetic
  - Parasympathetic




Superior ganglion IX
Geniculate ganglion VII
Trochlear nerve IV
Oculomotor nerve III
Inferior ganglion IX
Acoustic ganglion VIII
Semilunar ganglion V
Superior ganglion X
Roots of vagus nerve X
Commissural ganglion
Spinal accessory nerve XI
Hypoglossal nerve XII
First cervical ganglion
Opthalamic division, nerve V
Abducens nerve VI
Inferior ganglion X
Facial nerve
Mandibular division, nerve V
Lingual nerve
Chorda tympani nerve
Maxillary division, nerve V

Cranial Nerves

I – Olfactory; Telencephalon; No Ganglion; Sensory

II – Optic; Diencephalon; No Ganglion; Sensory

III – Oculomoter; Mesencephalon; Cilary Ganglion; Motor and Parasympathetic

IV – Troclear; Metencephalon; No Ganglion; Motor

V – Trigeminal (semilunar); Metencephalon, trigeminal placode; Trigeminal Ganglion; Sensory and Motor

VI – Abducens; Metencephalon; No Ganglion; Motor

VII – Facial; Metencephalon; 4 Ganglia – Superior, Inferior (Geniculate), Sphenopalatine, Submandibular; Motor, Sensory, Parasympathetic

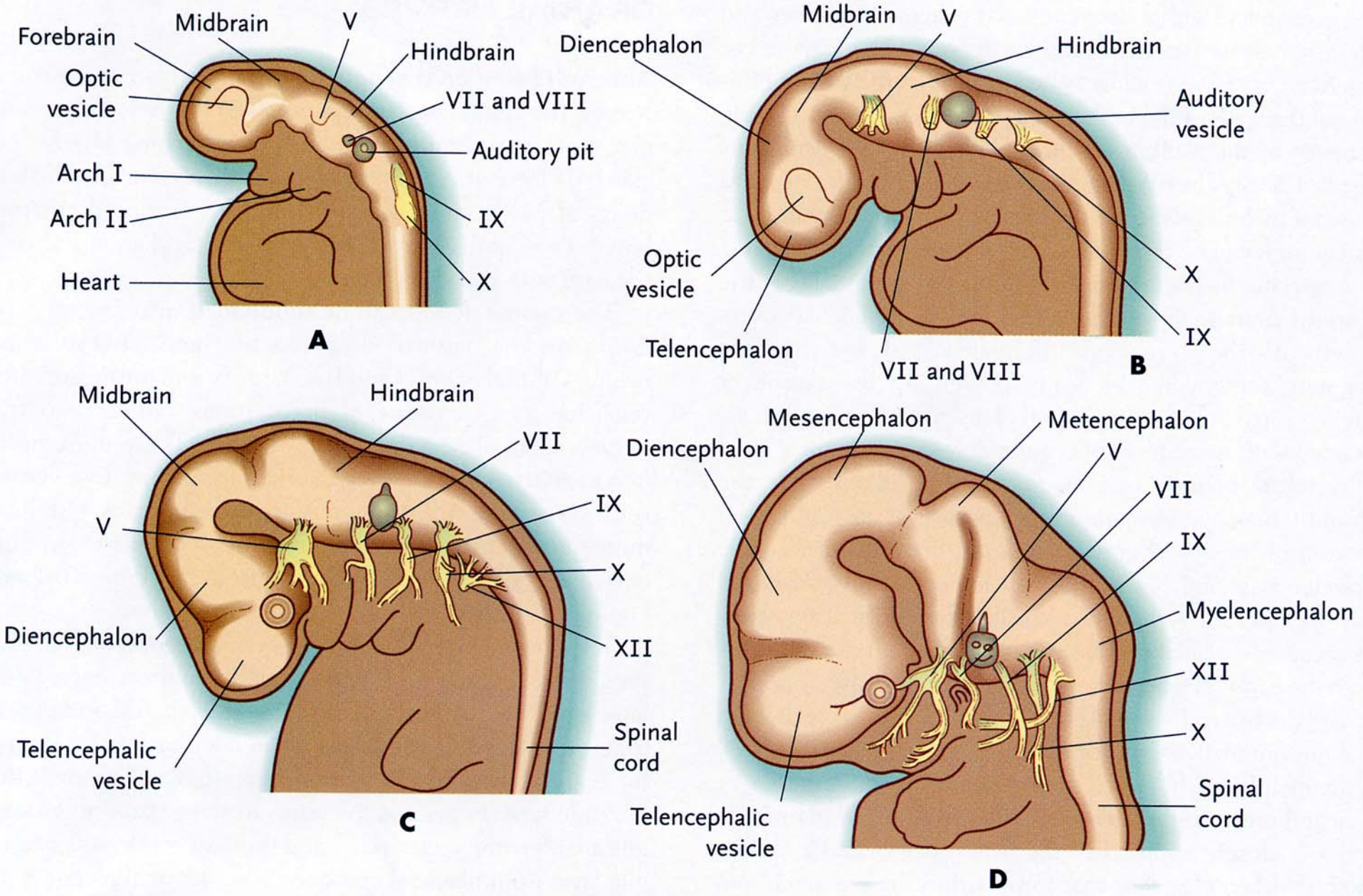
VIII – Vestibulocochlear; Metencephalon, 2 Ganglia – Acoustic, Vestibular; Sensory

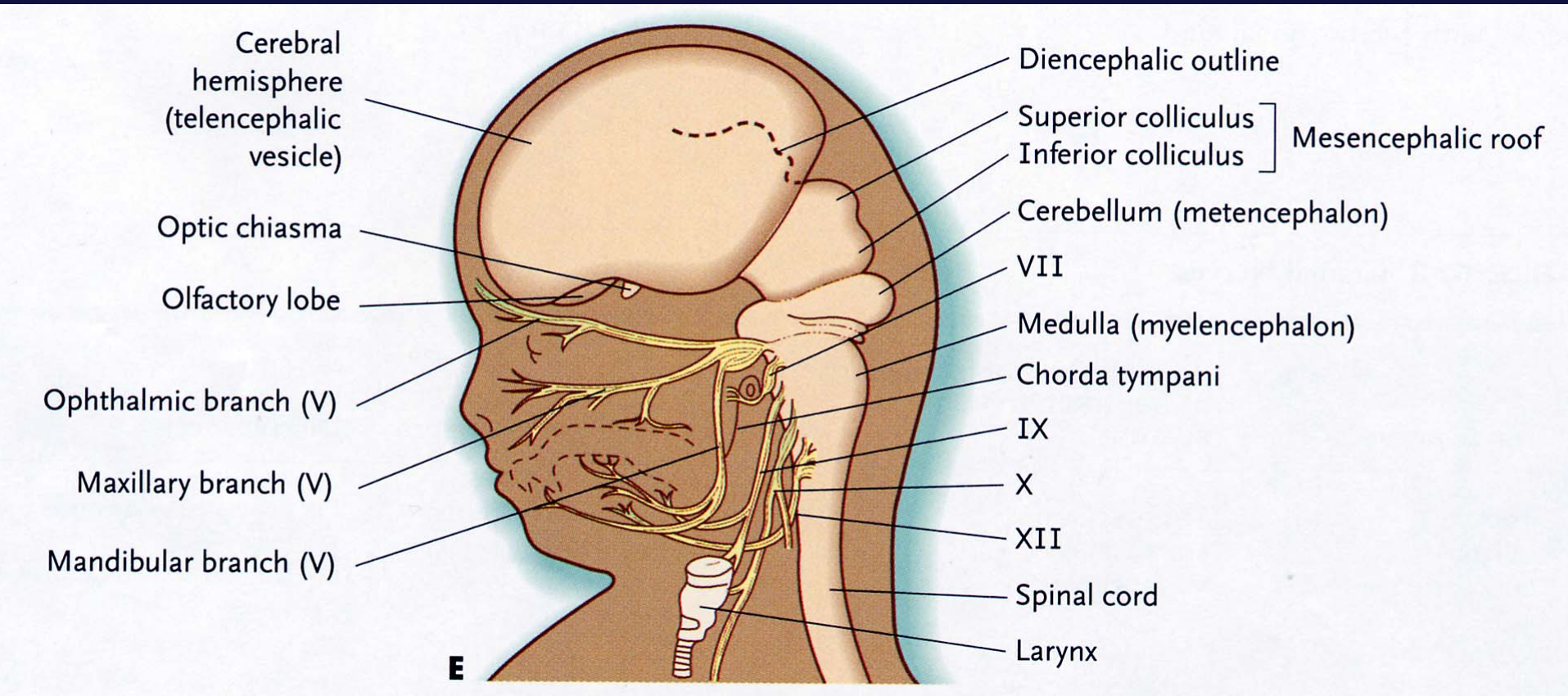
IX – Glossopharnygeal; Myelencephalon; 3 Ganglia – Superior, Inferior (Petrosal), Otic; Motor, Sensory, Parasympathetic

X – Vagus; Myelencephalon; 3 Ganglia – Superior, Inferior (Nodose), Vagal parasympathetic; Motor, Sensory, Parasympathetic

XI – Accessory; Myelencephalon; No Ganglia; Motor

XII – Hypoglossal; Myelencephalon; No Ganglia; Motor


Forebrain
Midbrain
V
Hindbrain
Optic vesicle
VII and VIII
Auditory pit
Arch I
Arch II
IX
Heart
X
A
Midbrain
V
Diencephalon
Hindbrain
Auditory vesicle
Optic vesicle
X
IX
Telencephalon
VII and VIII
B
Midbrain
Hindbrain
VII
IX
V
X
Diencephalon
XII
Telencephalic vesicle
Spinal cord
C
Mesencephalon
Metencephalon
Diencephalon
V
VII
IX
Myelencephalon
XII
X
Spinal cord
Telencephalic vesicle
D


Cerebral hemisphere (telencephalic vesicle)
Optic chiasma
Olfactory lobe
Ophthalmic branch (V)
Maxillary branch (V)
Mandibular branch (V)
Diencephalic outline
Superior colliculus
Inferior colliculus
Mesencephalic roof
Cerebellum (metencephalon)
VII
Medulla (myelencephalon)
Chorda tympani
IX
X
XII
Spinal cord
Larynx
E

Anomalies

Defective Neural Tube Closure
- Spinal Cord – Rachischisis
- Brain – Craniochisis (lethal)

Spina Bifida – Defective closure of anterior or posterior neuropore – lacking neural arch, bulging membranous sac called a Cele, containing cerebral spinal fluid +/- neural tissues

Spina bifida occulta – Defect in Neural Arch – mildest form

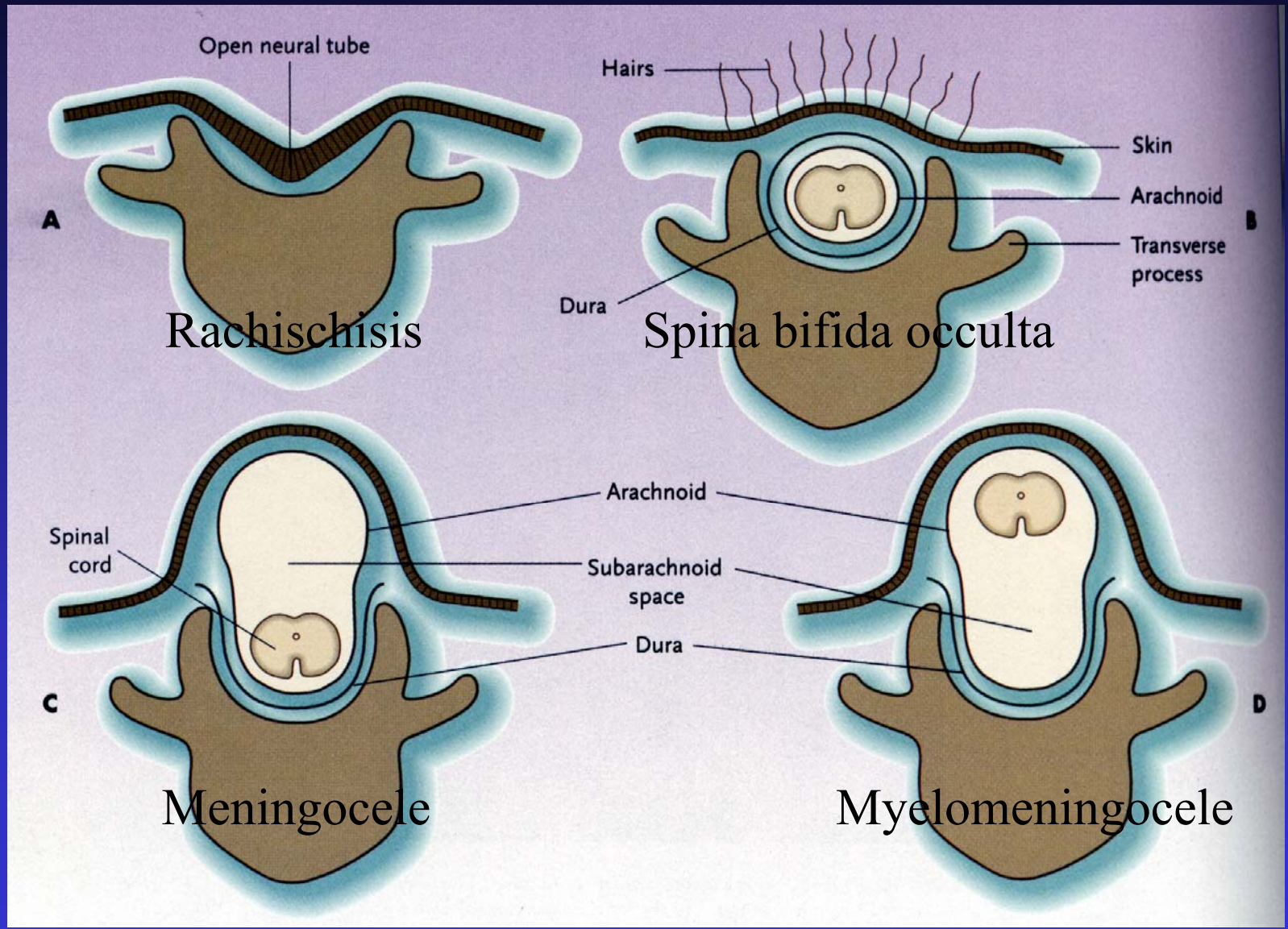
Meningocele – protruding dura and arachnoid tissues

Meningomyelocele – protruding spinal tissues

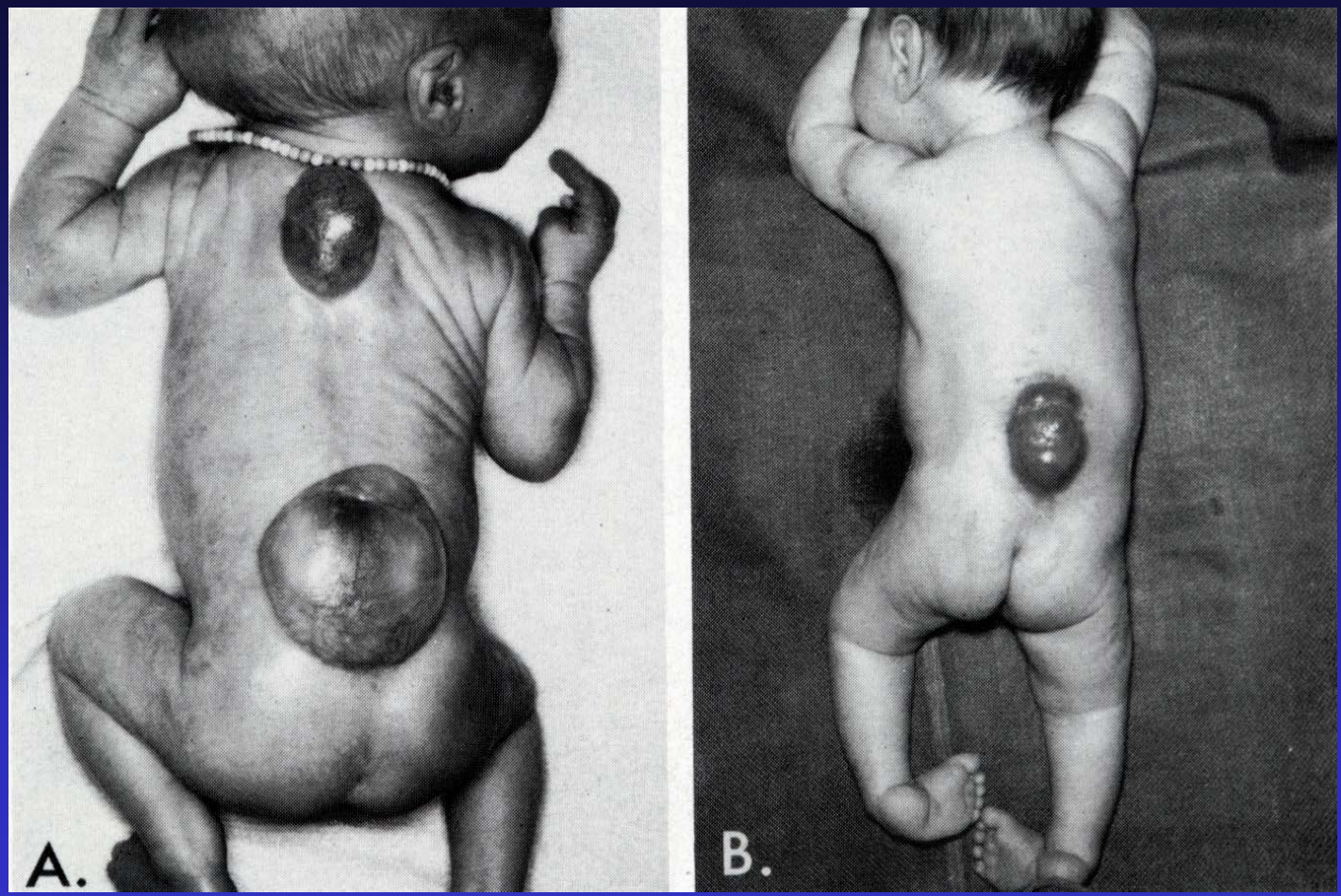
Meningoencephalocele – protruding brain tissues

Meningohydroencephalocele – protruding brain and ventricular tissues

Anomalies – Spinal Cord



Spinal Abnormalities



Spina bifida

Brain Abnormalities

microcephaly

holoprosencephaly

hydrocephaly