General anatomy of skeletal muscle, its innervation and blood supply, General anatomy of spinal nerve, General terms of angiology and lymphology

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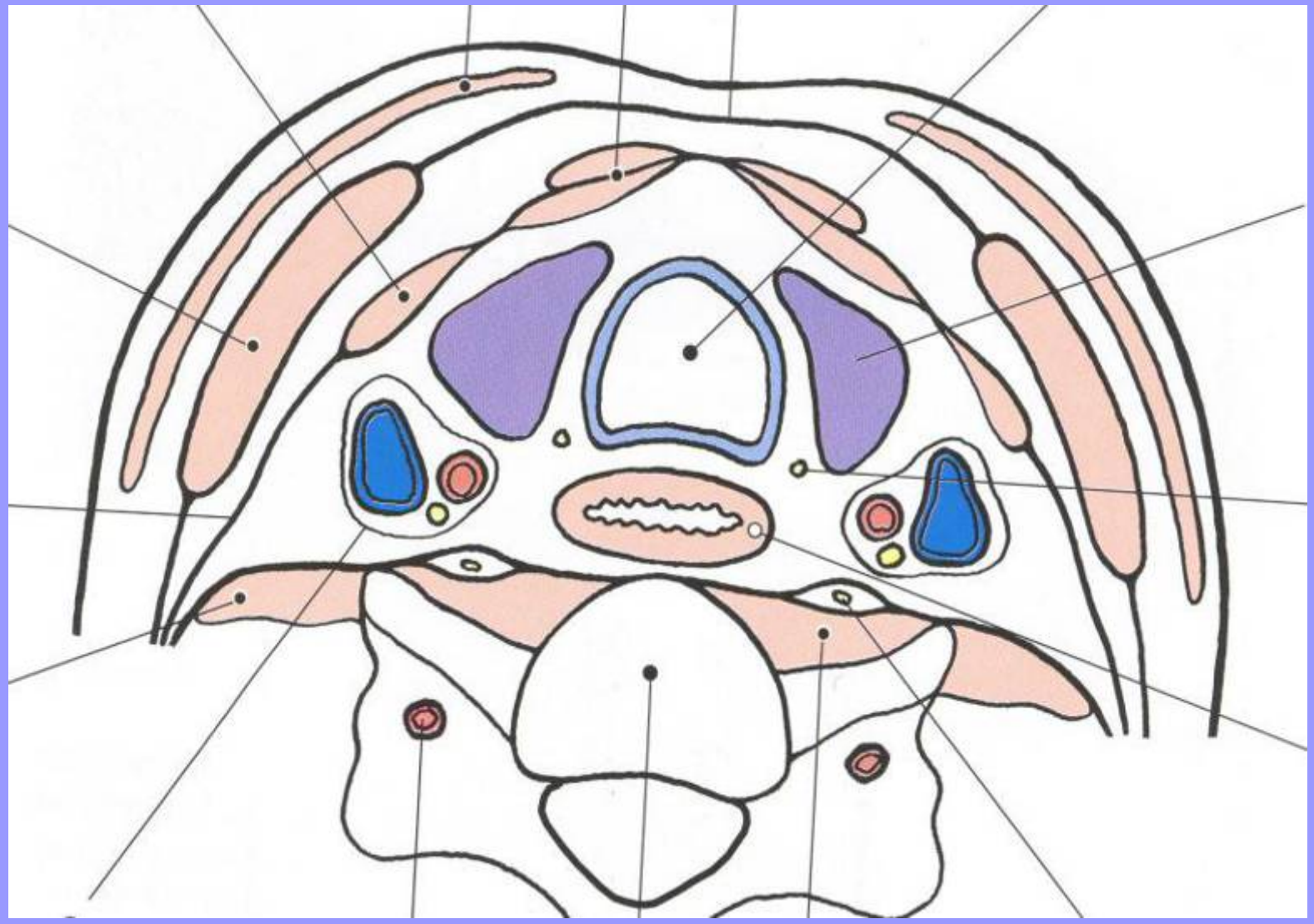
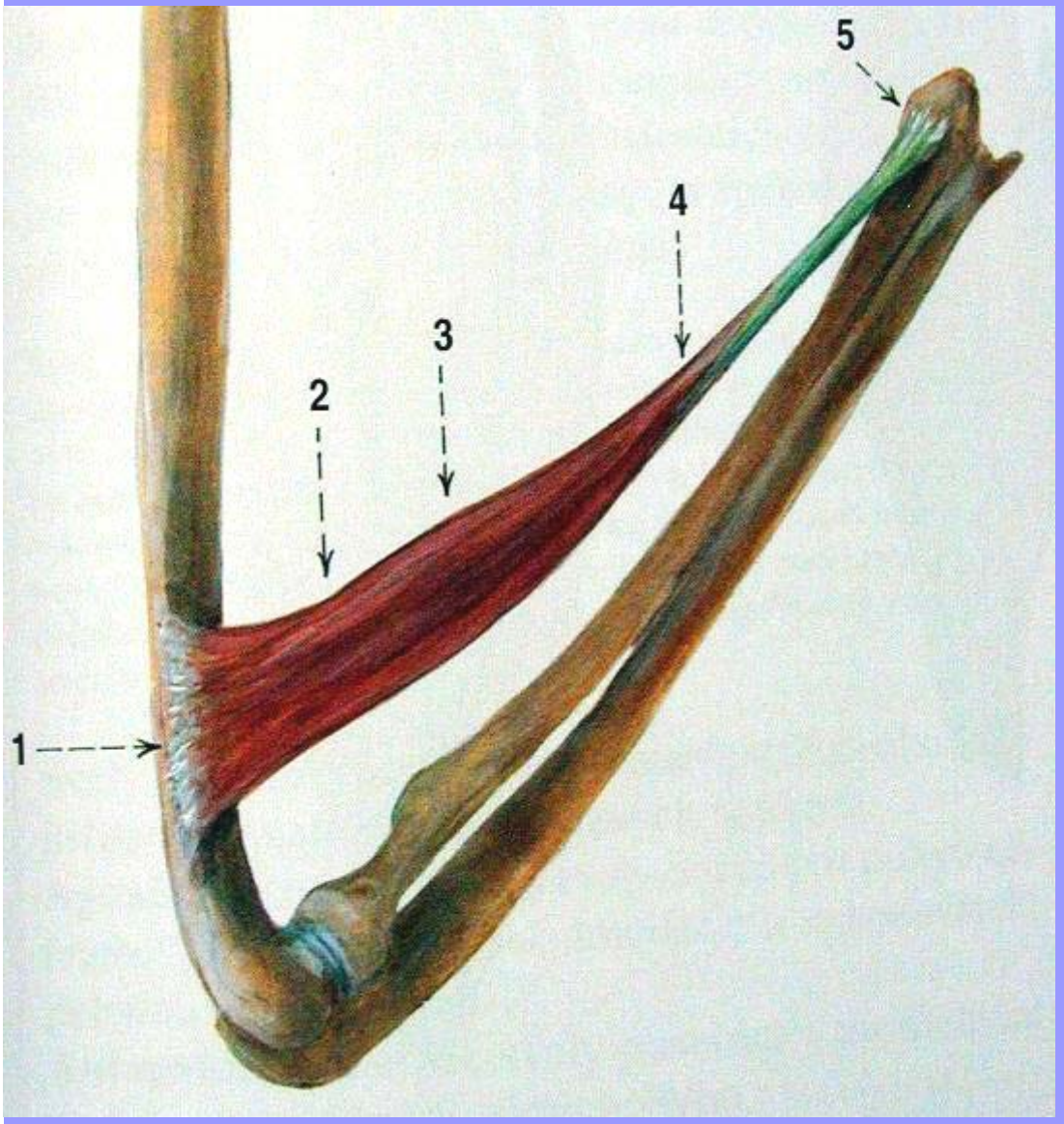
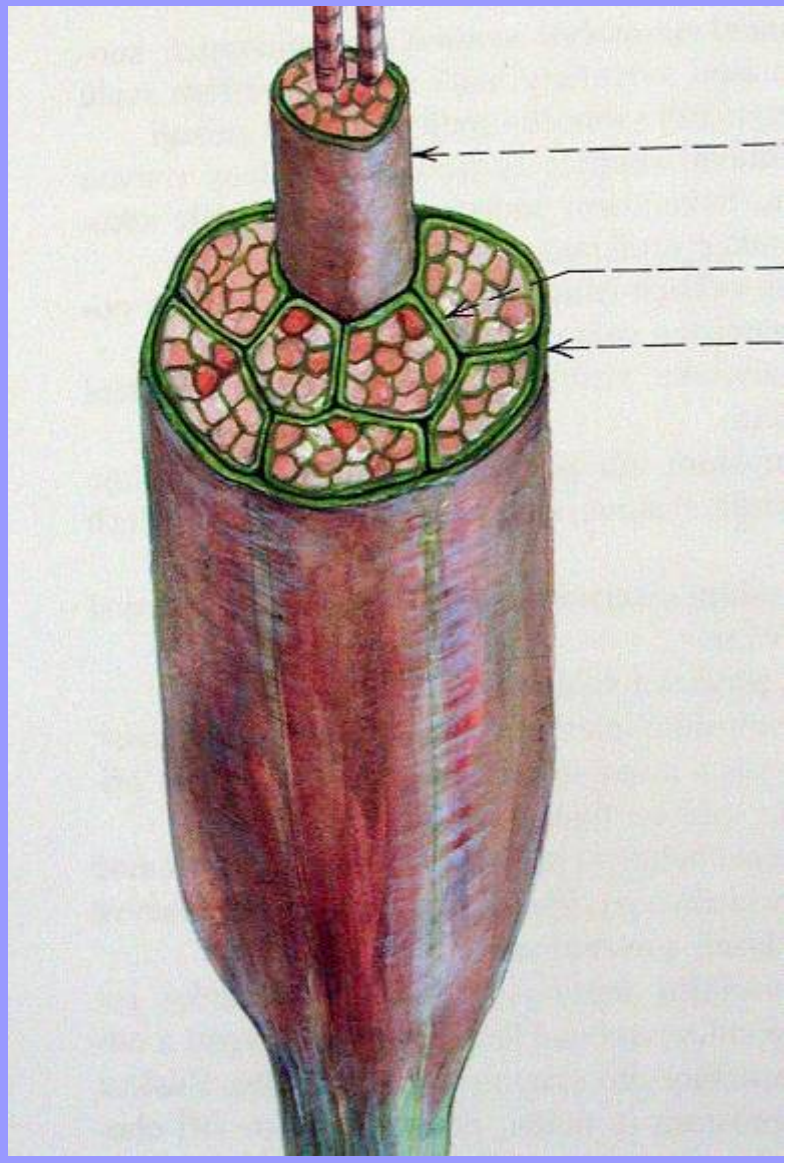
How to study skeletal muscles

origo, insertion, position (scheme, tables), identification, muscle groups, innervation, function,

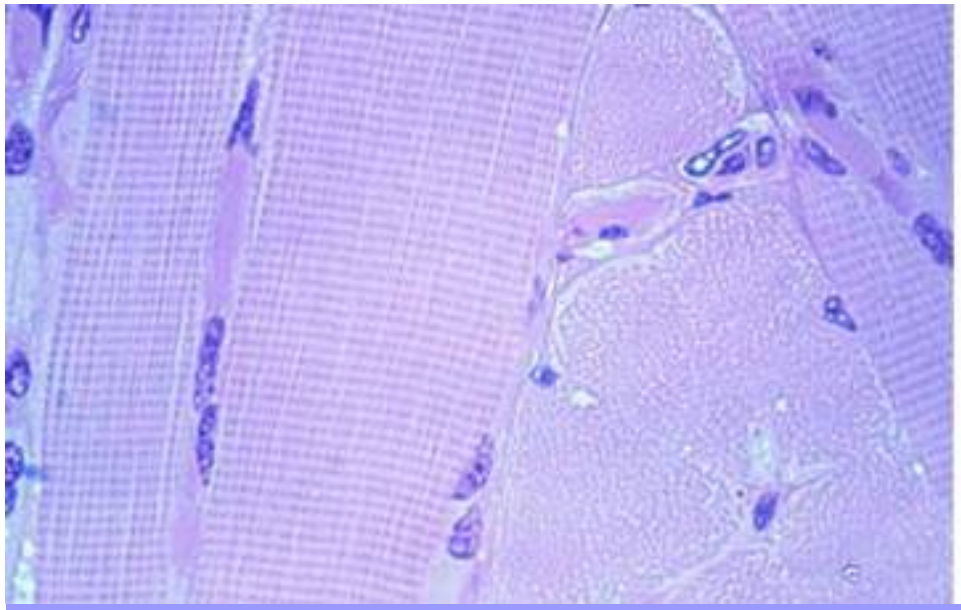
Osteofascial spaces (compartments), transverse sections of body segments

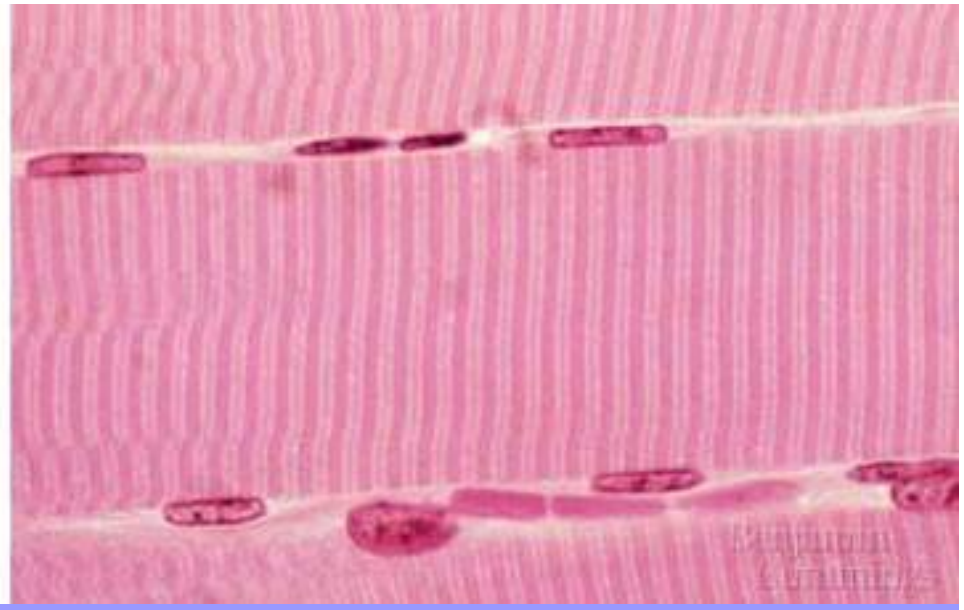




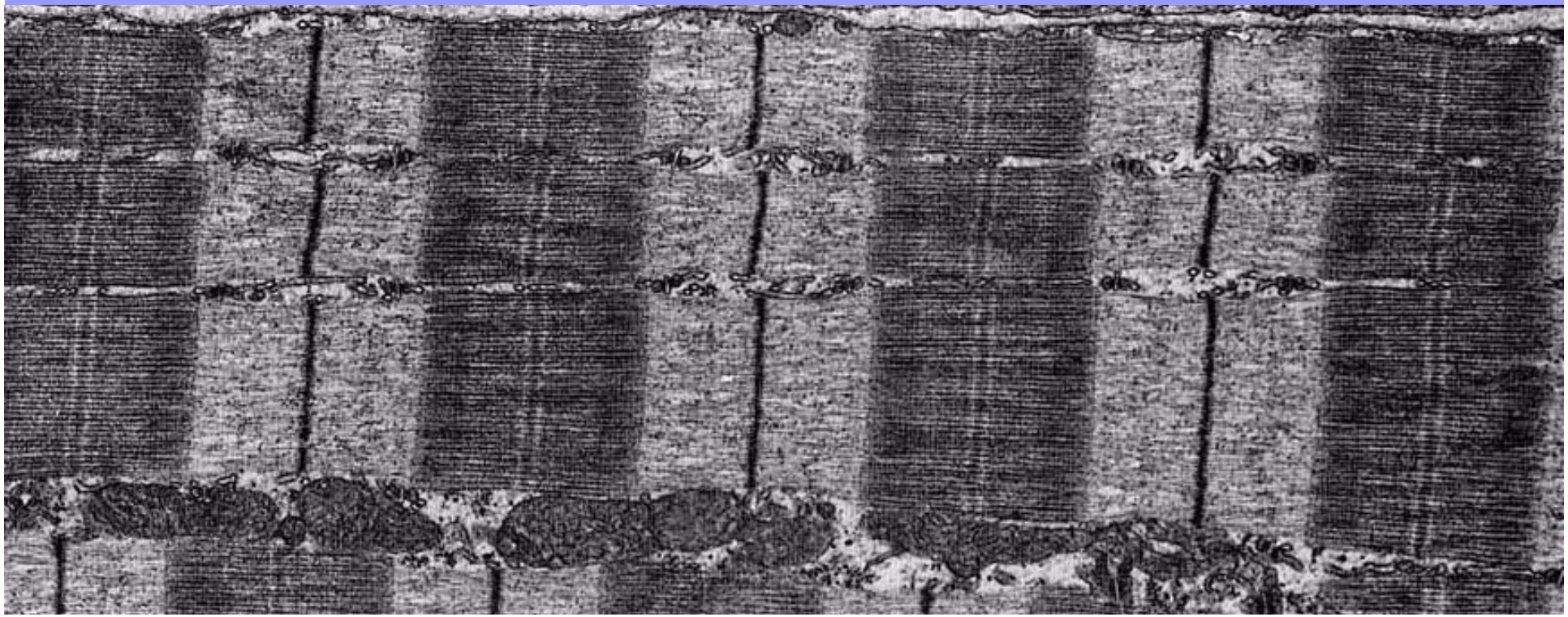


Attachments of skeletal muscles – origin, insertion, endomysial and perimysial sheaths, fascia

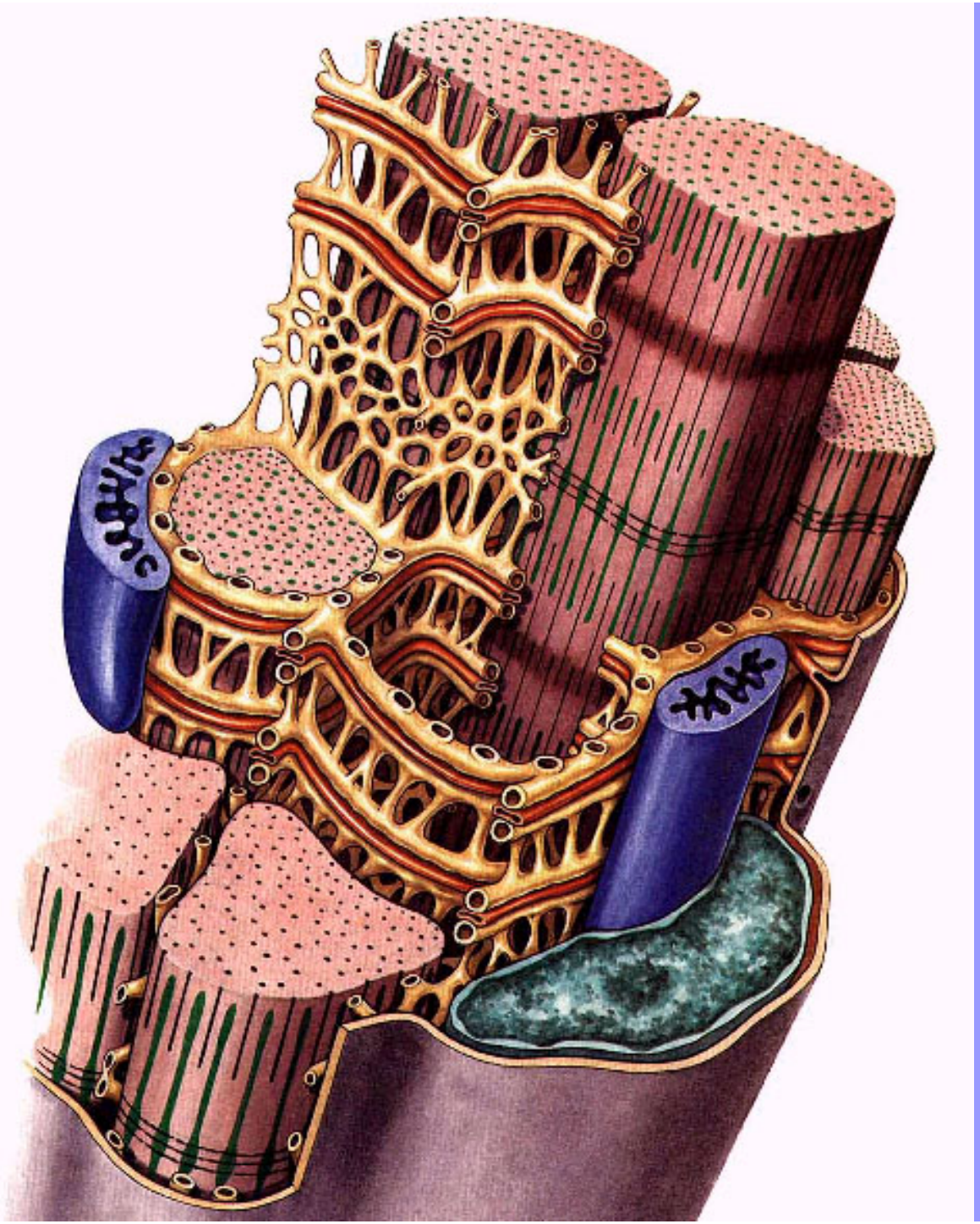


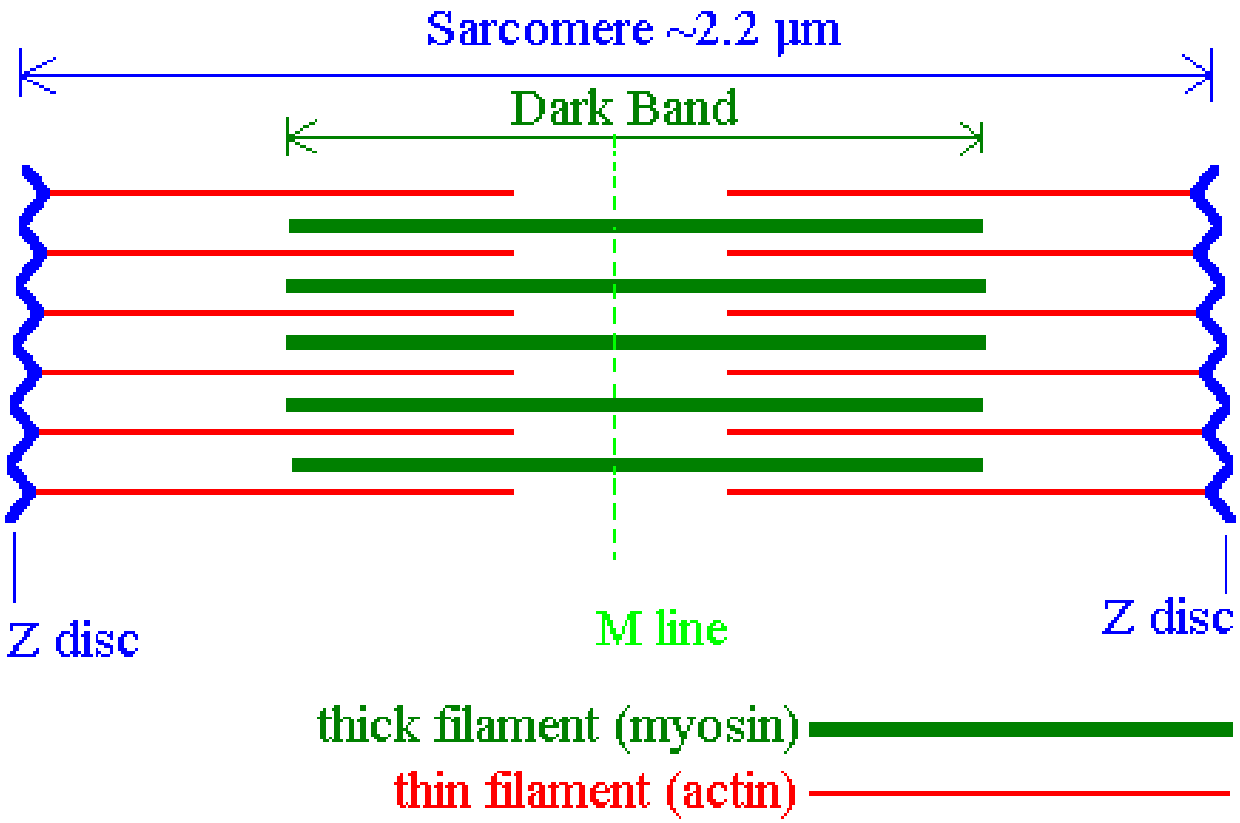


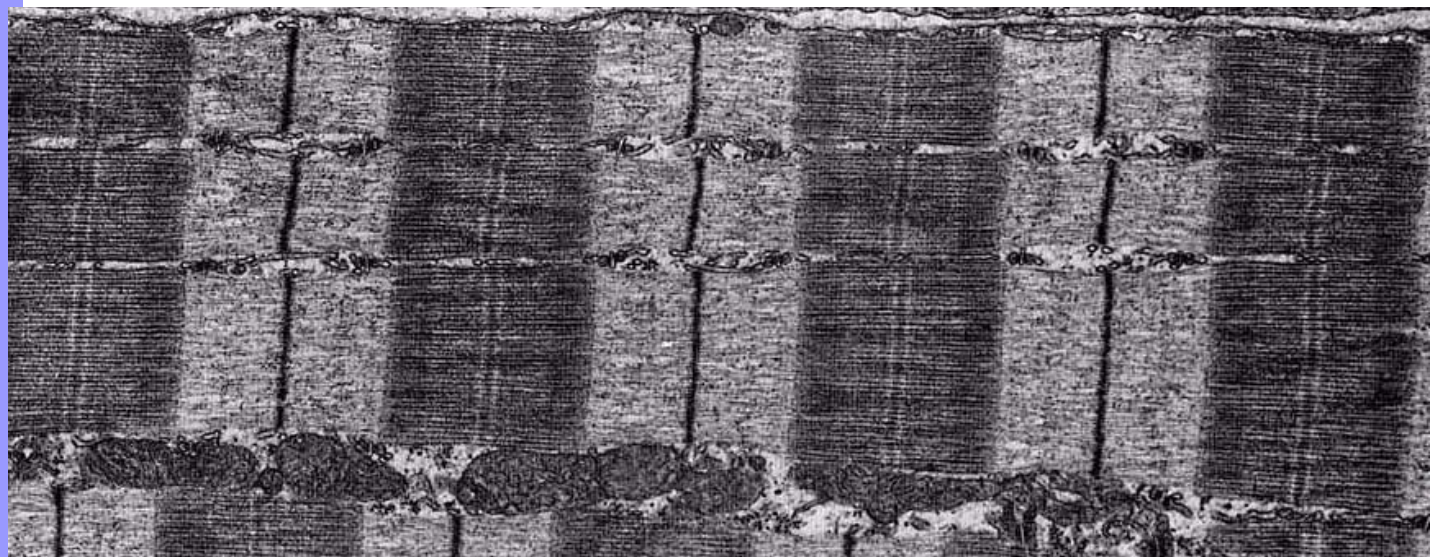
striated muscle fibres

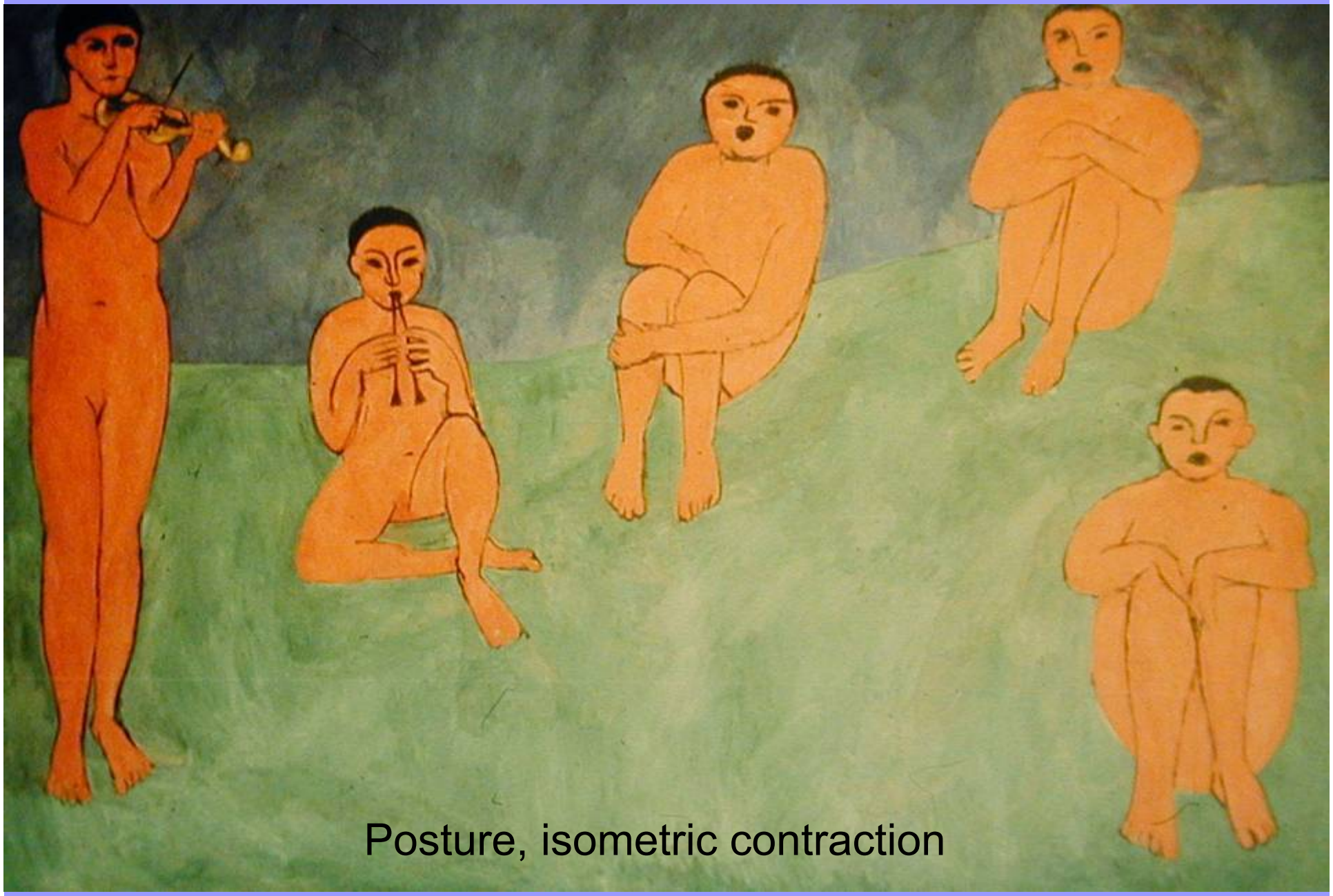


muscle fibre,
myofibrils,
sarcomeres
sarcoplasmic
reticulum,
T-tubules,
triads
mitochondria,
sarcolemma,
basal lamina




Sarcomere ~2.2 µm
Dark Band
Z disc
M line
Z disc
thick filament (myosin)
thin filament (actin)

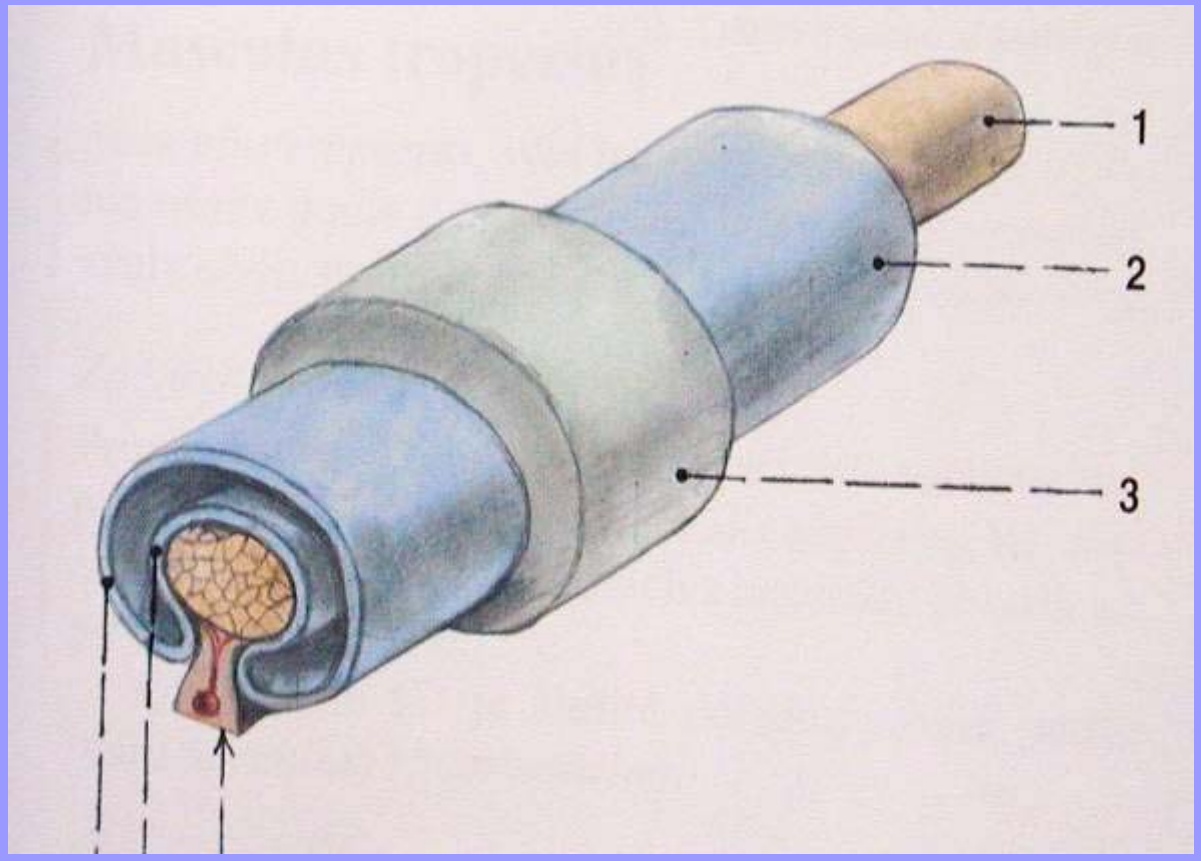


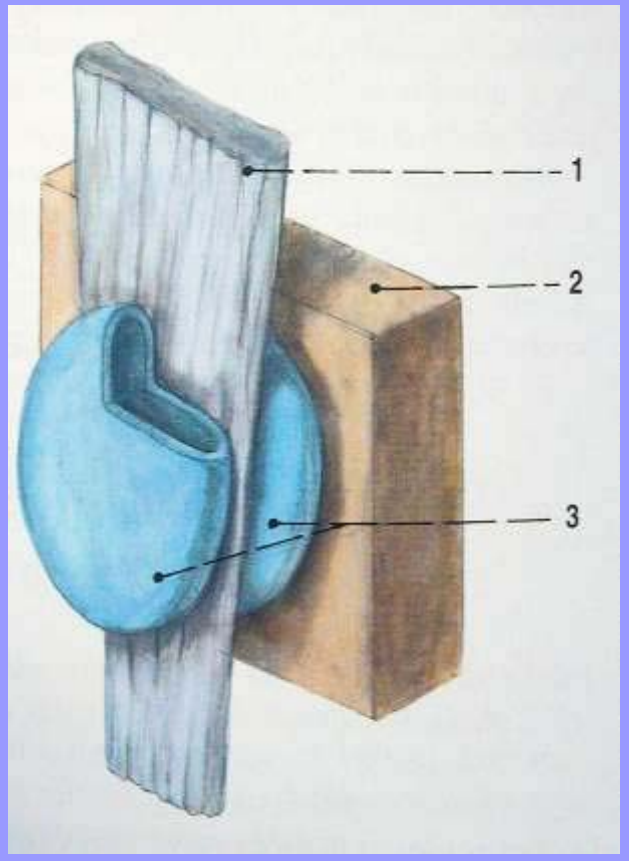


Posture, isometric contraction


Motion, isotonic contraction

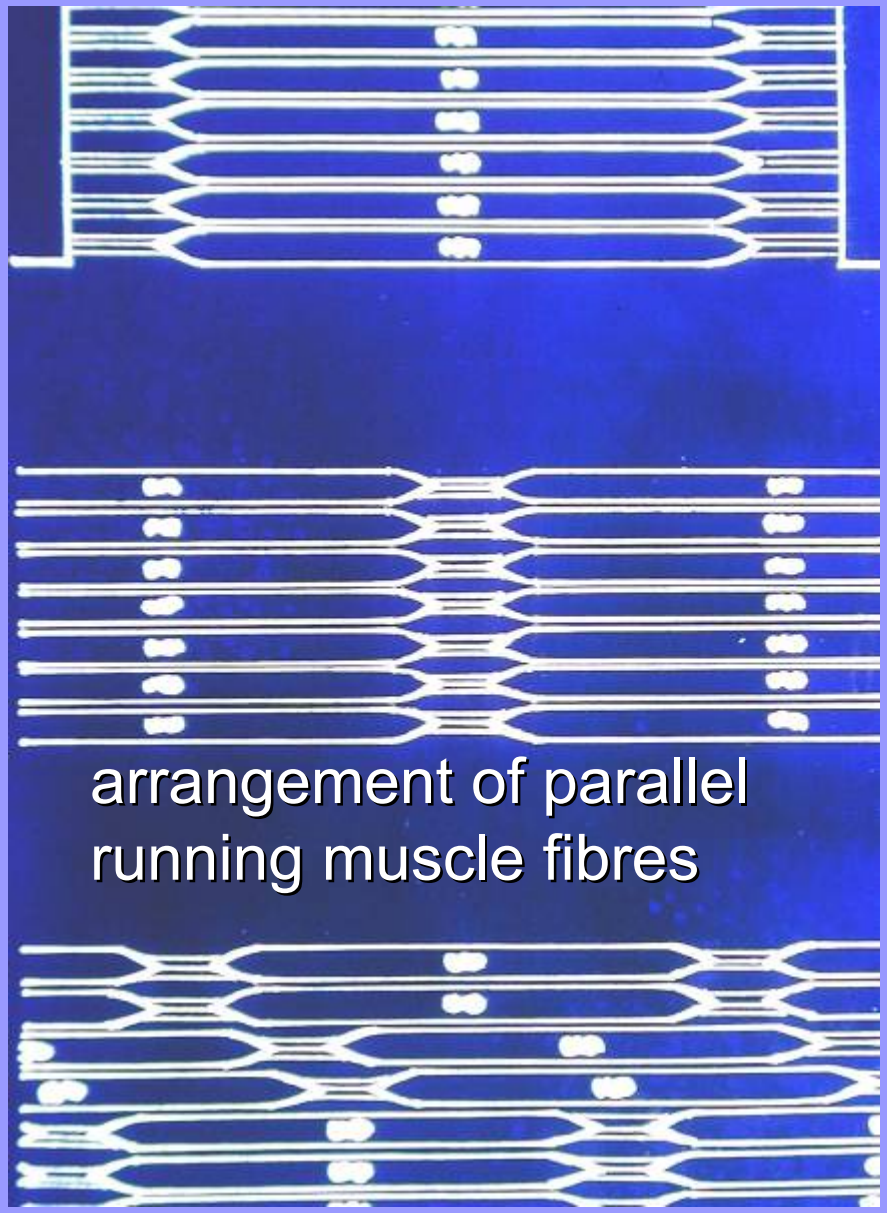
myo-tendinous junction

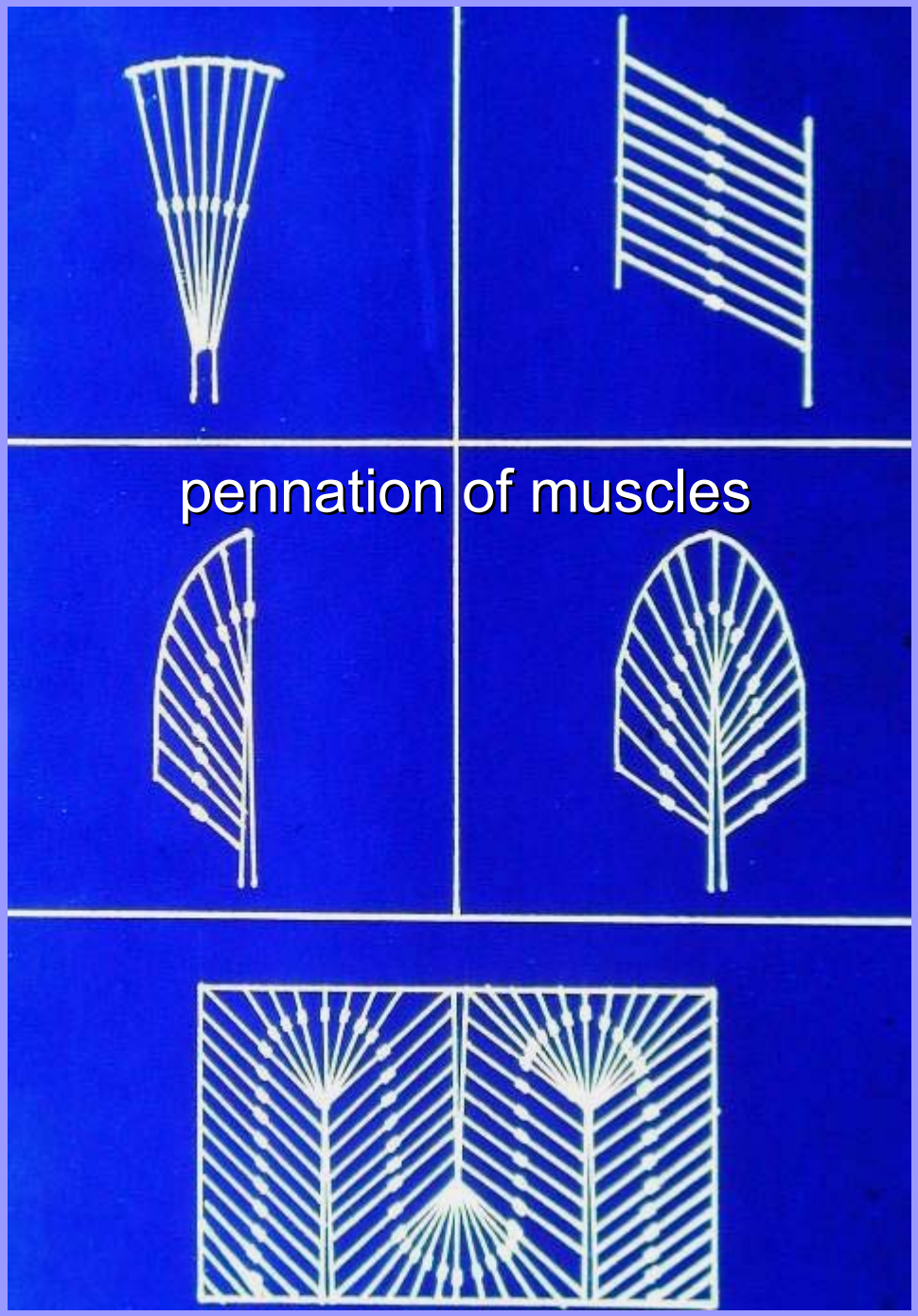


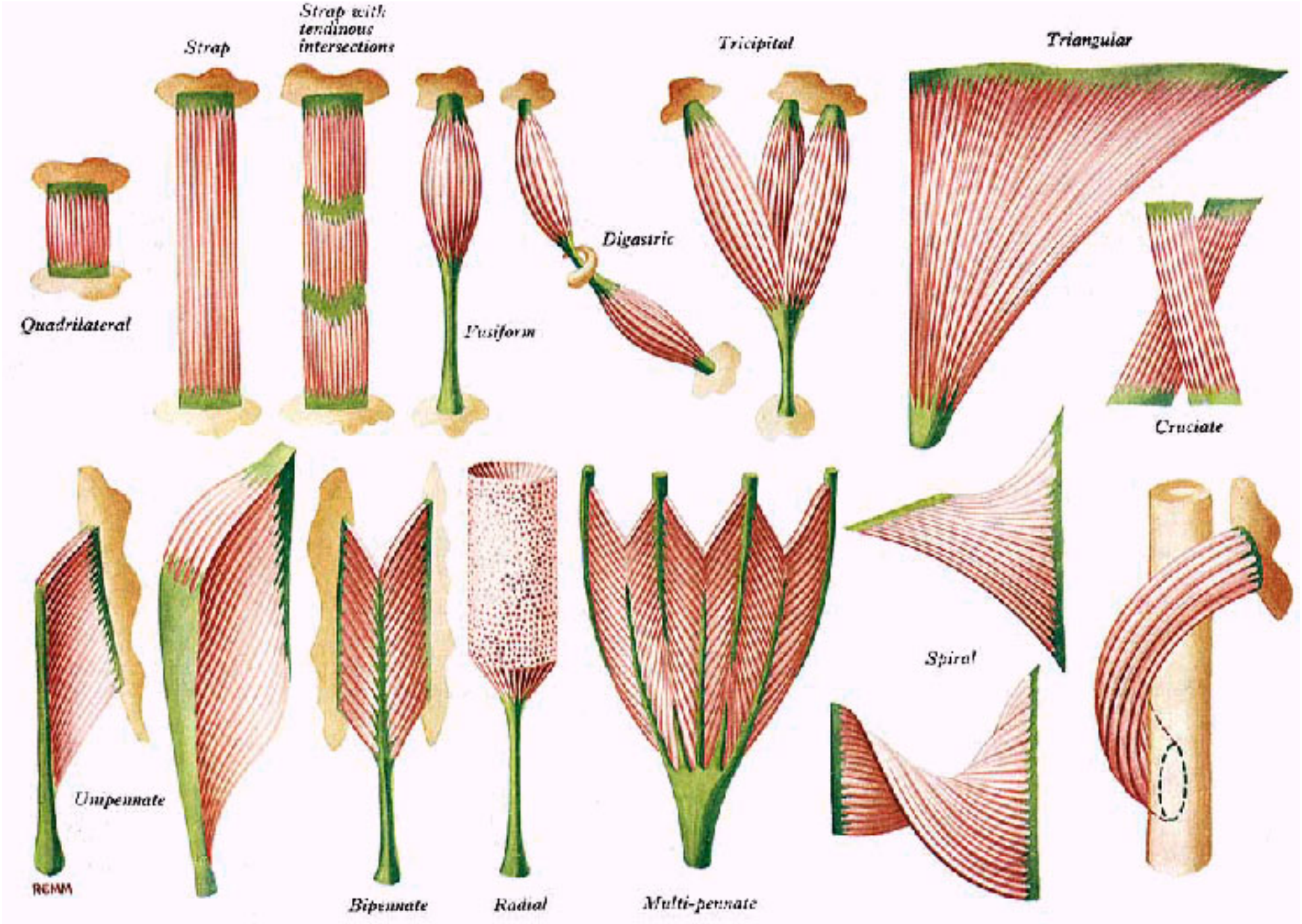


synovial sheath, synovial bursa

visualization of motor end plates


arrangement of parallel
running muscle fibres


pennation of muscles


Strap
Strap with tendinous intersections
Tricipital
Triangular
Quadrilateral
Fusiform
Digastric
Cruciate
Spiral
Unipennate
Bipennate
Radial
Multi-pennate

Naming of Muscles

Shape:

deltoid (= triangular), quadratus (= square), rhomboid (= diamond-shaped)

teres (= round), gracilis (= slender), rectus (= straight), lumbrical (= worm-like)

Size : major, minor, longus (= long), brevis (= short), latissimus (= broadest), longissimus (= longest)

Number of Heads or Bellies:

biceps (= 2 heads), triceps (= 3 heads), quadriceps (= 4 heads)

digastric (= 2 bellies), biventer (= 2 bellies),

Position:

anterior, posterior, interosseus (= between bones)

supraspinatus (= above spine of scapula),

infraspinatus (= below spine),

dorsi (= of the back), abdominis (= of the abdomen)

pectoralis (= of the chest), brachii (= of the arm)

femoris (= of the thigh), oris (= of the mouth)

Naming of Muscles

Depth:

superficialis (= superficial), profundus (= deep),
externus (or externi), internus (or interni)

Attachment:

sternocleidomastoid
(from sternum and clavicle to mastoid process)
coracobrachialis (from the coracoid process to the arm)

Action:

extensor, flexor, abductor, adductor,
levator (= lifter), depressor,
supinator, pronator, constrictor, dilator

Innervation of skeletal muscle

Q:General structure of the spinal nerve and its main branching (draw scheme)

Neurovascular hilum

Blood supply

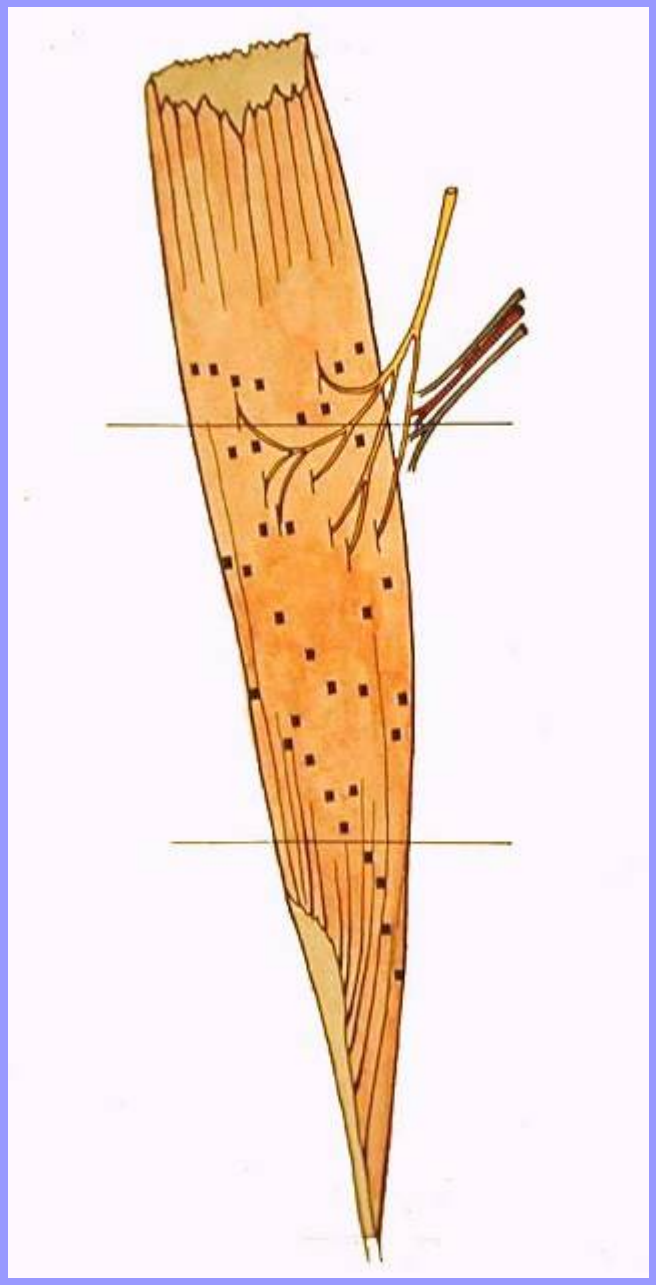
Motor innervation

motoneurons: slow and fast alfa motoneurons, gamma motoneurons, motor end-plate, ACh

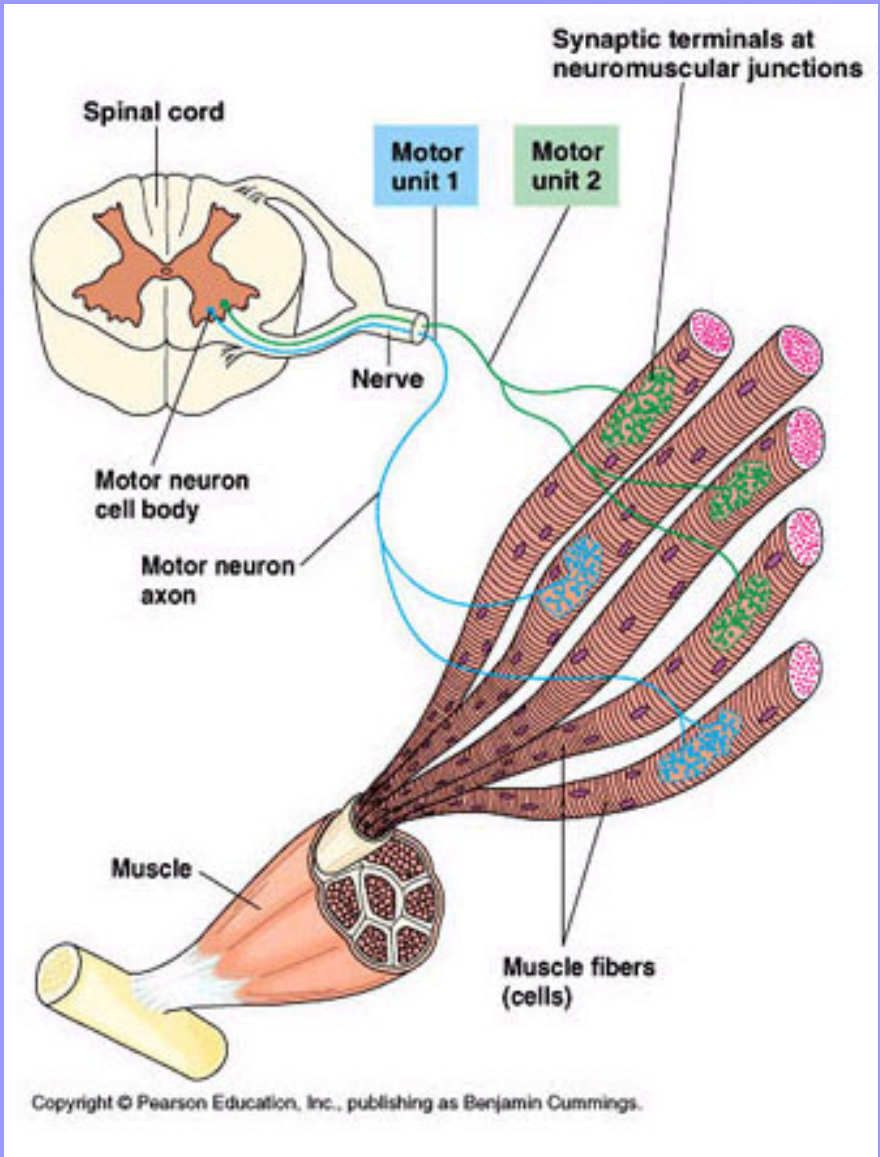
motor unit, zone of motor end-plates, polyneural innervation, segmental innervation

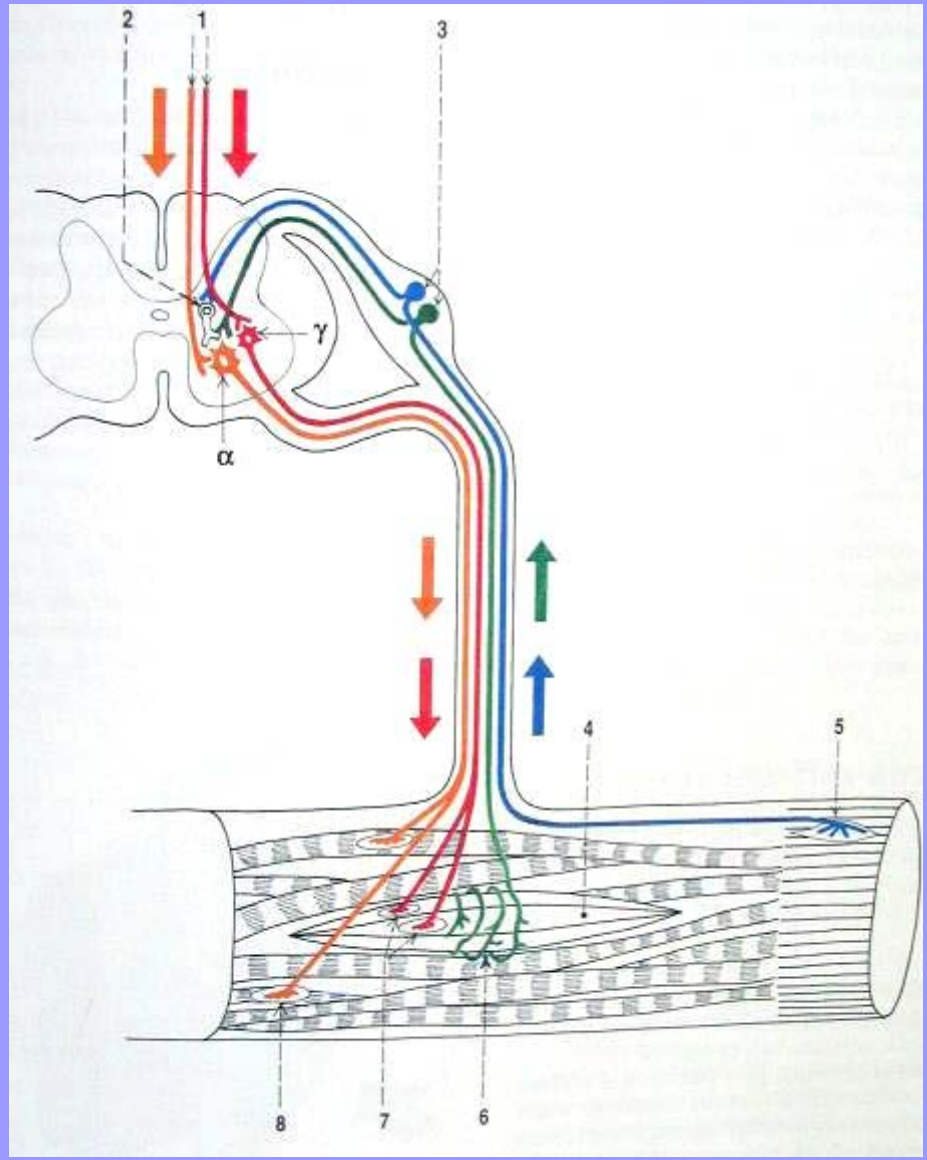
Sensory (proprioceptive) innervation

muscle spindle, Golgi tendon organ, proprioceptive reflexes

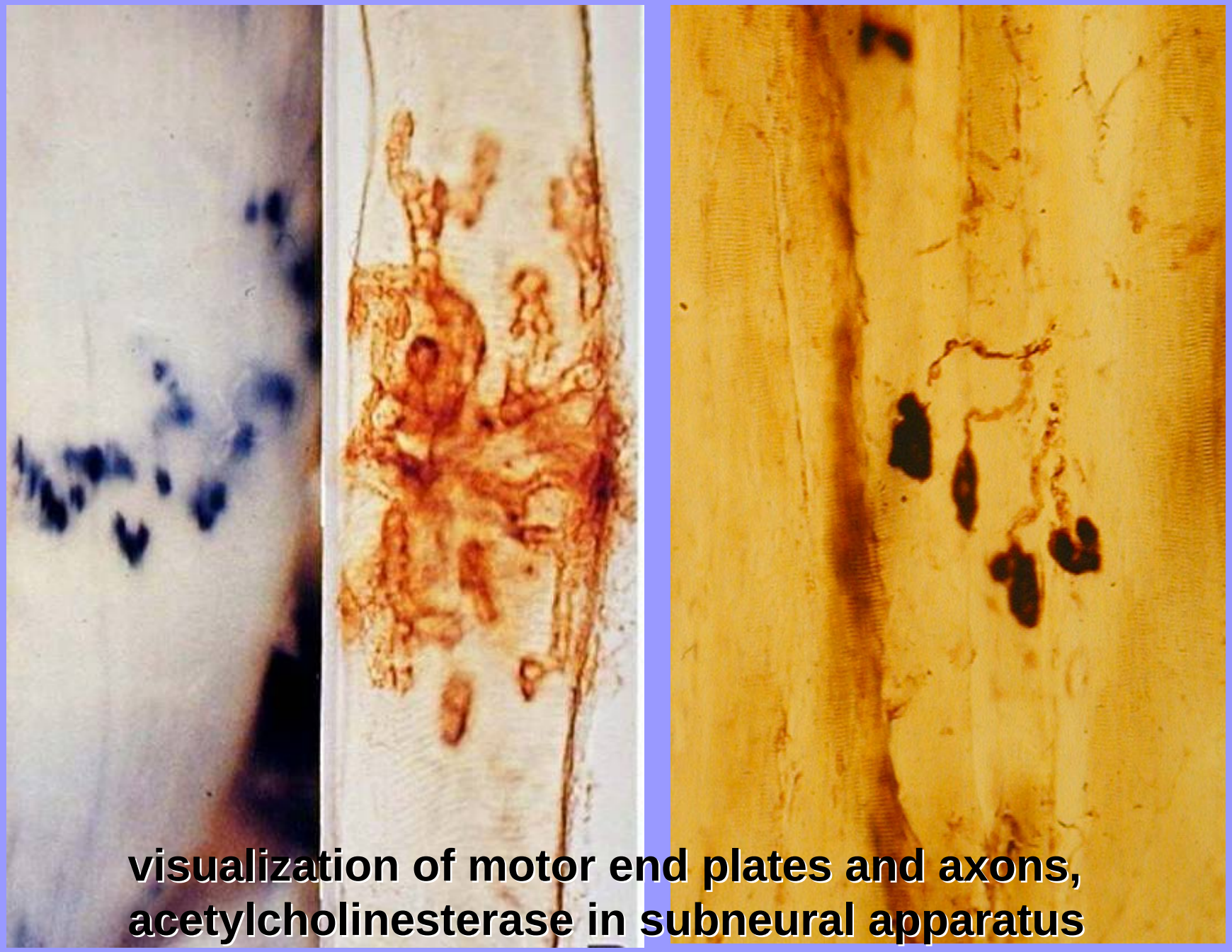


tendons, aponeuroses, neuro-vascular hilum (motor point)

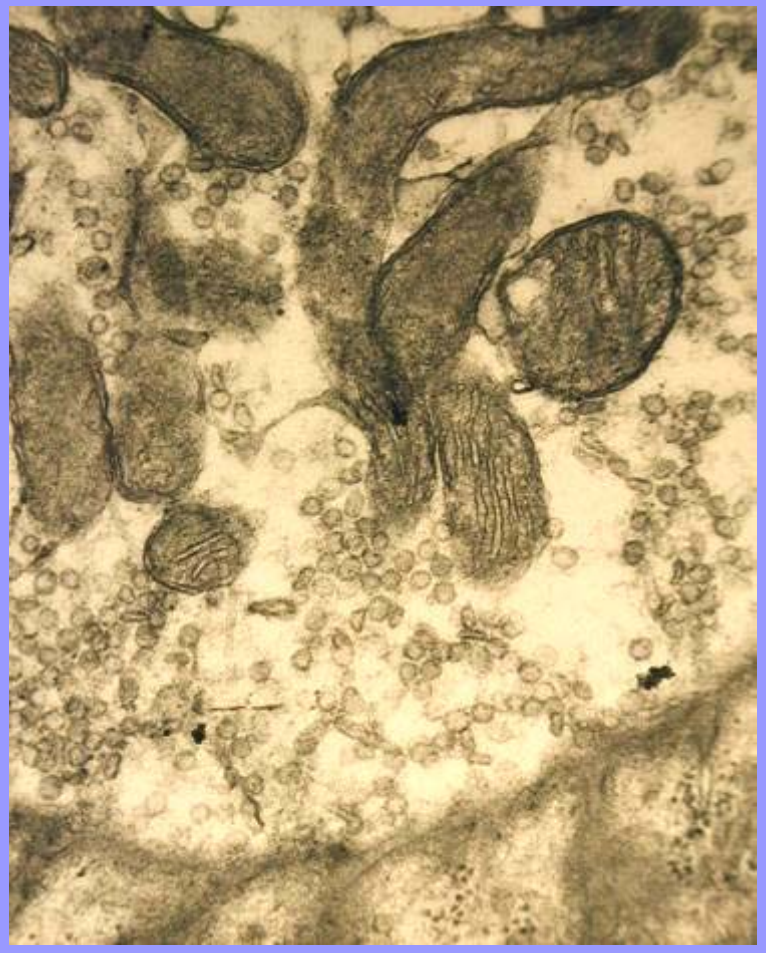


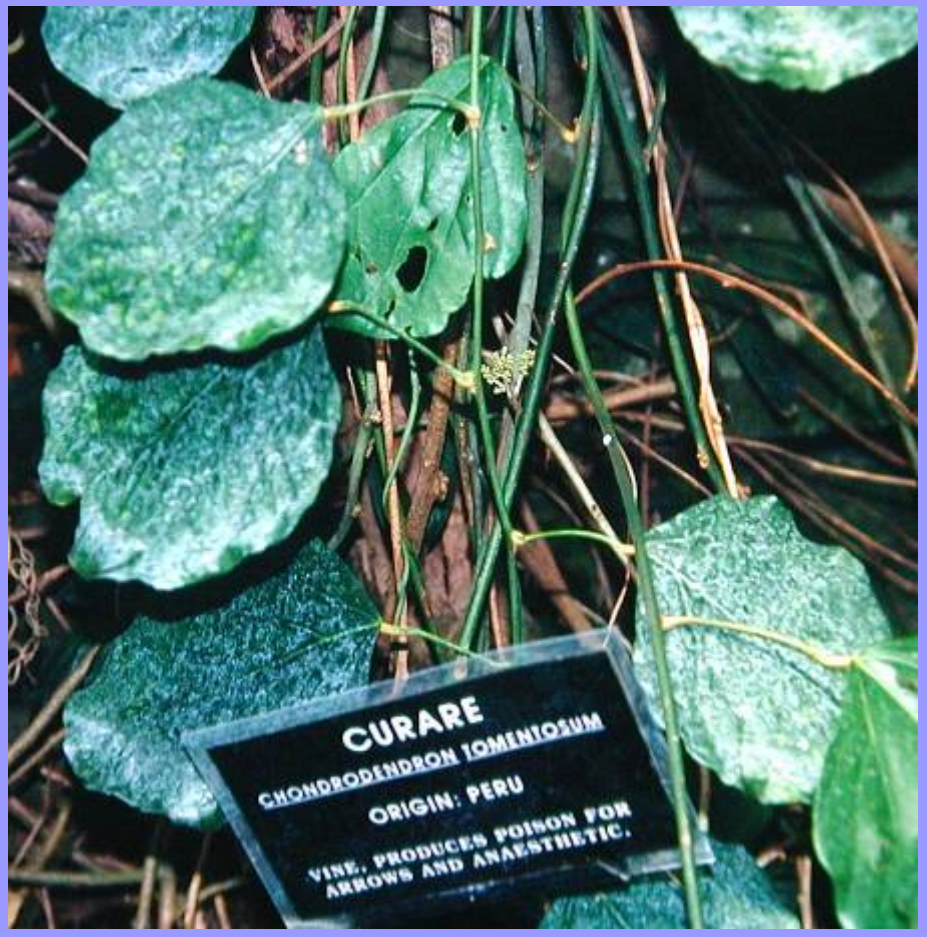


Innervation of skeletal muscle: motoneurons, motor units, motor end- plates, acetylcholine, proprioceptive neurons, muscle spindles, Golgi tendon organs

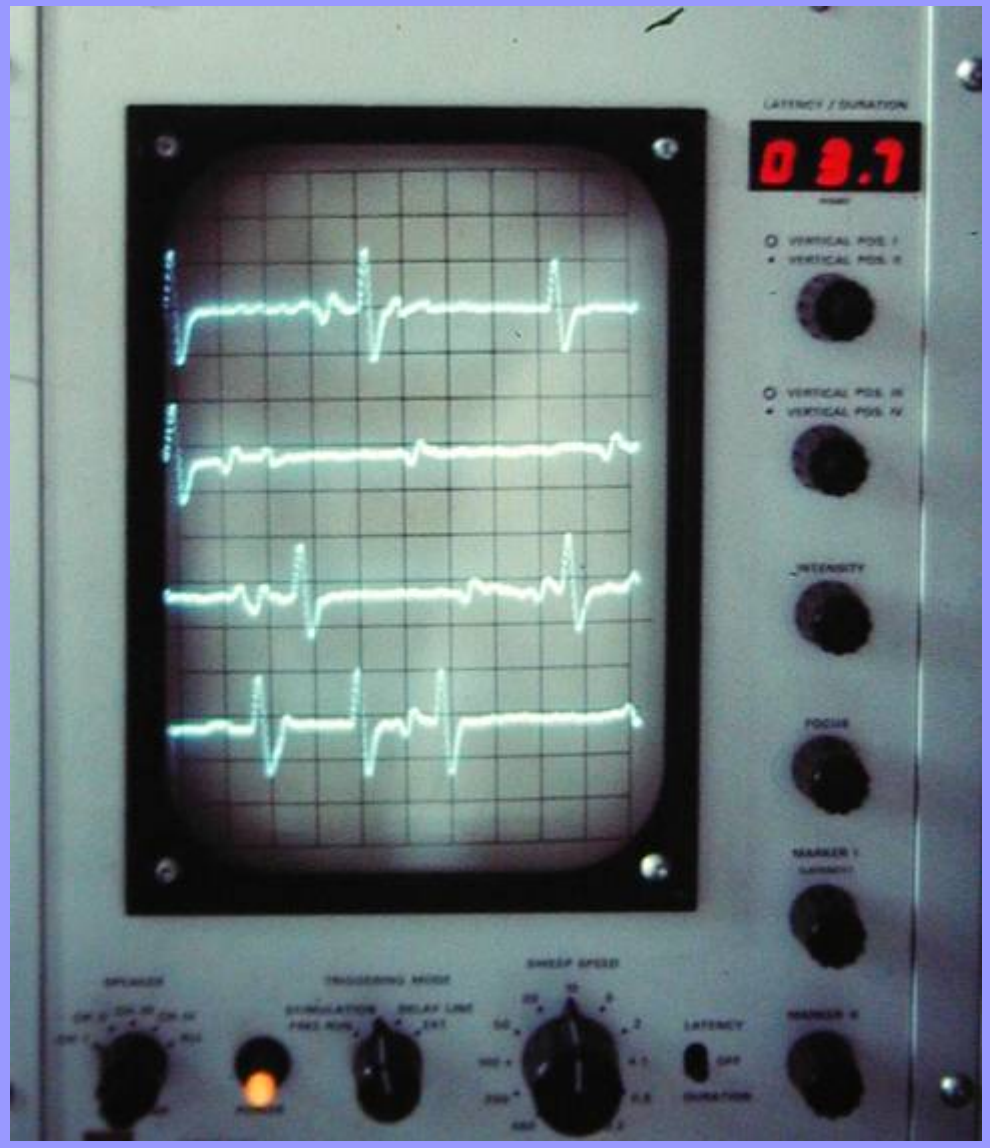


visualization of motor end plates and axons, acetylcholinesterase in subneural apparatus





synaptic vesicles containing acetylcholine (neurotransmitter) in axon terminal of motor end-plate; curare blocks the transmission



Elektromyography (EMG)

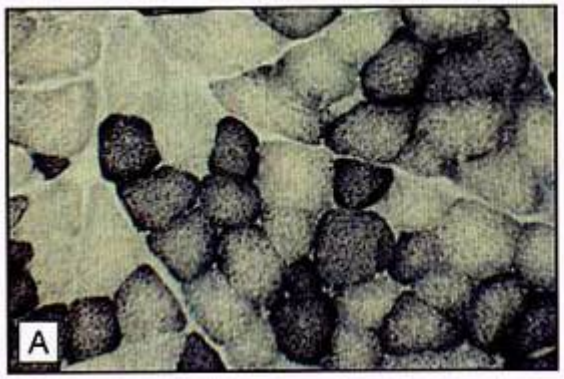
A young women with sensory neuropathy of unknown origin who completely lost proprioceptive sensation:
She could not stand without watching her feet,
she could not held anything in her hands, and they wandered around without her awareness…

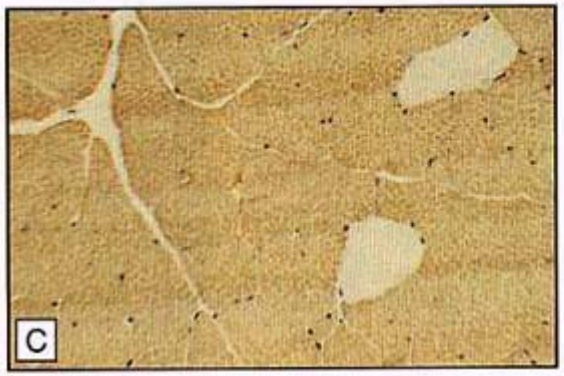
„Something awful´s happened, I can´t feel my body.
I feel weird-disembodied“, she said, and „I may lose my arms. I think they´re one place and I find they´re another“.
After having proprioception explained, she said:
„This proprioception is like the eyes of the body, the way the body sees itself. And if it goes, as it´s gone with me, it´s like the body is blind…so I have to watch it - be its eyes. Right?“

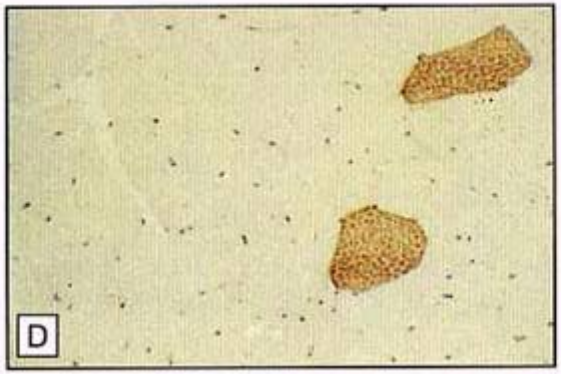
Fibre Types of Skeletal Muscle

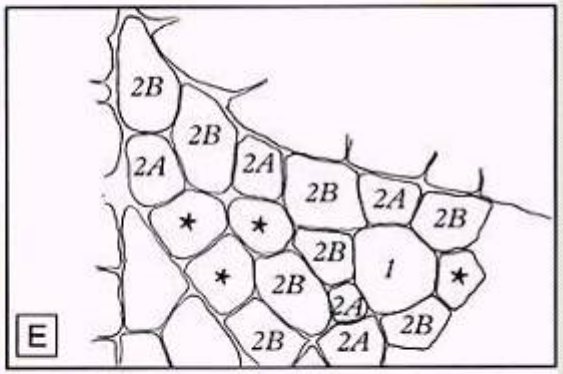
- Type 1 fibres are slow-contracting and fatigue-resistant
- Type 2A fibres are fast-contracting and fatigue-resistant
- Type 2X fibres are fast-contracting and susceptible to fatigue

Fibre Type Transformation
Adaptive Capacity of Skeletal Muscle
Denervation and Disuse Atrophy





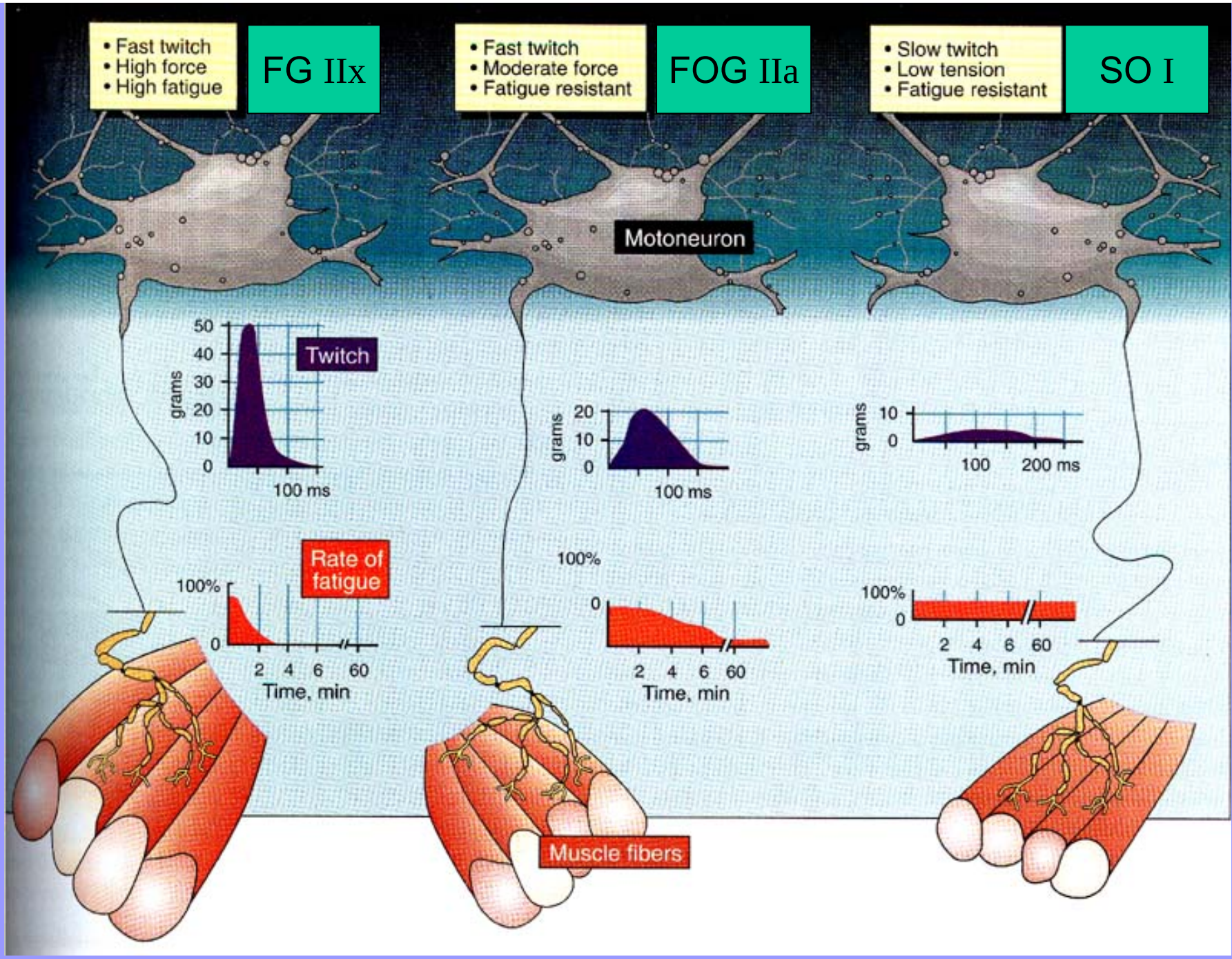


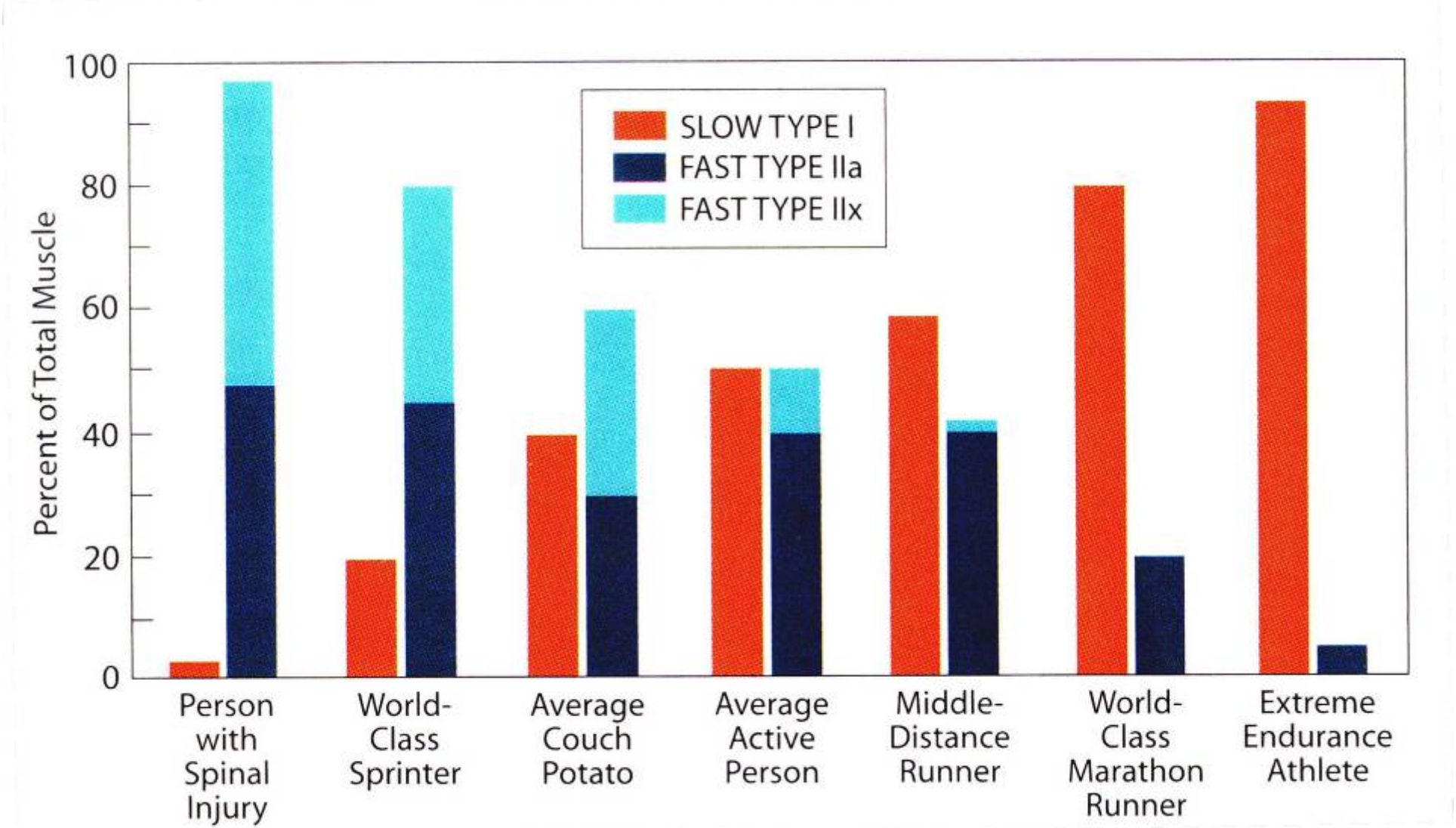


Relative Distributions of Slow Twitch & Fact Twitch Myosin Isoforms (Type I & Type II)				
	Type I (slow)	Type II (fast)	Type IIa	Type IIx
Average person	50%	50%	40%	10%
spinal injury	4%	96%	48%	48%
sprinter	20%	80%	45%	35%
couch potato	40%	60%	30%	30%
marathoner	80%	20%	20%	0%

These myosin isoforms are conserved evolutionarily: Comparing myosin isoforms from different mammals reveals remarkably little variation species to species. Rat type I is more similar to human type I myosins, than it is to rat type II's. Thus selective evolution has maintained a functional difference between type I's & type II's over eons of evolution.

back


• Fast twitch
• High force
• High fatigue
FG IIx
• Fast twitch
• Moderate force
• Fatigue resistant
FOG IIa
• Slow twitch
• Low tension
• Fatigue resistant
SO I
Motoneuron
Twitch
grams
50
40
30
20
10
0
100 ms
20
10
0
grams
100 ms
10
0
grams
100
200 ms
Rate of fatigue
100%
0
2 4 6 60
Time, min
100%
0
2 4 6 60
Time, min
100%
0
2 4 6 60
Time, min
Muscle fibers


100
80
60
40
20
0
Percent of Total Muscle
SLOW TYPE I
FAST TYPE IIa
FAST TYPE IIx
Person with Spinal Injury
World-Class Sprinter
Average Couch Potato
Average Active Person
Middle-Distance Runner
World-Class Marathon Runner
Extreme Endurance Athlete

Development and Differentiation of Skeletal Muscle

Myogenesis,
Myogenic Determination Factors
Myf-5, myogenin, MyoD and Myf-6 (herculin)
Myostatin

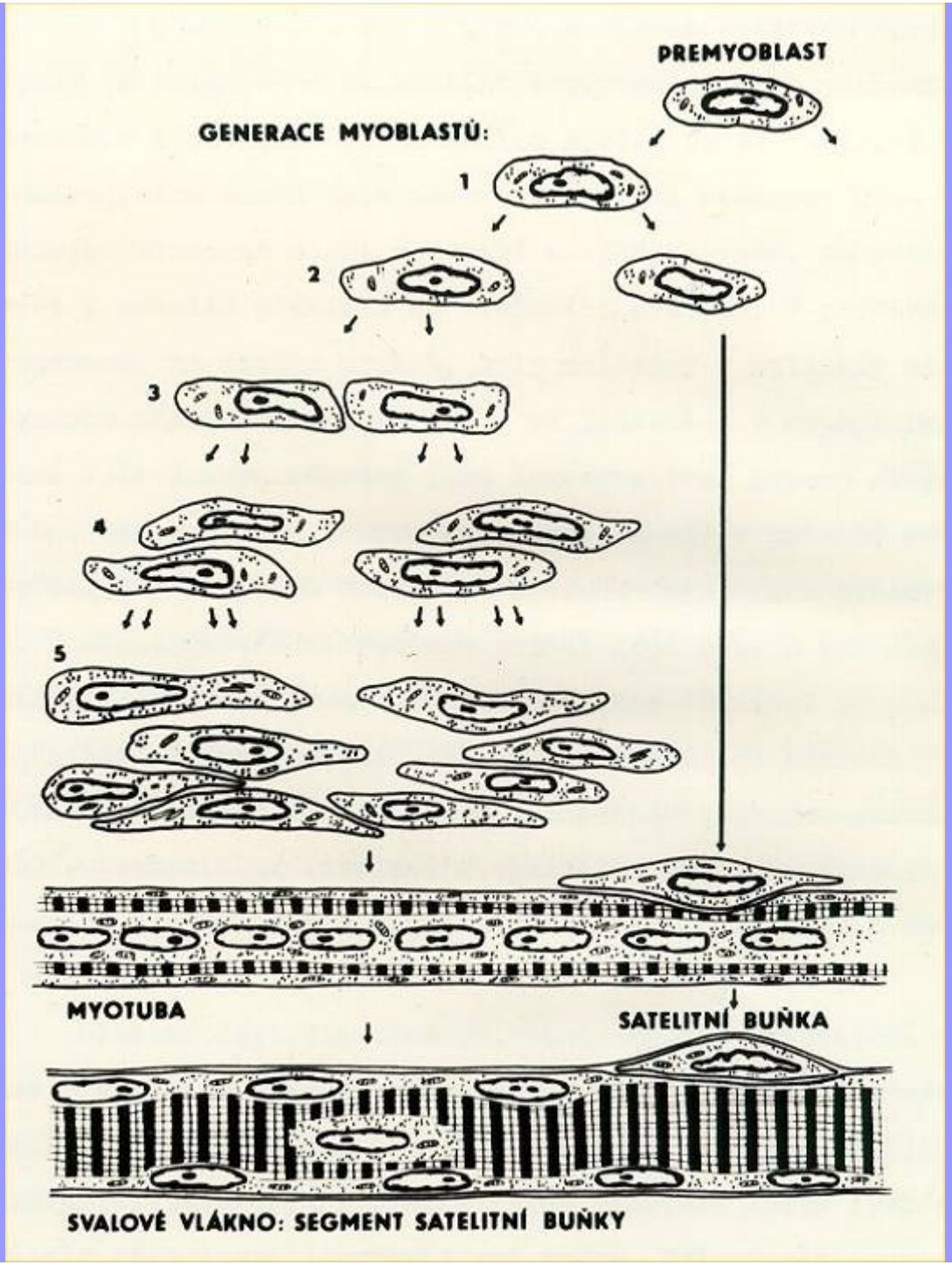
Growth of Skeletal Muscle
Hypertrophy, not hyperplasia
Anabolic Steroids

Regeneration of Skeletal Muscle

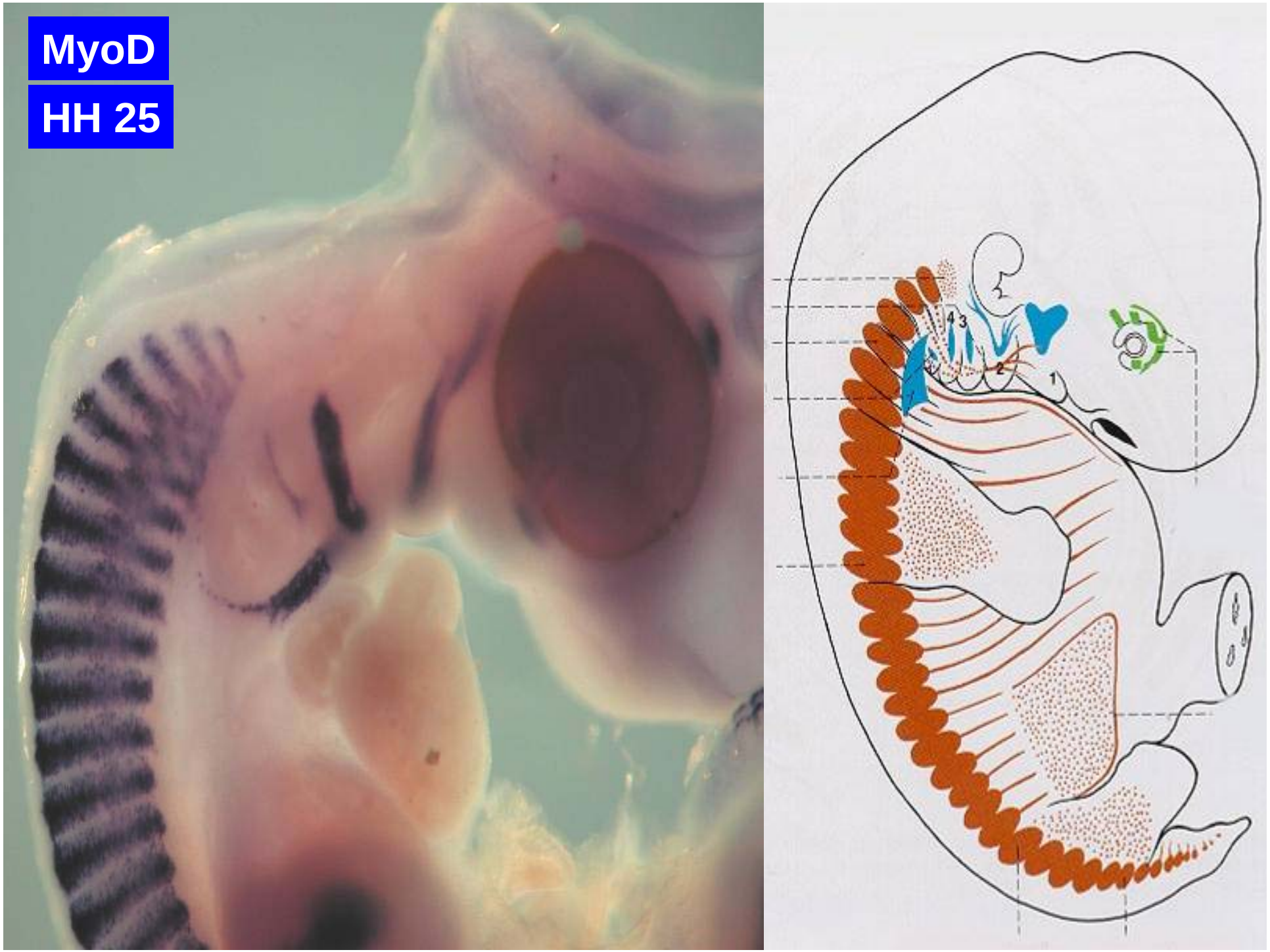
Satellite cells

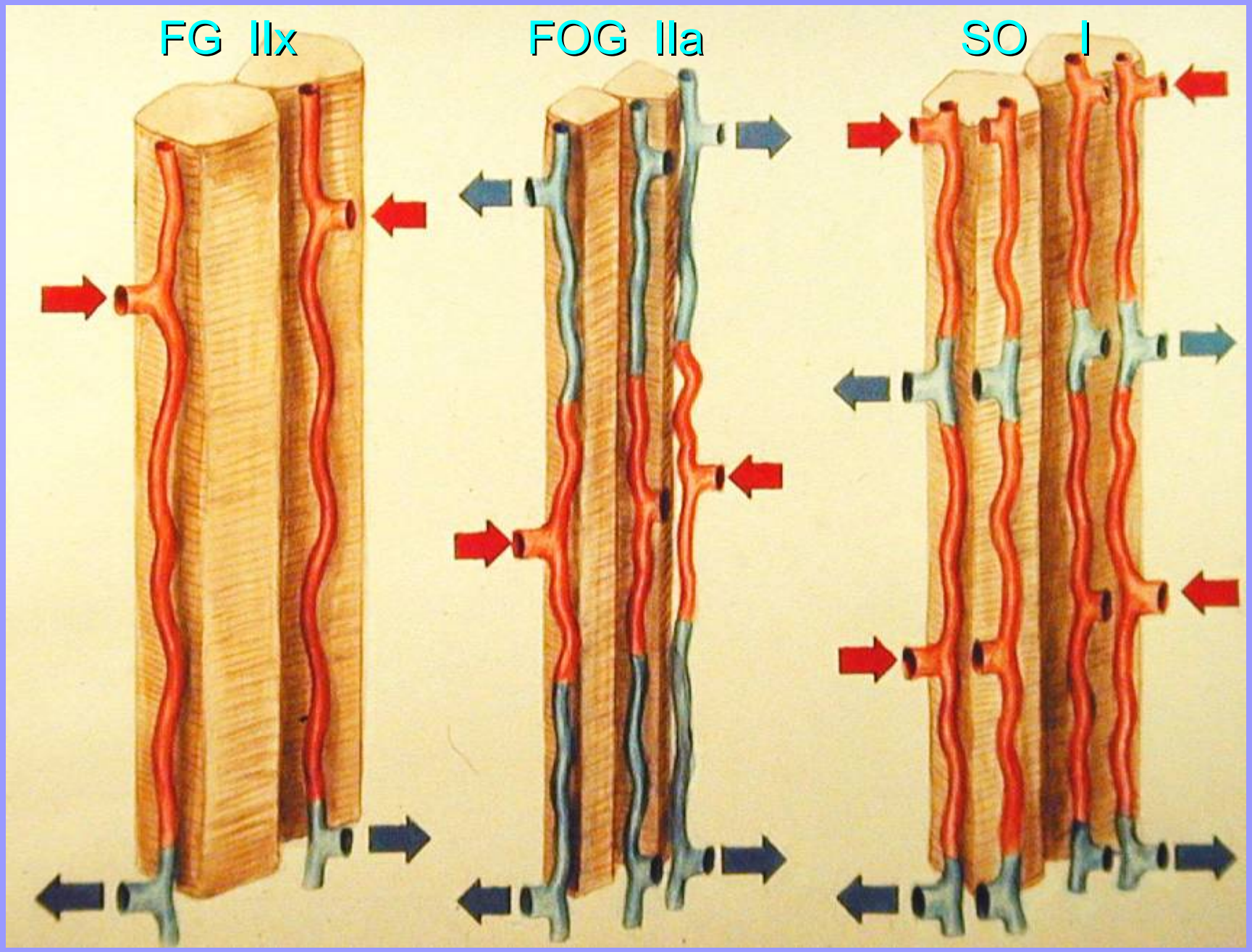
Myogenesis

Myoblast
Myotube
Muscle fibre
Satellite cell
Myogenic Determination Factors
Myostatin



Mutation of myostatine gene resulting in overproduction of myogenic cells

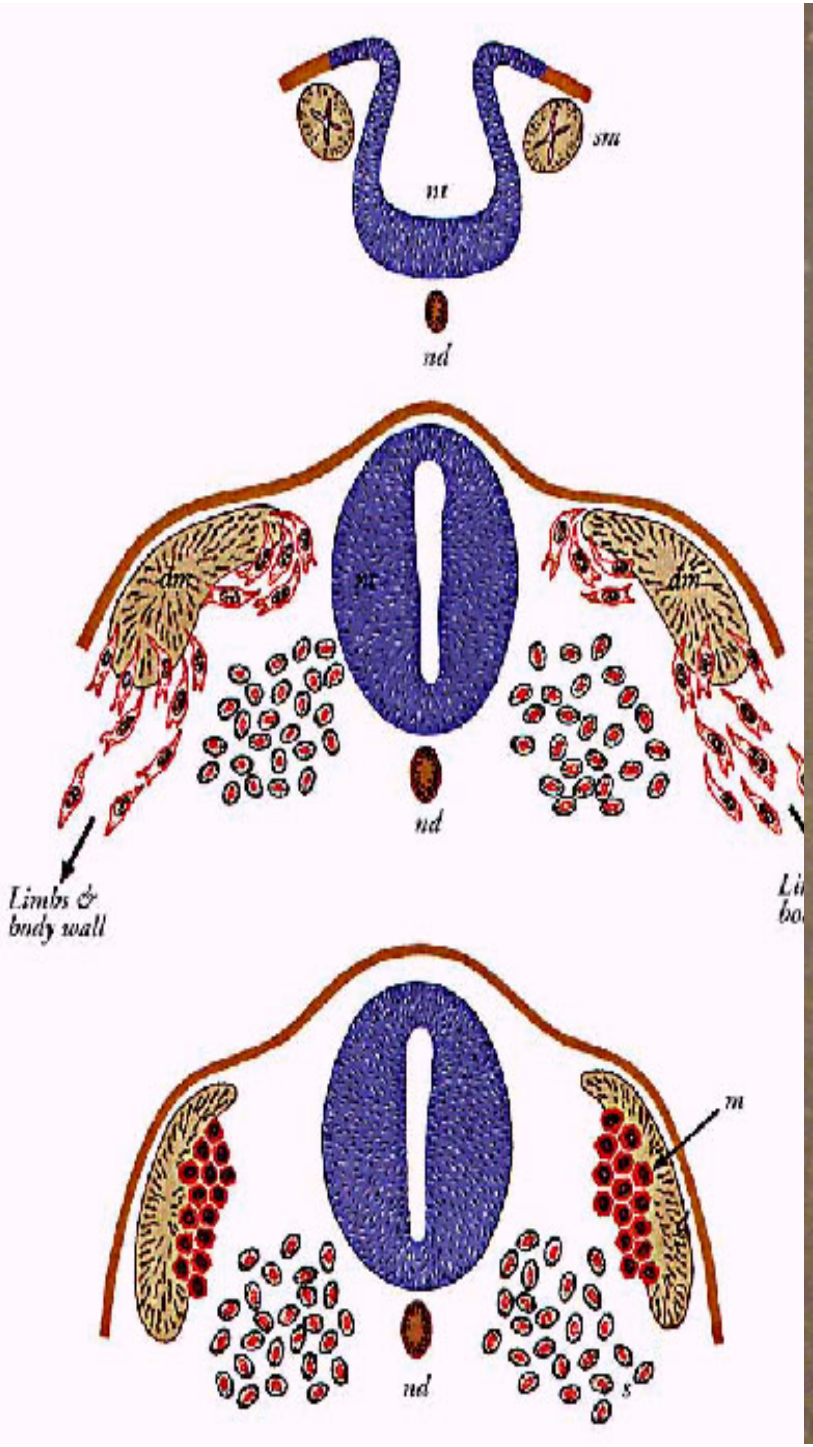

MyoD
HH 25
4
3
2
1

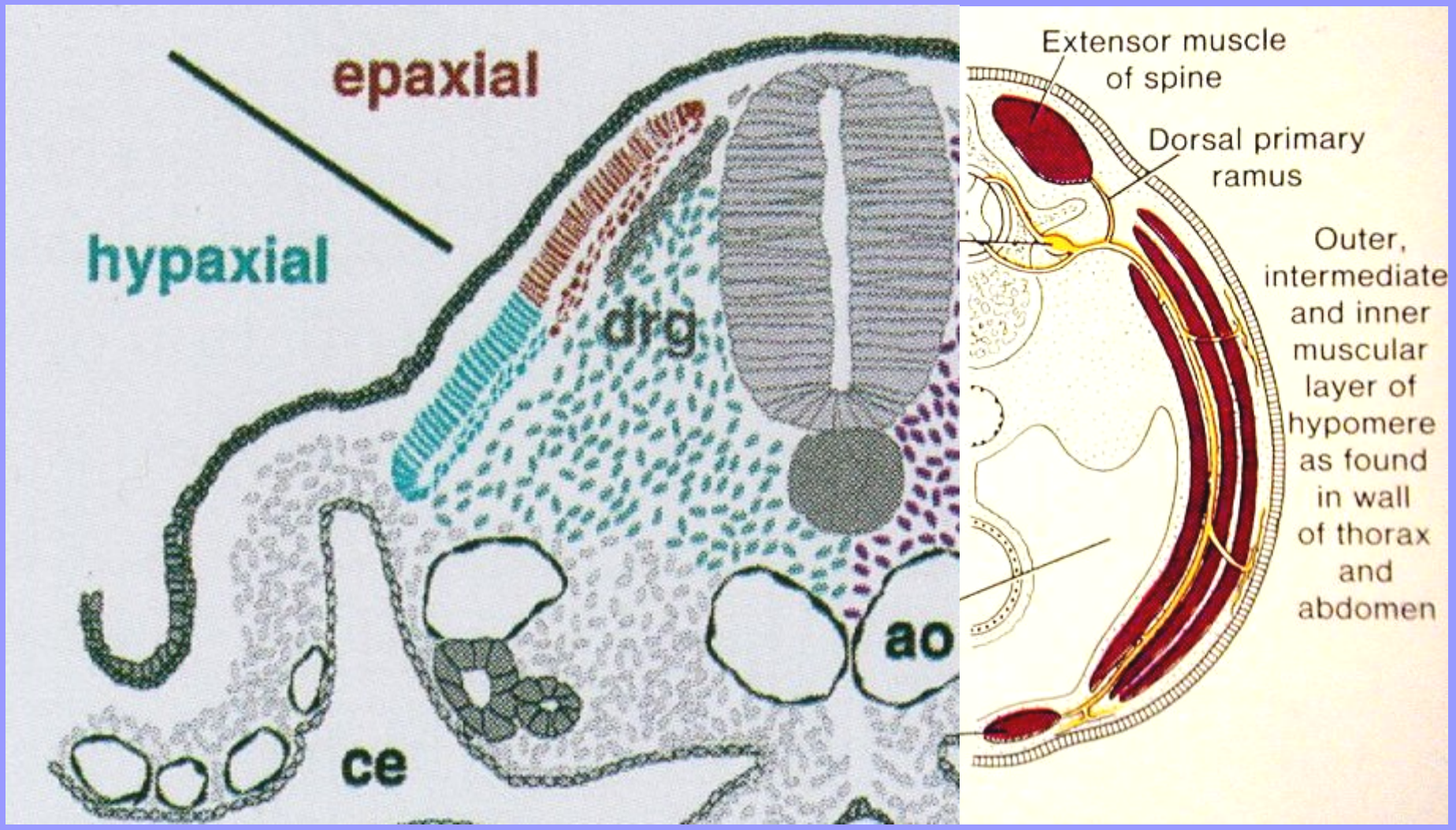


Capillaries of skeletal muscle

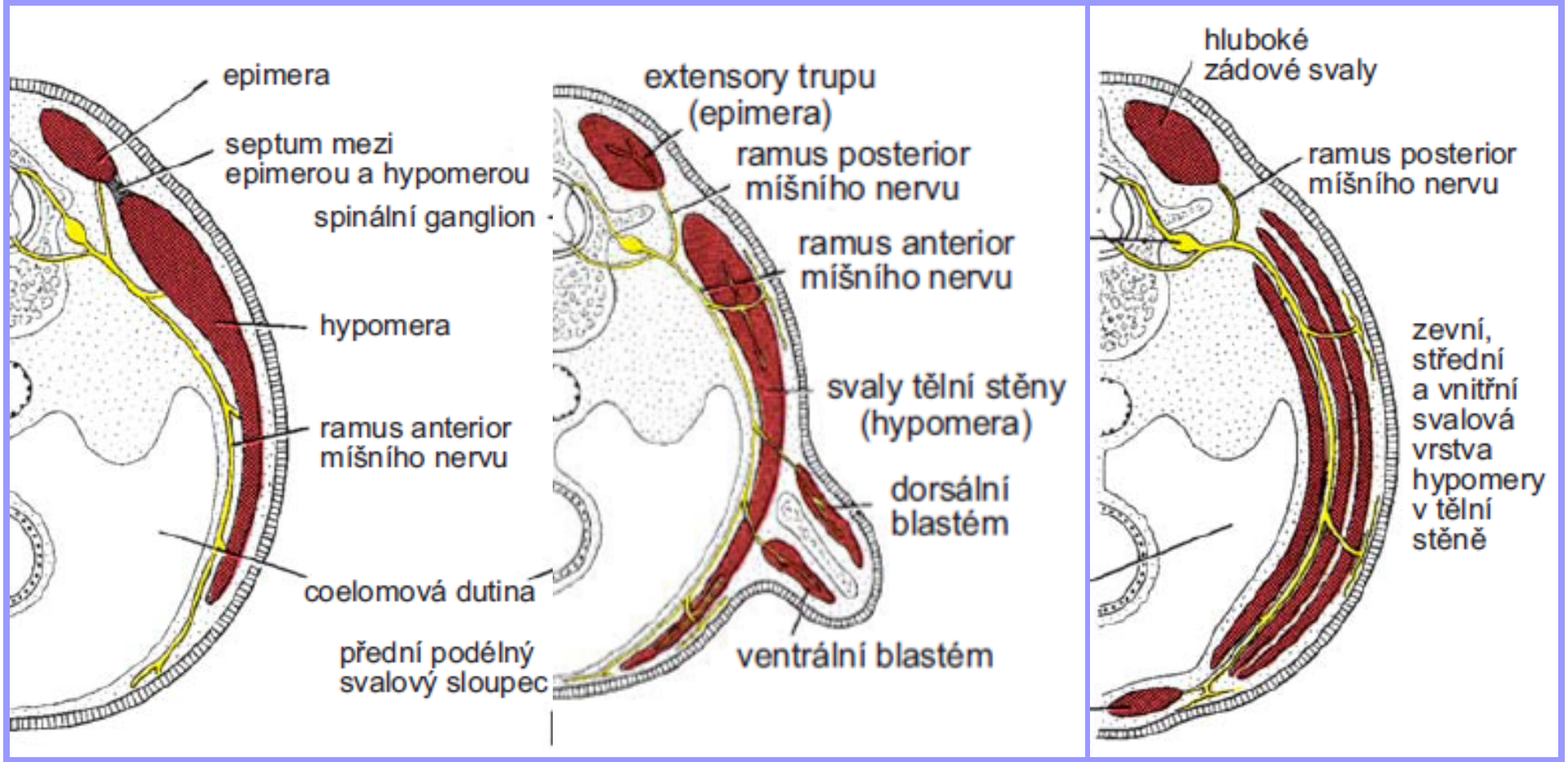
Paraxial mesoderm
Nonsegmented in the head, somites in the trunk
Myogenic cells

Growth and migration of myogenic cells from somites into the body wall and limb primordia



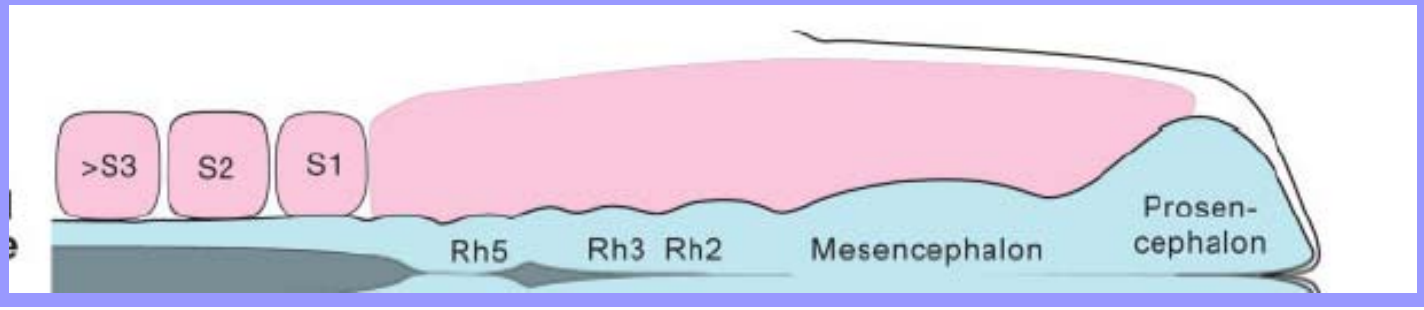


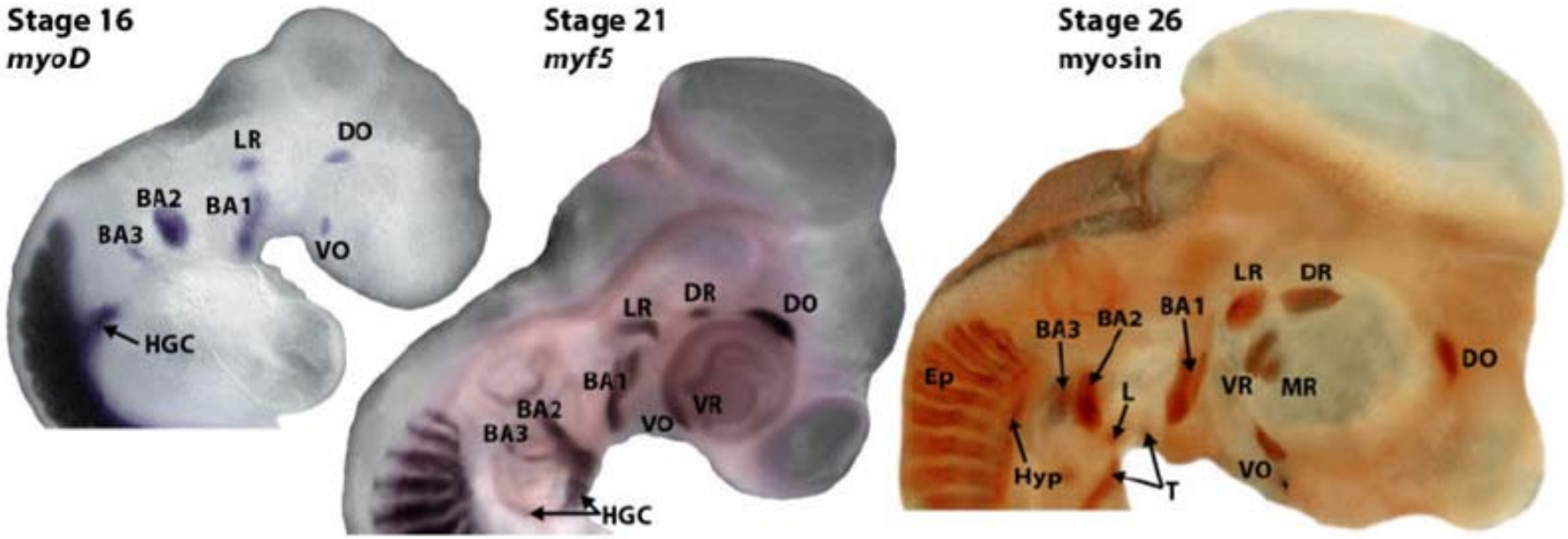
Epaxial and hypaxial musculature and its innervation from dorsal and ventral branches of spinal nerves



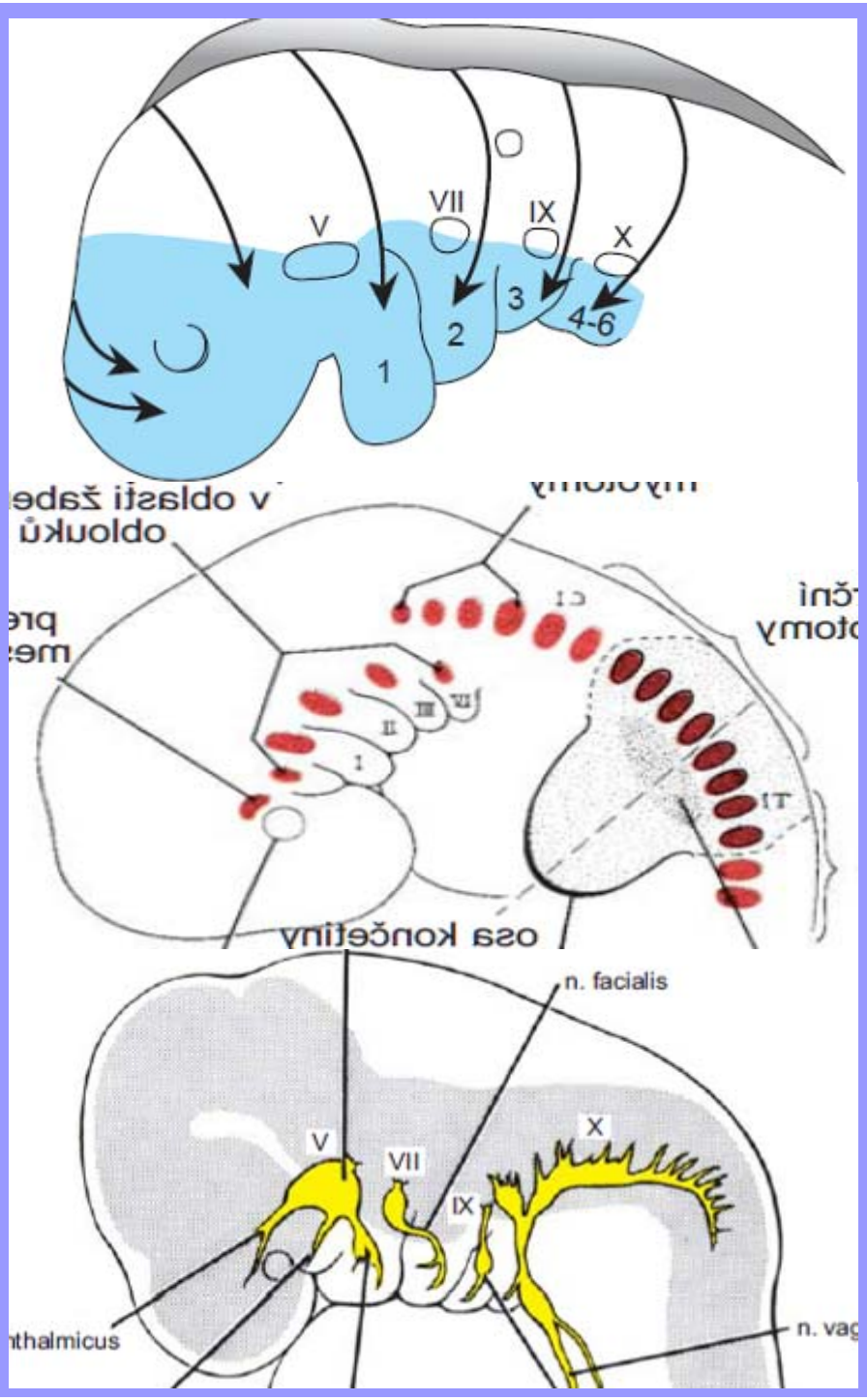
Epaxial and hypaxial musculature and its innervation from dorsal and ventral branches of spinal nerves

Development of head musculature





Extra-ocular muscles, muscles of auditory ossicles, facial muscles, masticatory muscles, musculi linguae, musculi palati mollis et at faucium



Extra-ocular muscles
(Innervation III.,IV. VI.)

Muscles of branchial (pharyngeal) arches
Muscles of auditory ossicles
(BA 1,2.- V., VII.)

Masticatory muscles
(BA 1 -V.)

Facial muscles (BA 2 -VII.)

Musculi palati mollis et at faucium (IX., X.)

Muscles from occipital somites
Musculi linguae (XII.),

Developmental origin of head musculature

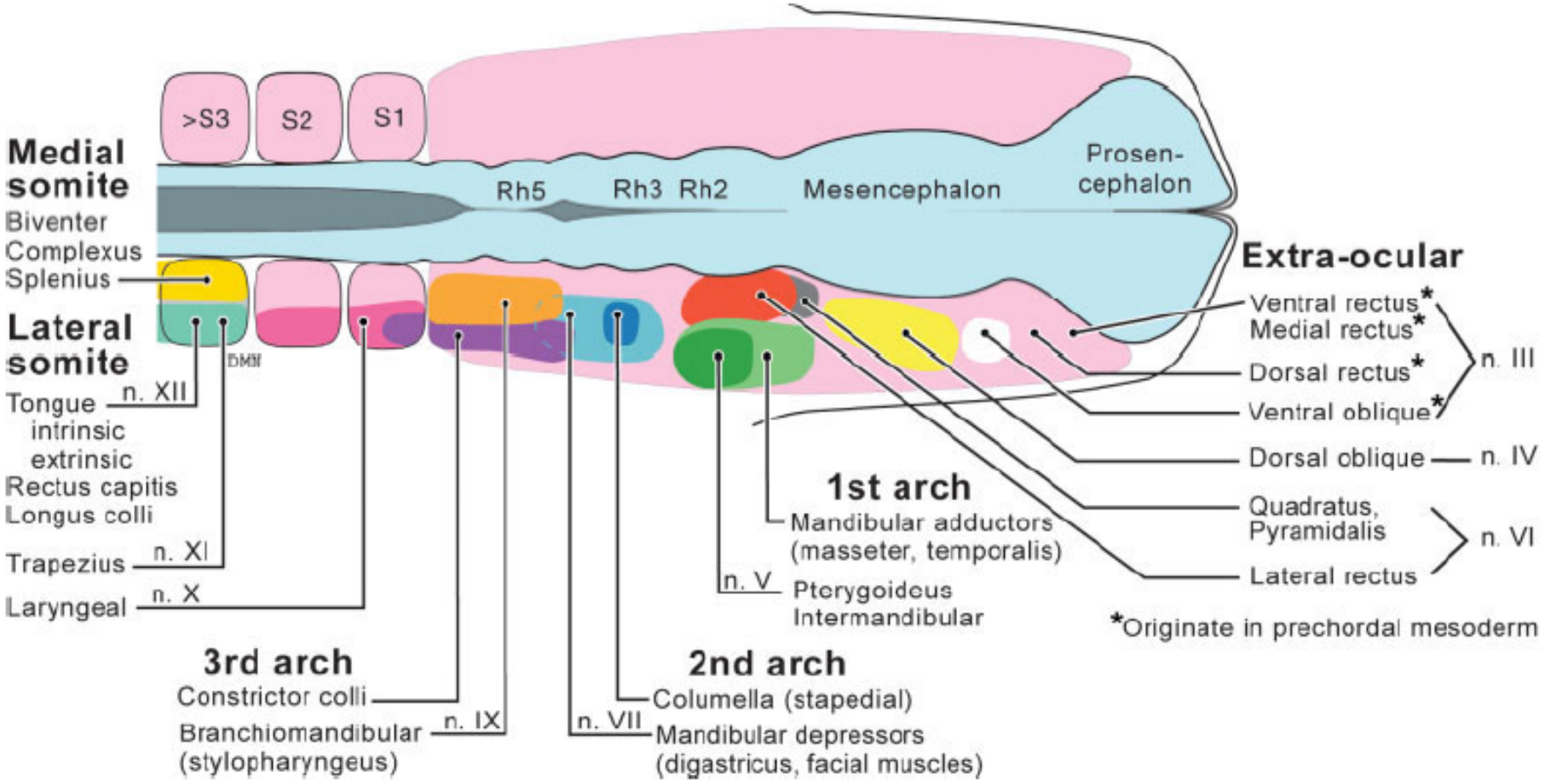
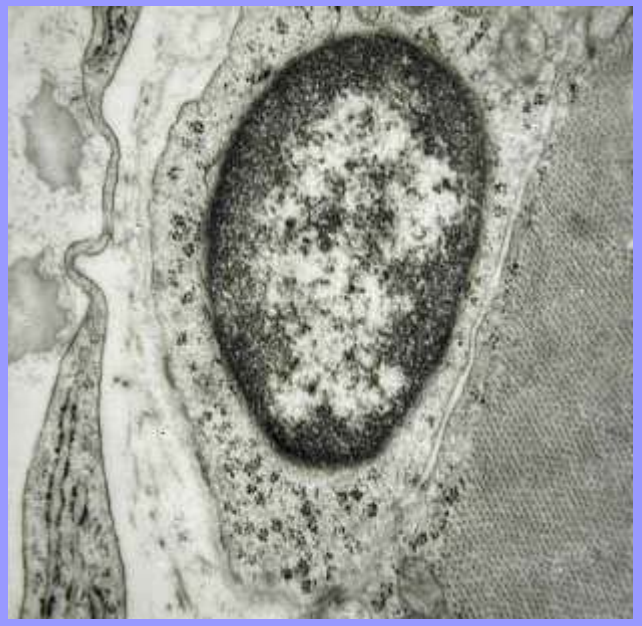
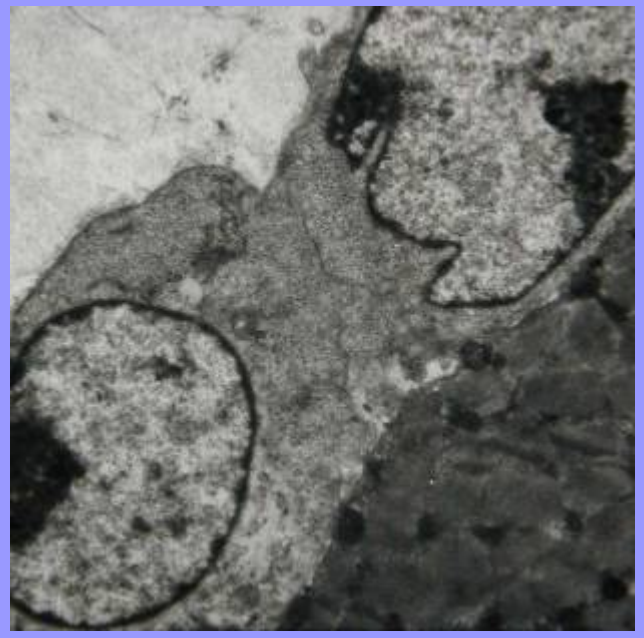


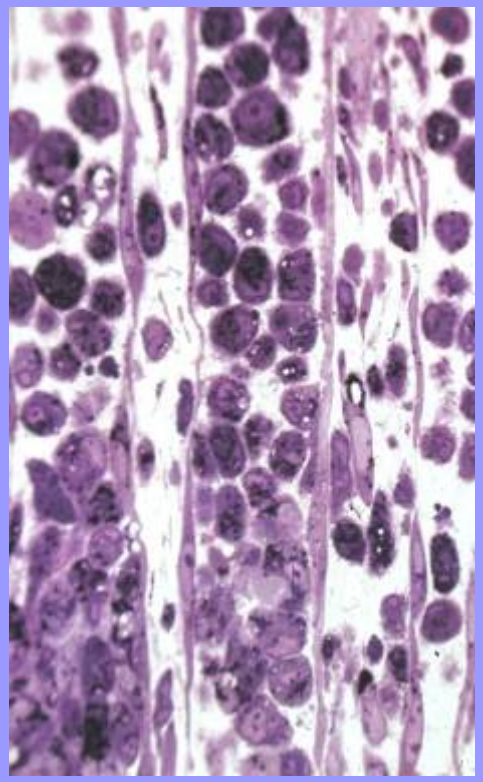
Fig. 8. Summary map showing the locations of muscle primordia within chick cephalic paraxial mesoderm, based on the results of quail–chick transplants and retroviral injections. Names in parentheses indicate some mammalian homologues.

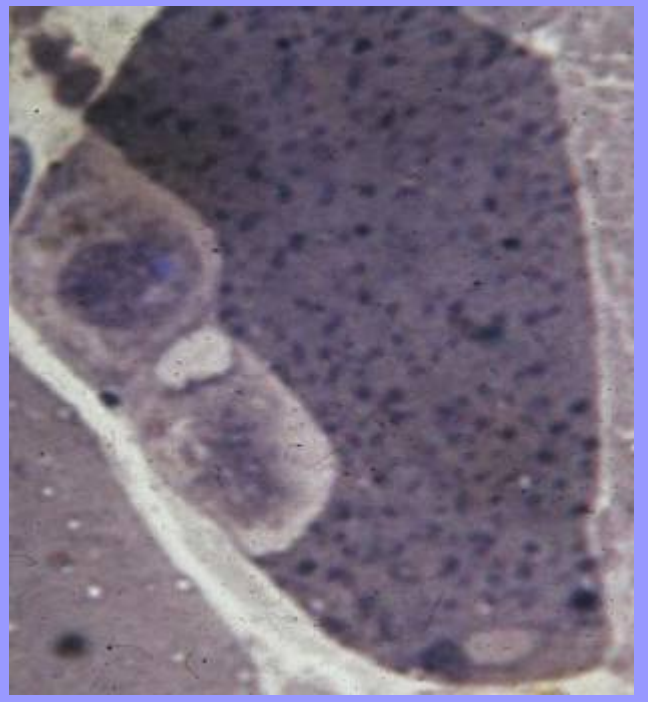
Regeneration of skeletal muscle

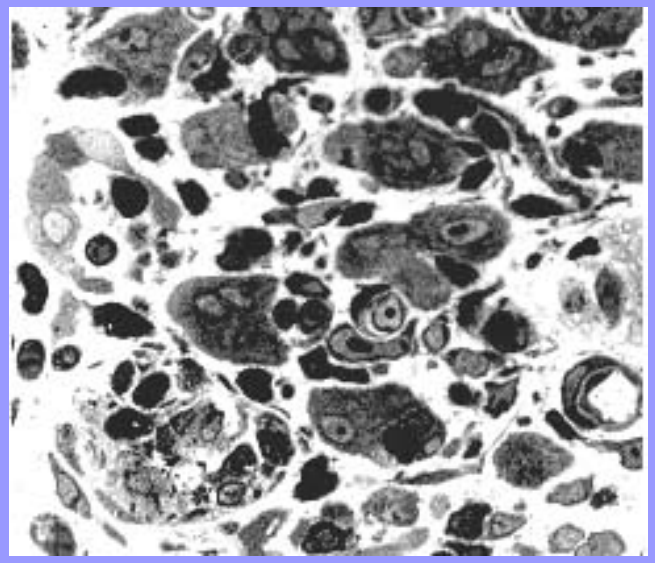
Activation of satellite cells in muscle regeneration



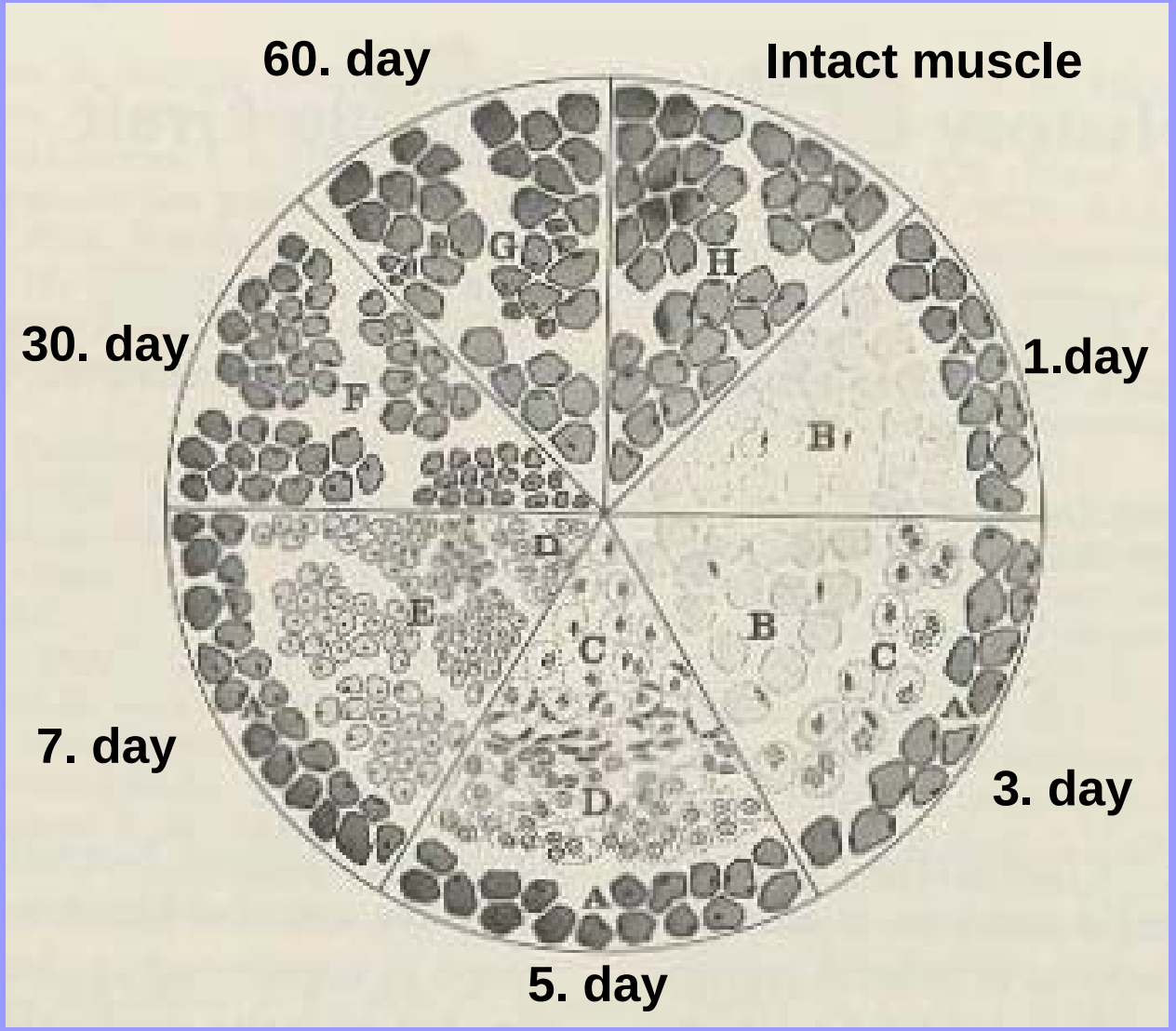








Fate of the free muscle graft in the rat



General Anatomy of Skeletal Muscle

General features of striated muscle, its auxiliary structures, motor end plate, motor unit, muscle spindle, Golgi tendon organ
Attachments of skeletal muscles – origin, insertion
Muscle fibres, myofibrils, sarcomeres
Naming of muscles
Shape and fibre architecture, pennation
The endomysial and perimysial sheaths
The interface between muscle and connective tissue
Myofibrilar proteins
Sliding filament mechanism of contraction
Tendons, Aponeuroses
Synovial sheaths and bursae
Fascia, intermuscular septa, osteofibrous spaces

General anatomy of peripheral nerves
PNS – peripheral nervous system
Cranial nerves
Spinal nerves
Autonomic nervous system
sympathetic and parasympathetis part

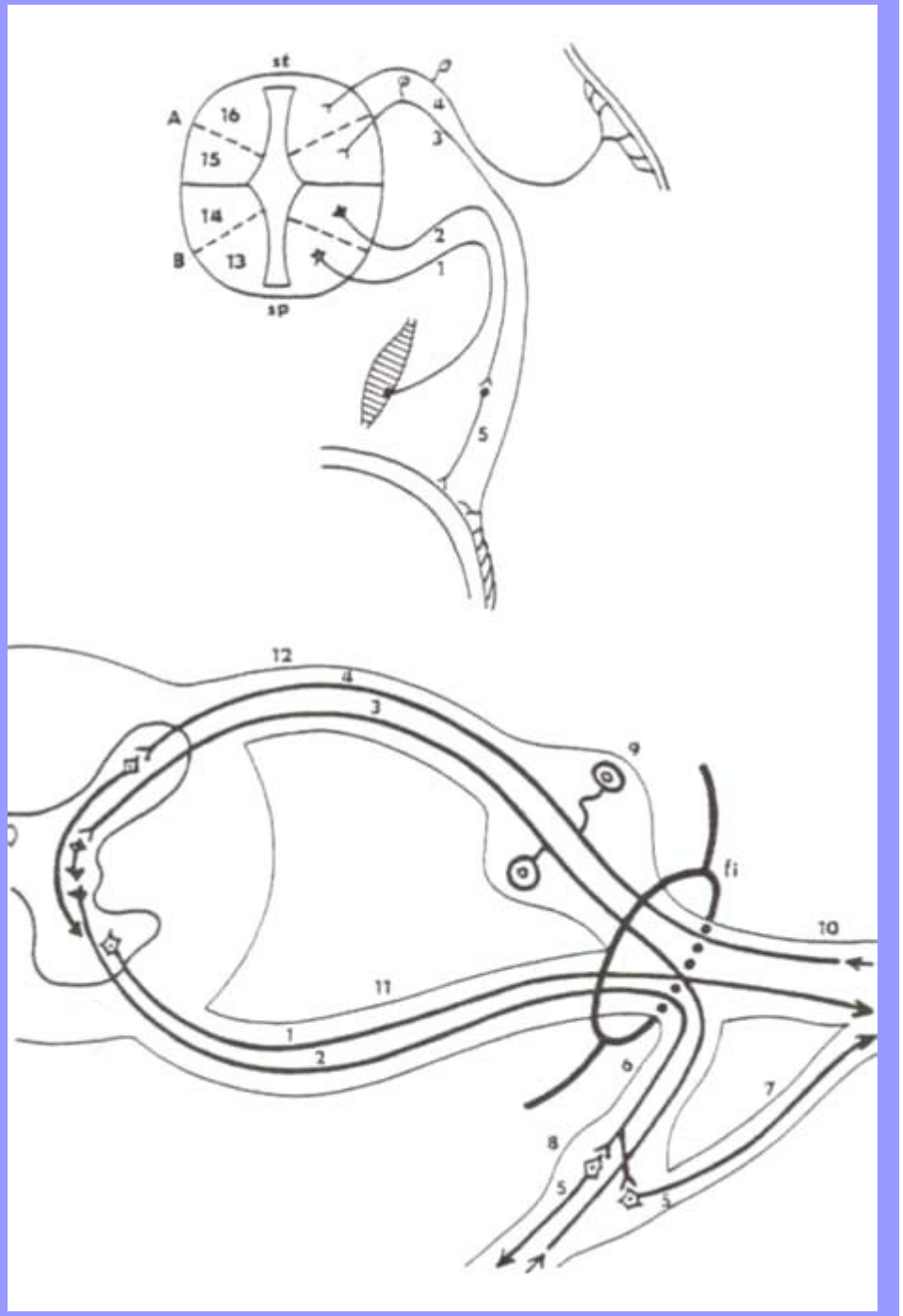
neurons, neuroglia (Schwann cells)
nerve fibres,
endoneurium, perineurium, epineurium,
synapse, ganglion,

Scheme of the spinal nerve

rootlets,
anterior root,
motor root, efferent nerve,
motor nerve,

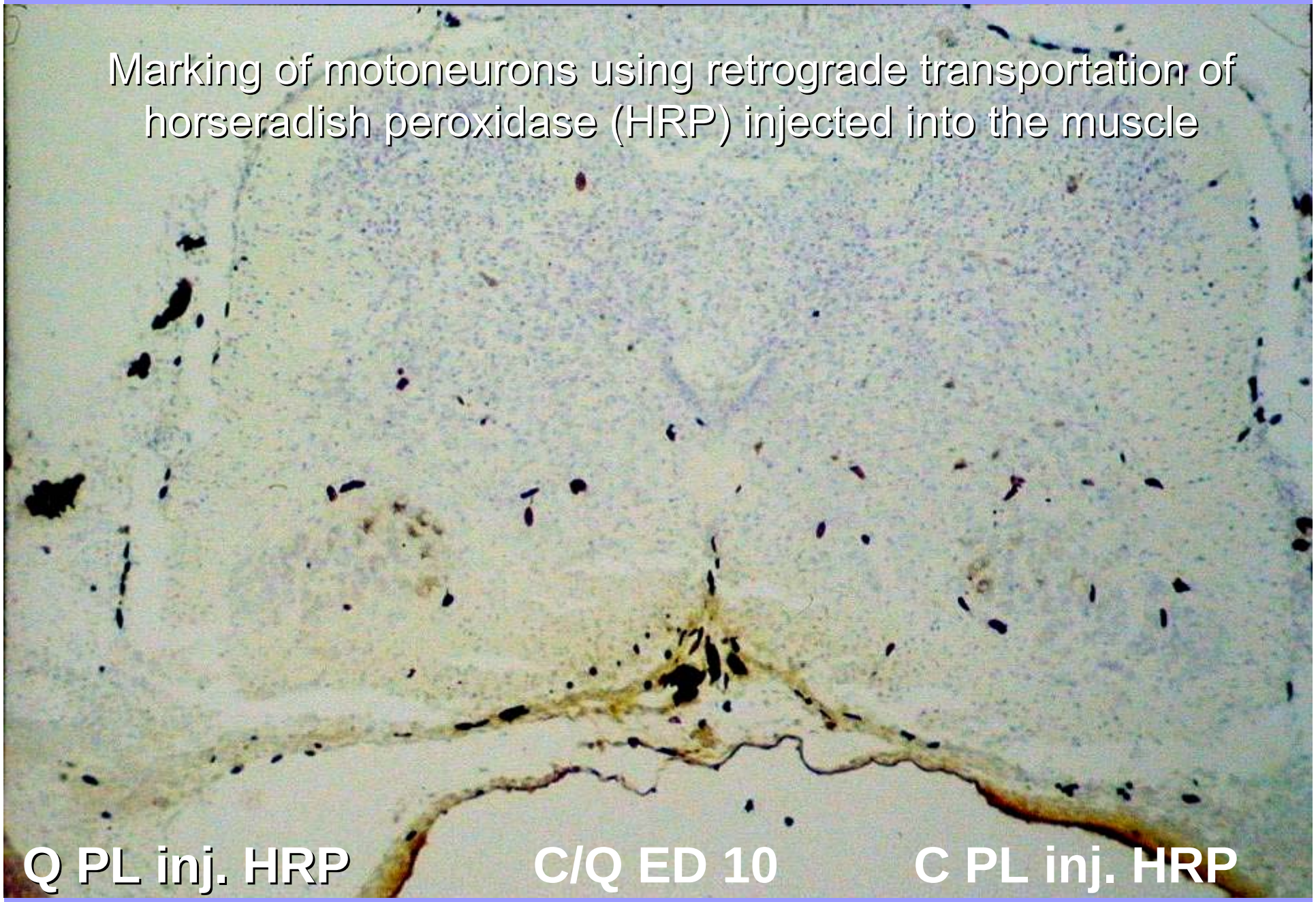
posterior root, sensory root,
afferent nerve, sensory
nerve, dorsal root ganglion,

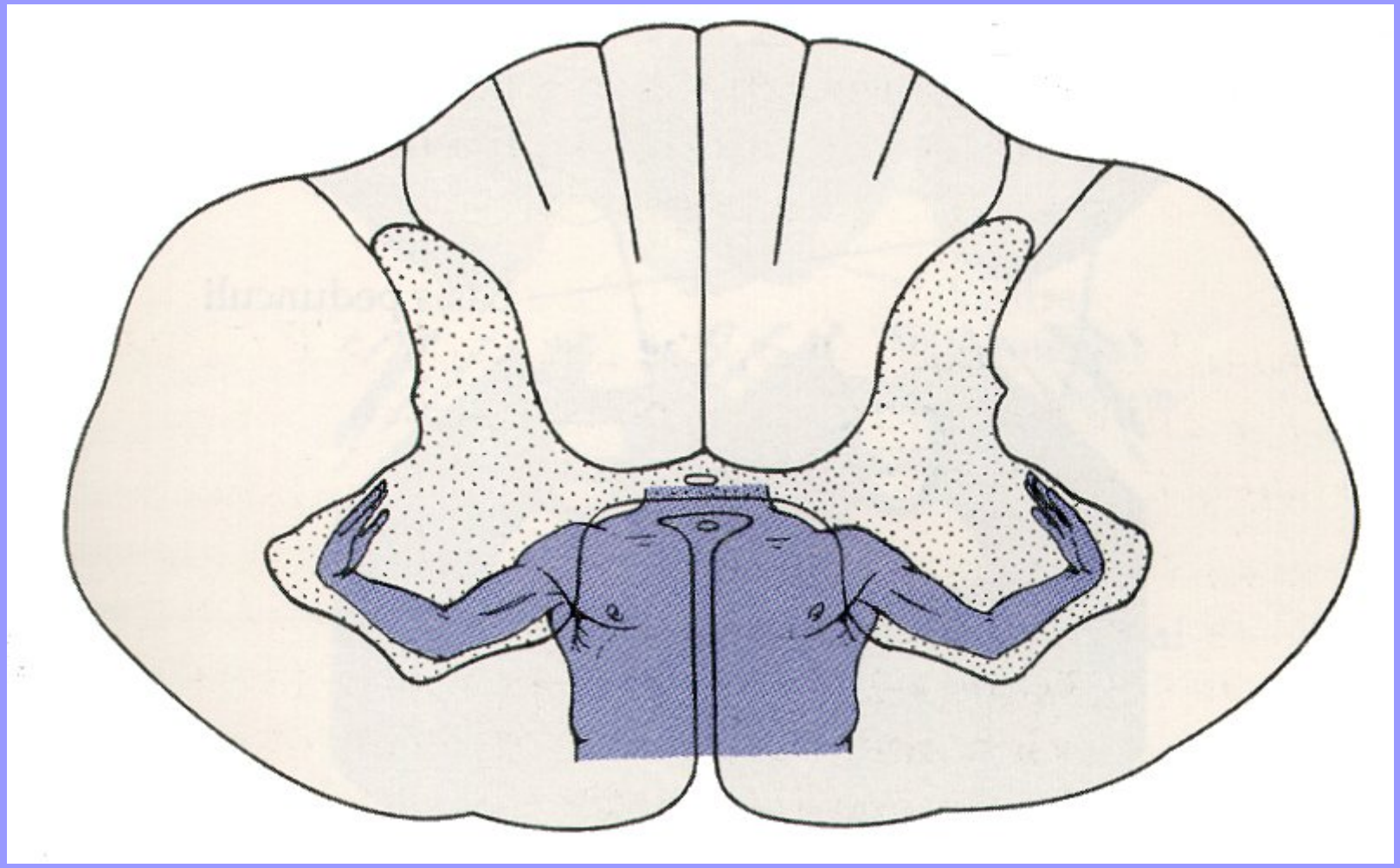
spinal nerve
trunk of spinal nerve,
mixed nerve,
r. anterior, r. posterior of



Spinal nerve
trunk of spinal nerve,
rootlets,
anterior root,
motor root,
posterior root,
sensory root,
spinal ganglion,
mixed nerve,

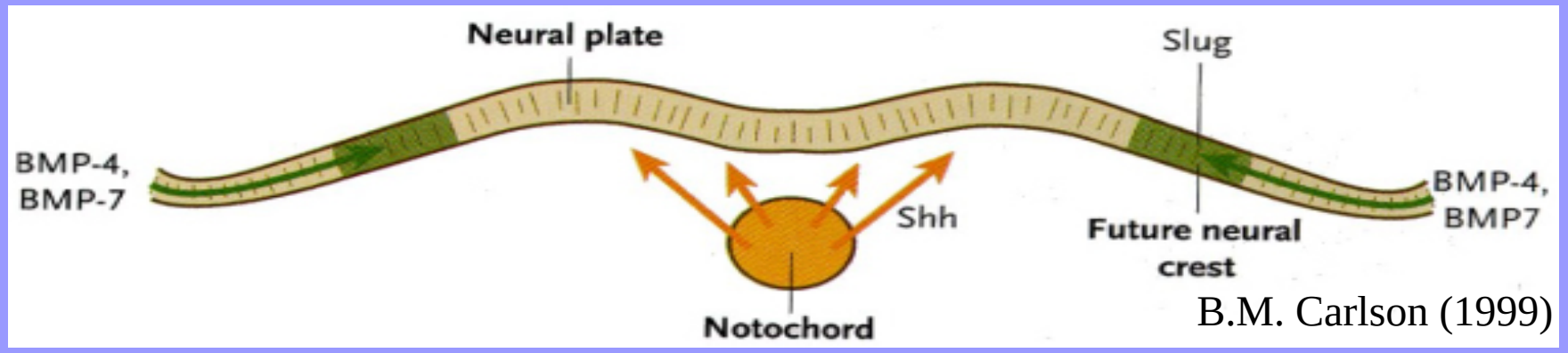
Marking of motoneurons using retrograde transportation of horseradish peroxidase (HRP) injected into the muscle



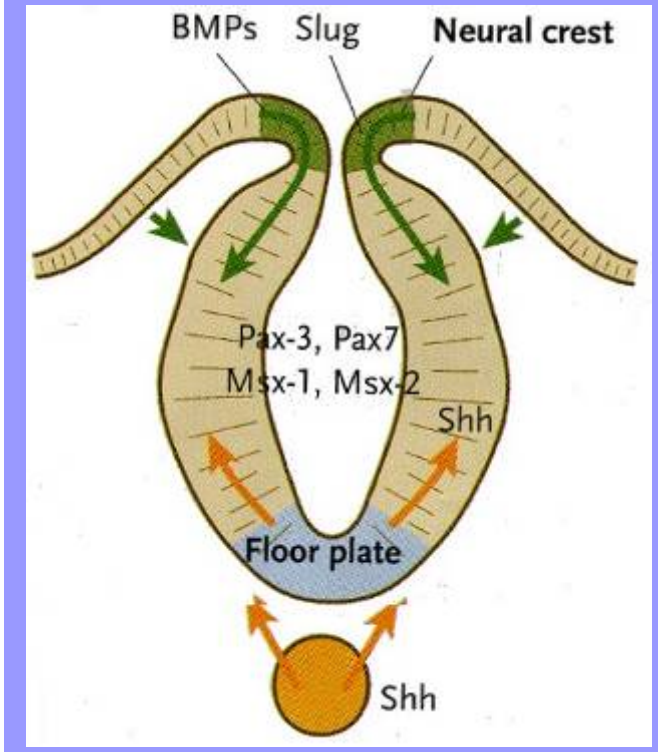


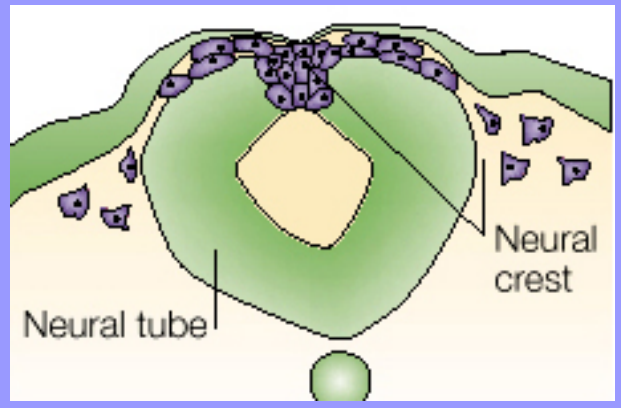
Localization of motoneurons for individual muscle groups on transverse section of cervical spinal cord

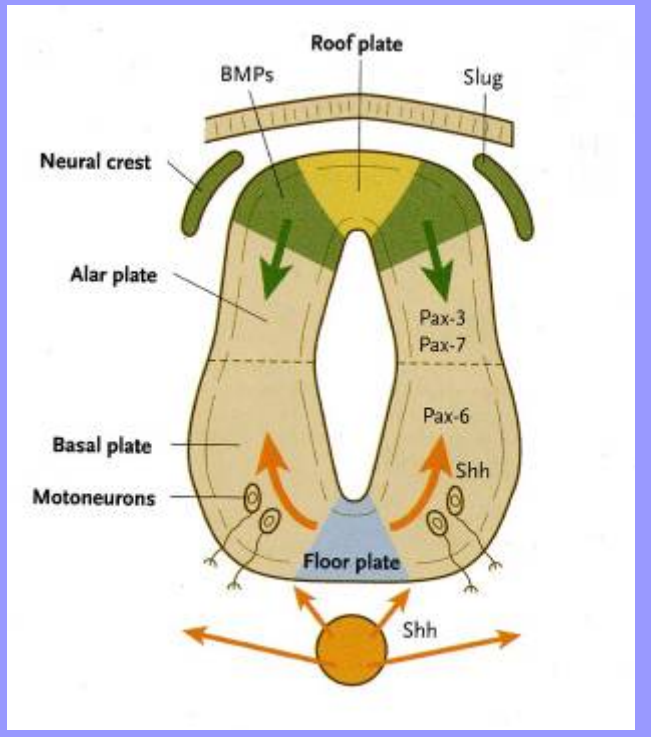
Development of nervous system - neurulation



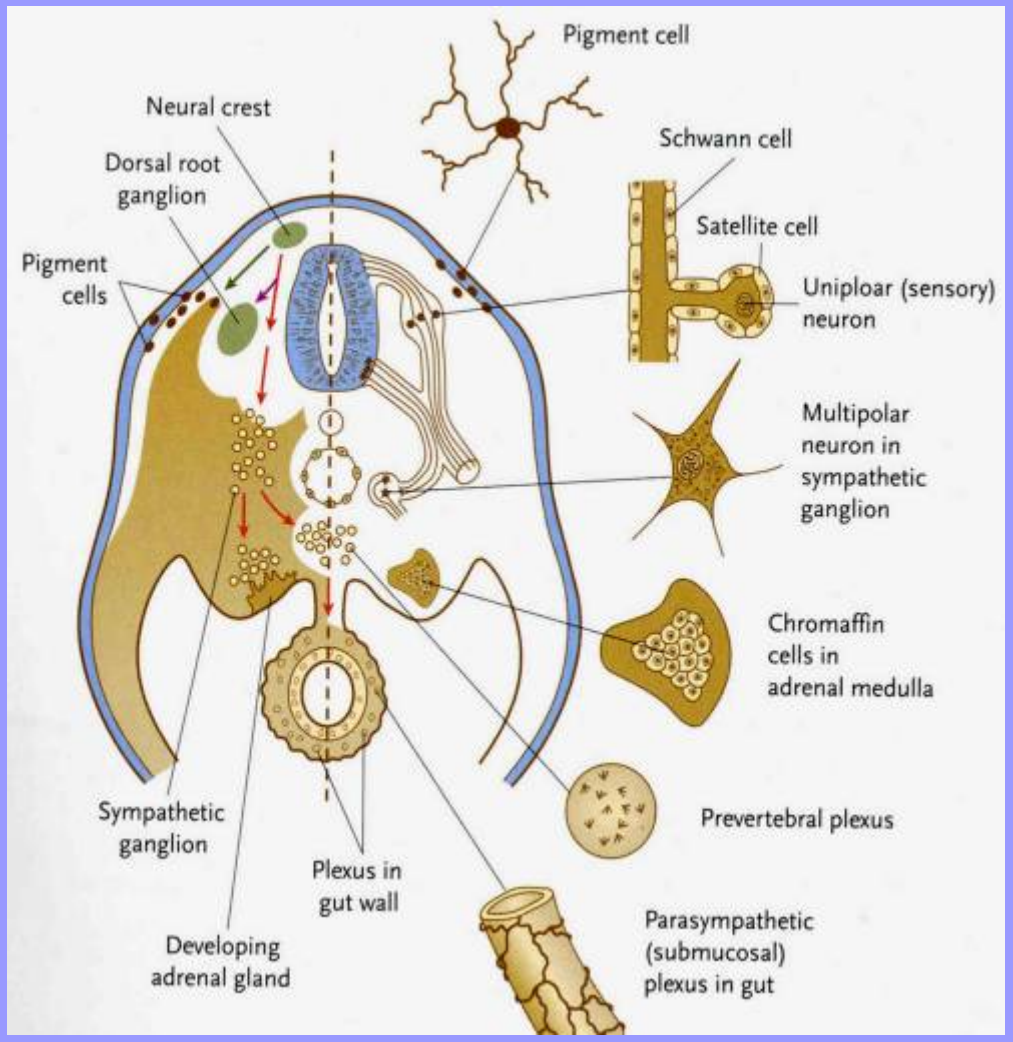
B.M. Carlson (1999)





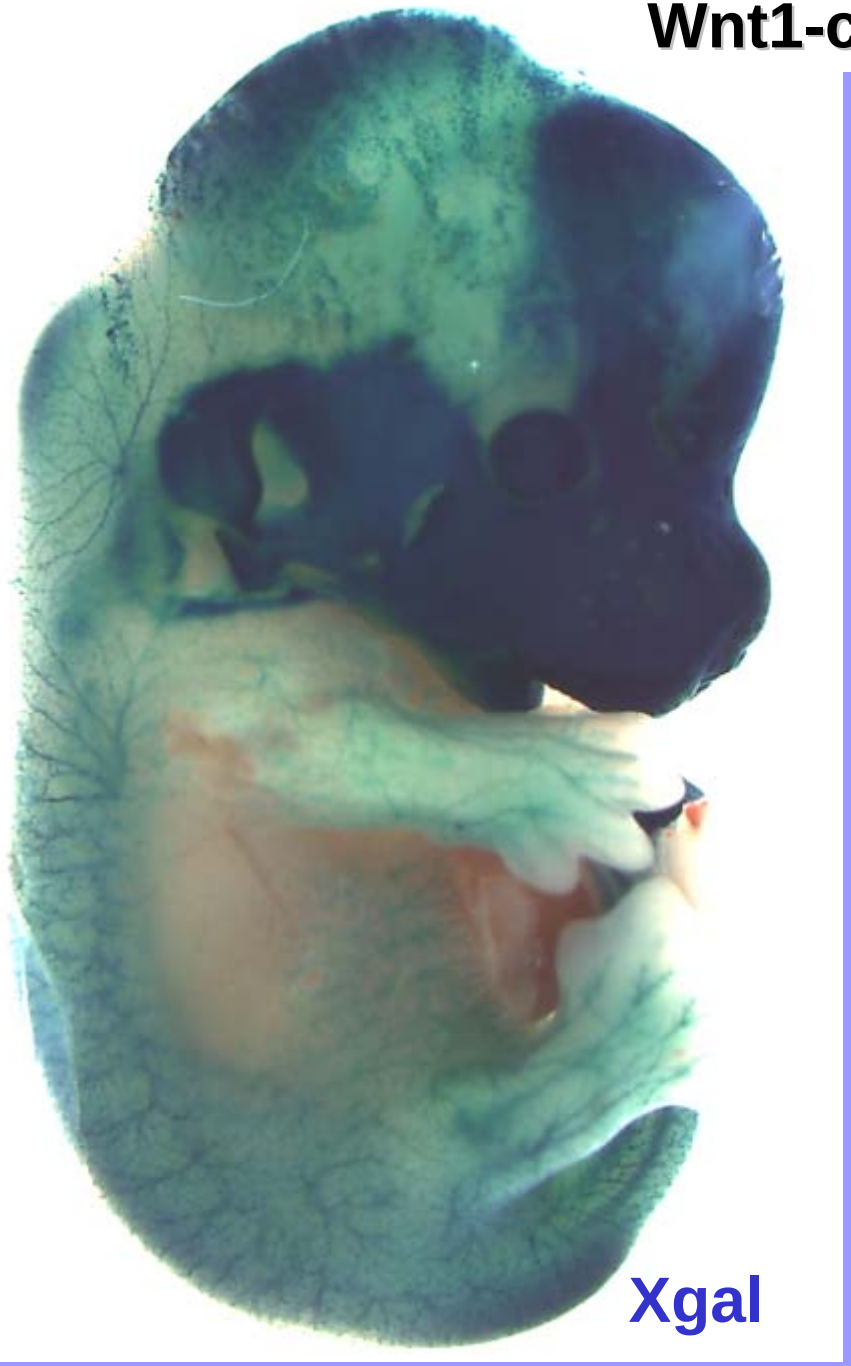


Derivatives of neural crest cells

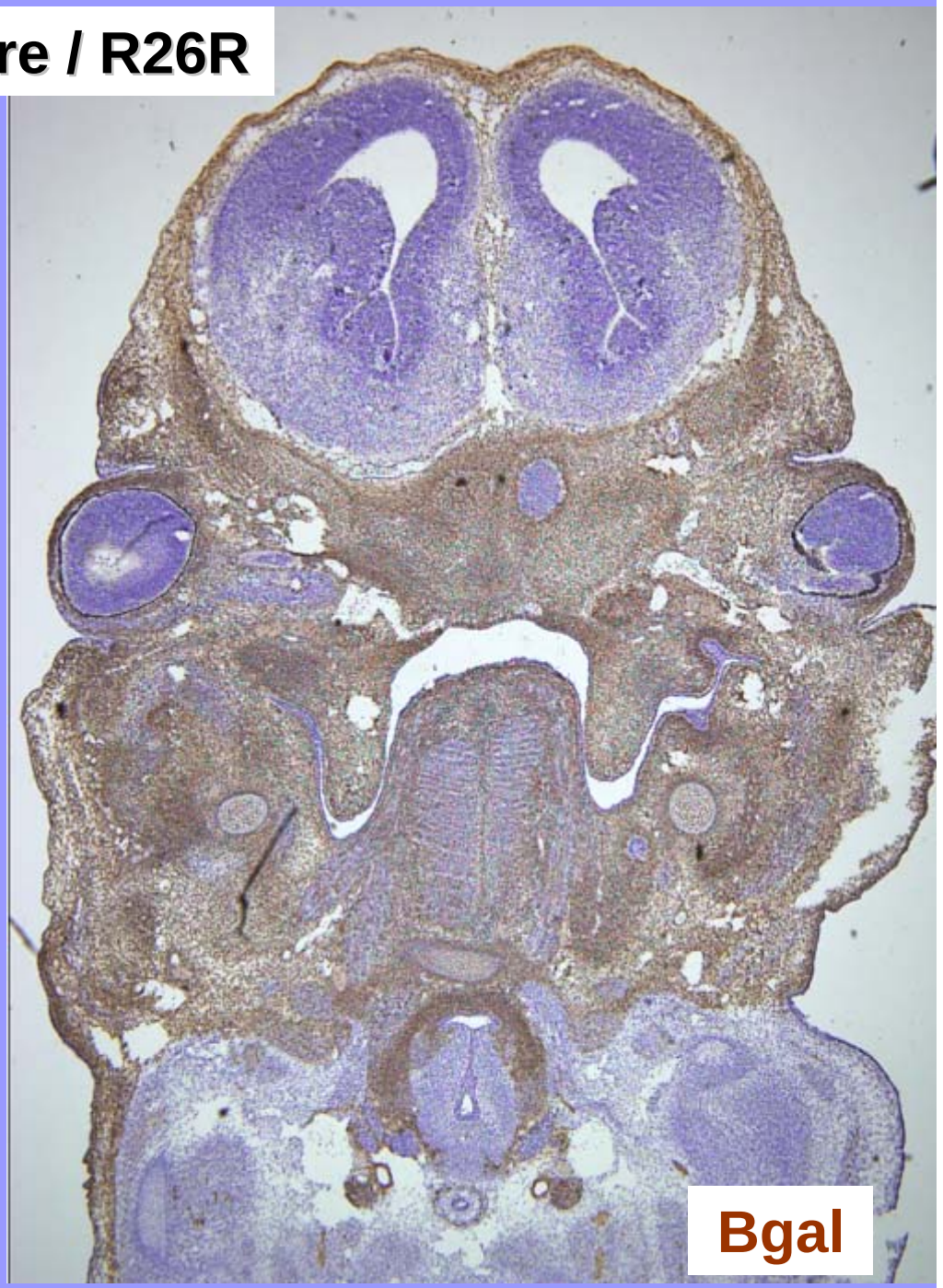


Neurons of spinal ganglia, of autonomic ganglia, enteric neurons, Schwann cells, pigment cells, cells of adrenal medulla

Wnt1-cre / R26R

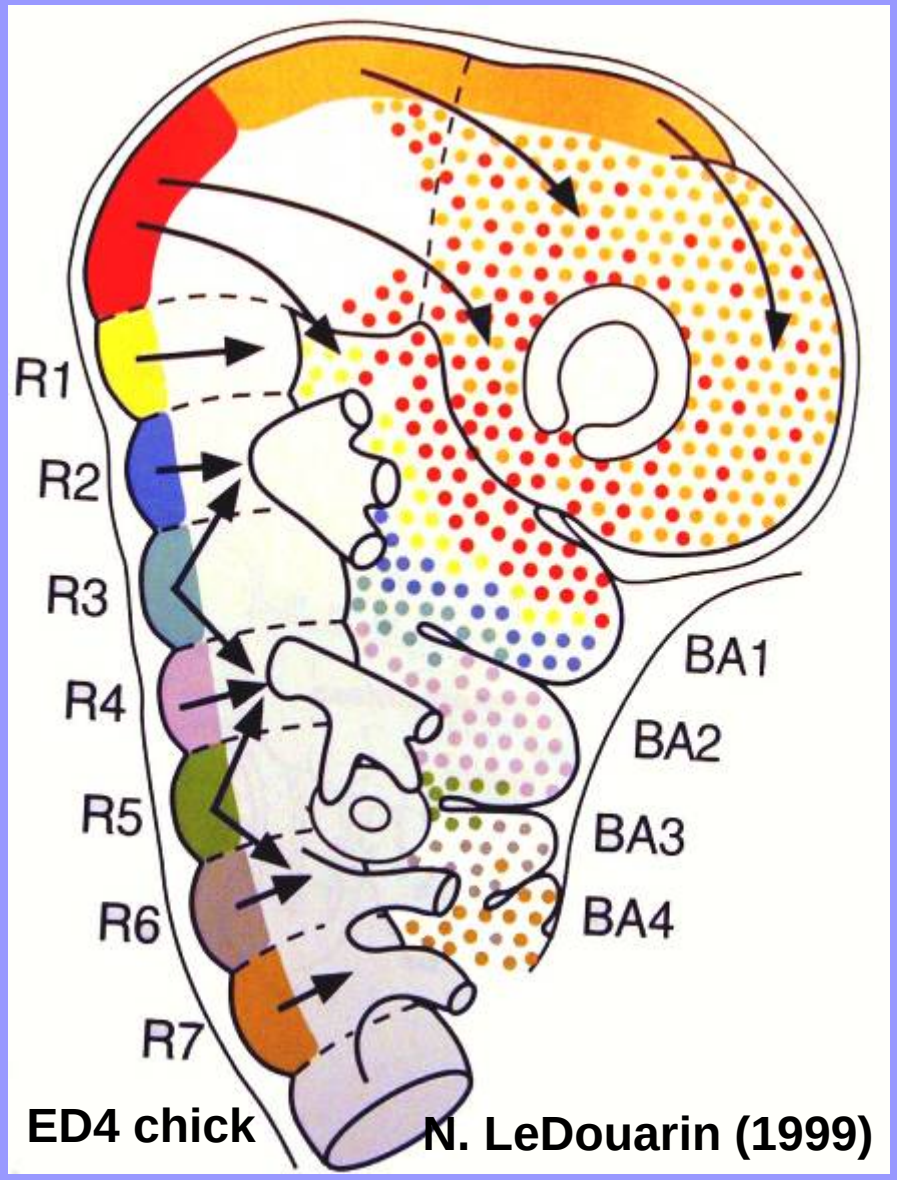


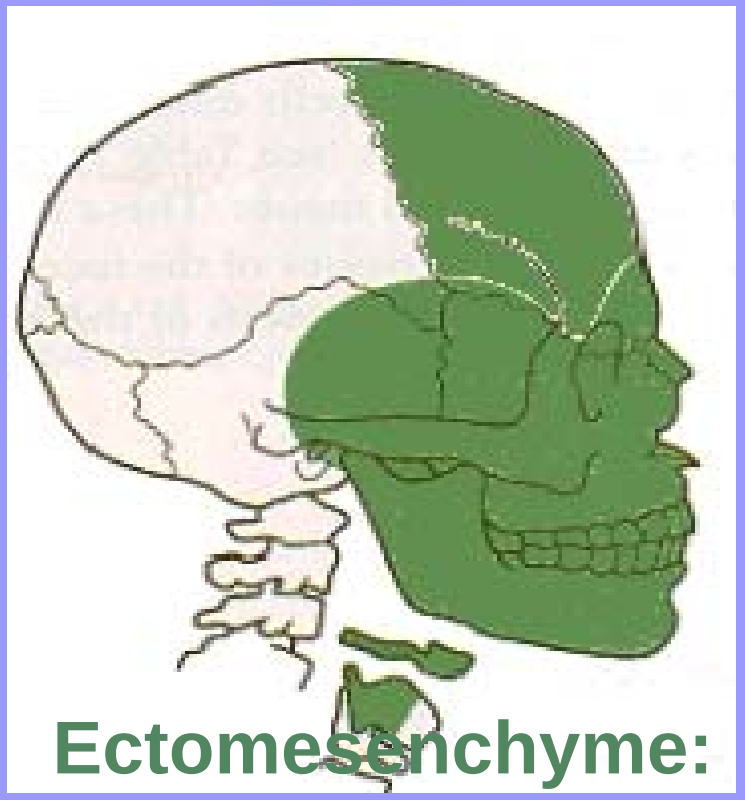
Xgal



Bgal

Migration of NC cells of the head

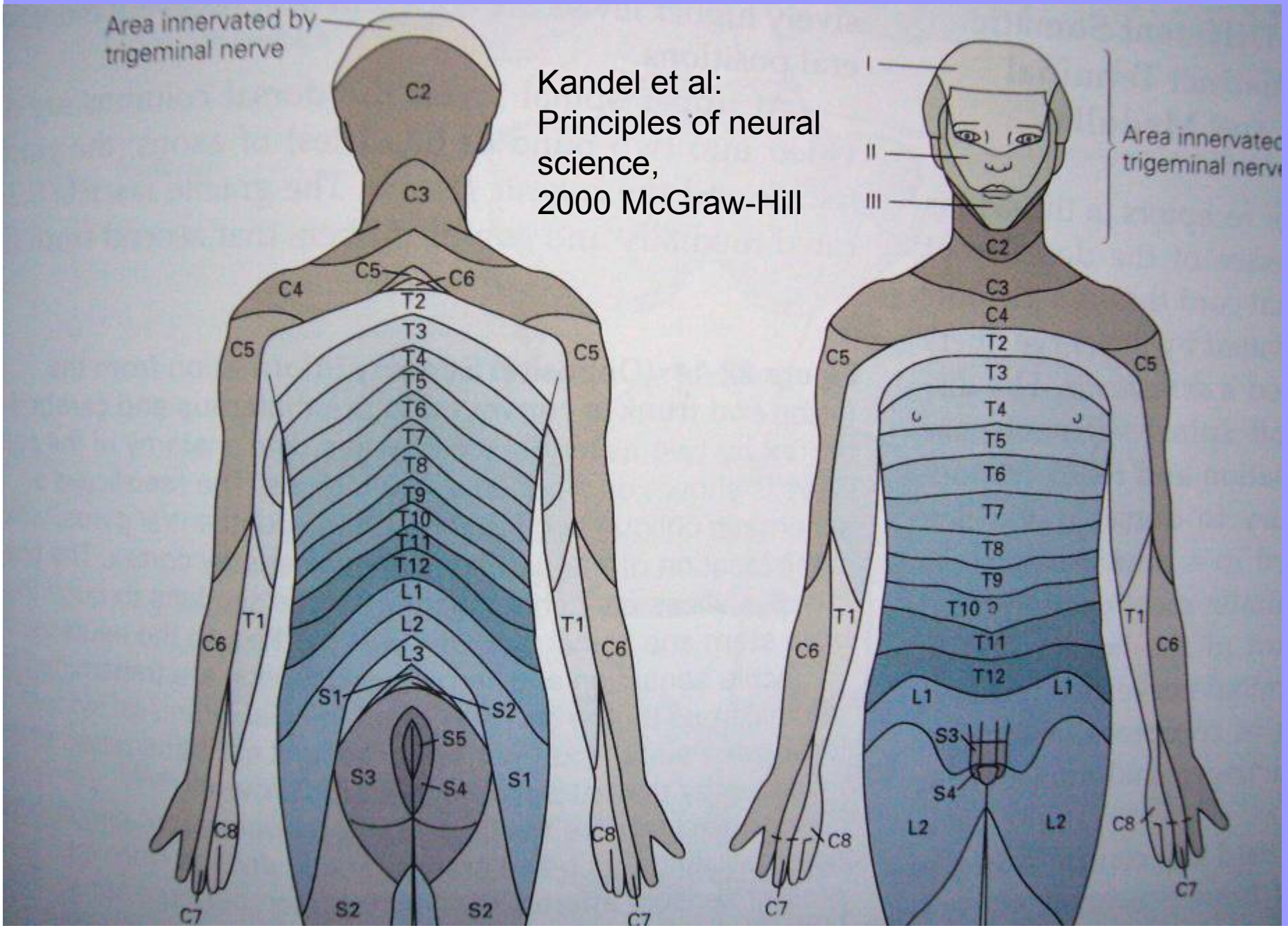




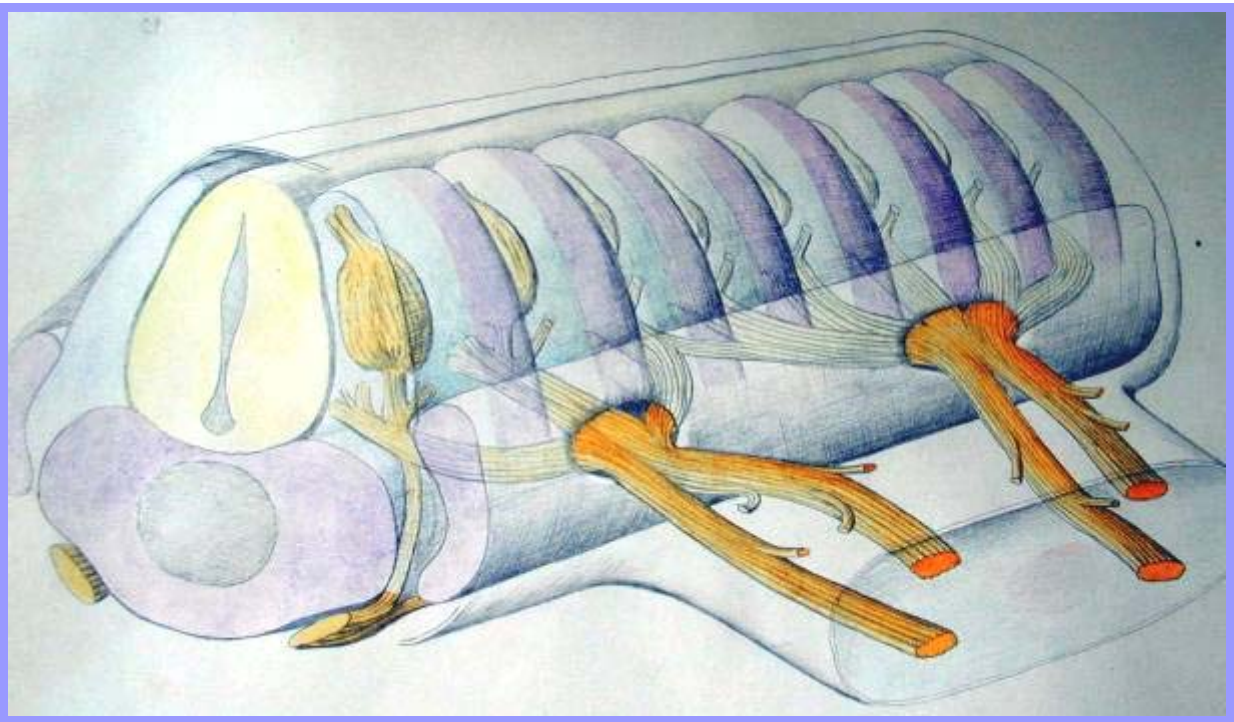
Ectomesenchyme:

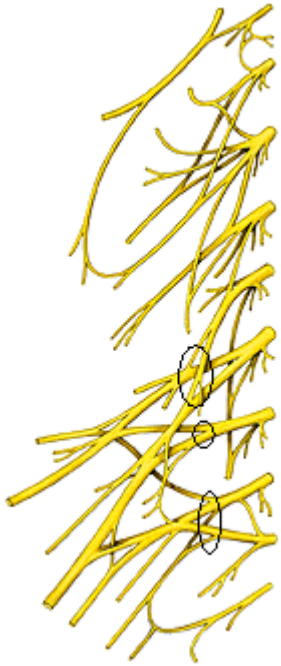
osteoblasts, fibroblasts, chondroblasts, smooth muscle cells, odontoblasts
Cardiac NC (R4-R8):
for cardiac outflow tract

Segmental innervation - areae radiculares (dermatomes)

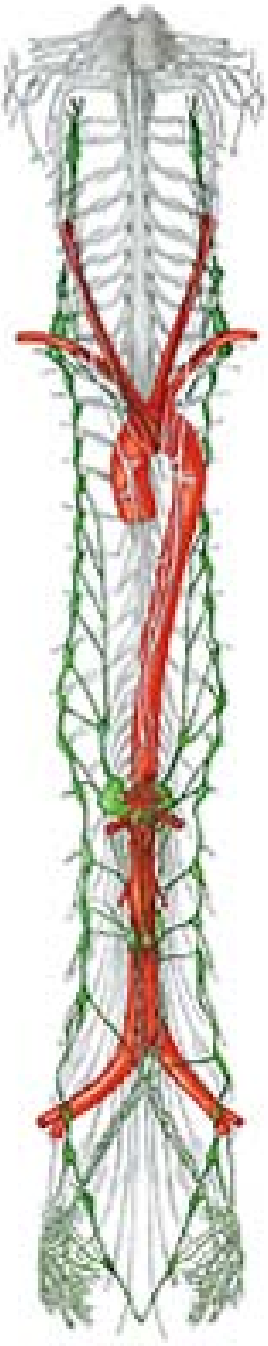


Kandel et al:
Principles of neural science,
2000 McGraw-Hill

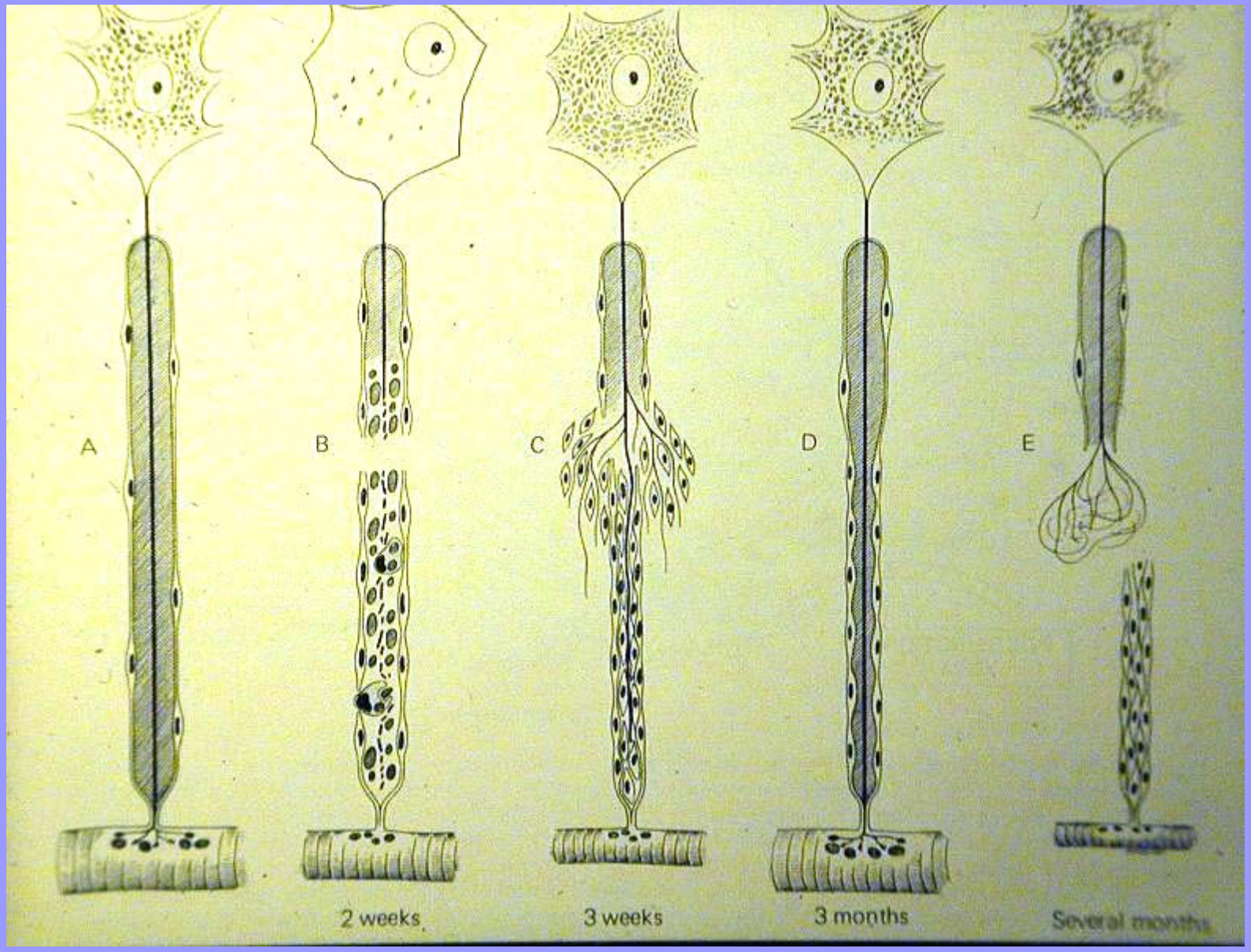




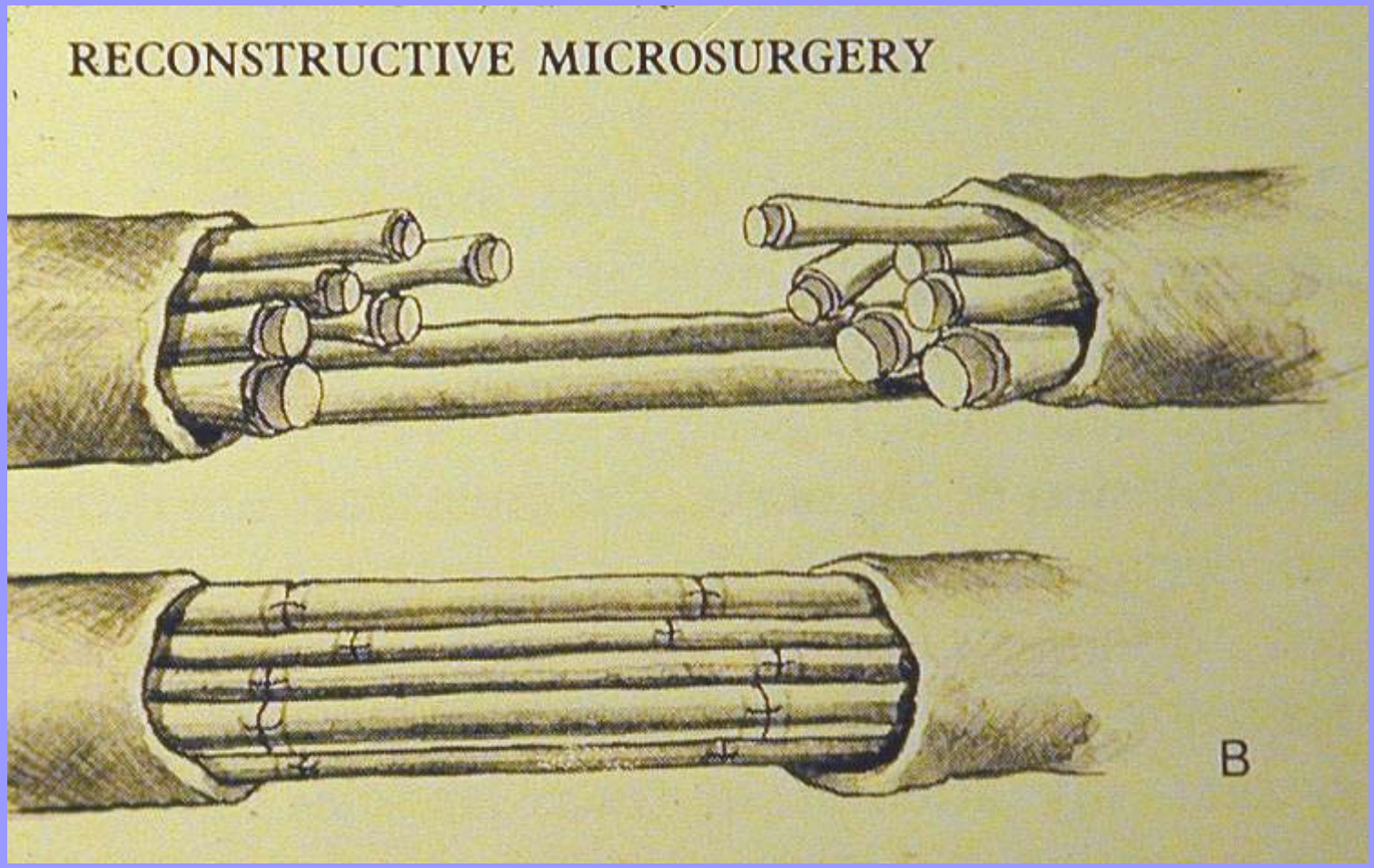
spinal nerve plexuses,
autonomic plexuses,
perivascular plexuses



Regeneration of interrupted nerve fibre



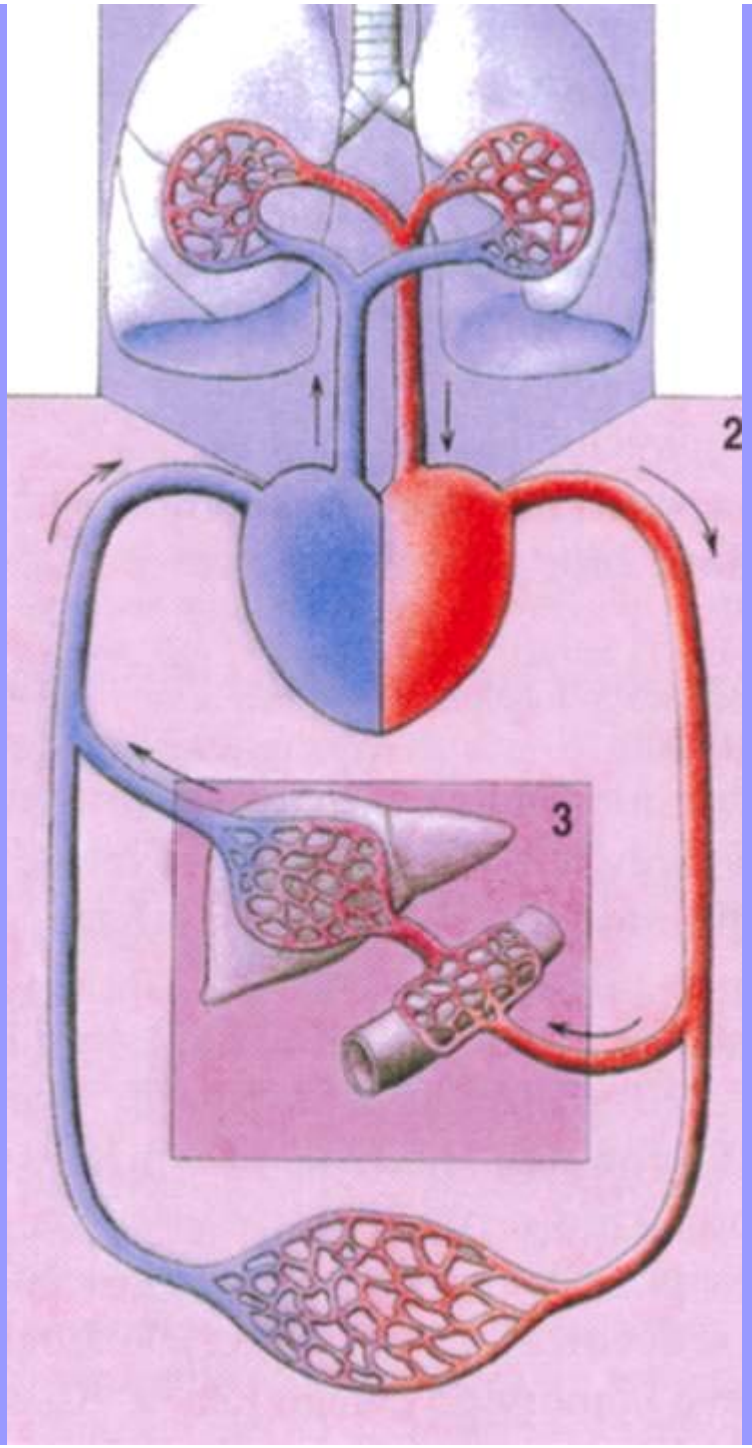
peripheral nerve, endoneurium, perineurium, epineurium

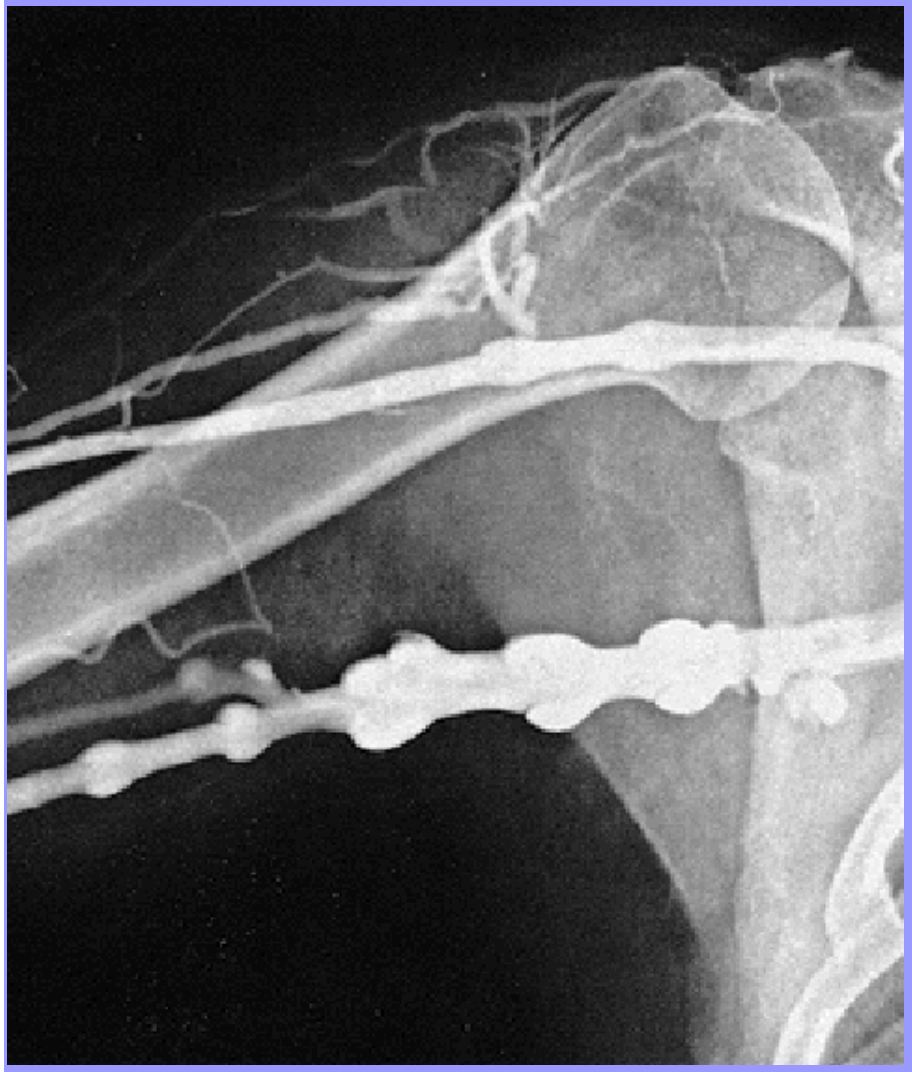


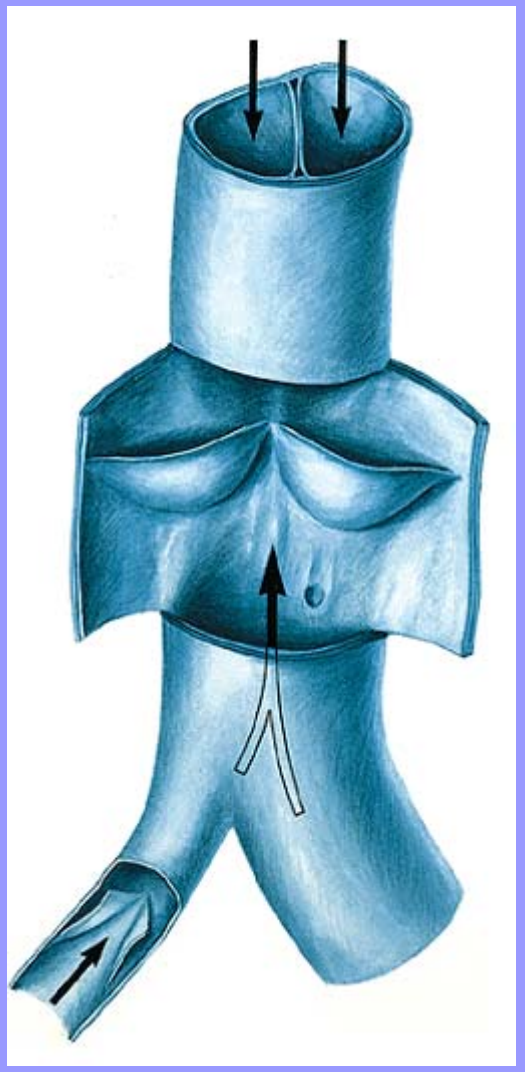
Nerve graft bridging the partial defect, suture of perineurium

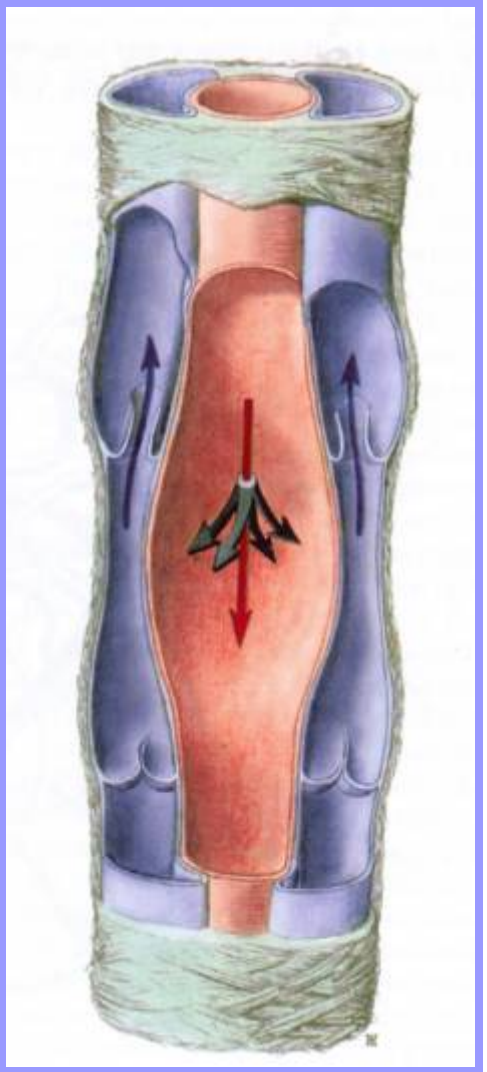
Terms of general angiology

blood vessels,
arteries,
veins,
capillaries,
arteriovenous anastomosis,
collateral vessels,
venous plexuses,
hepatic portal vein,

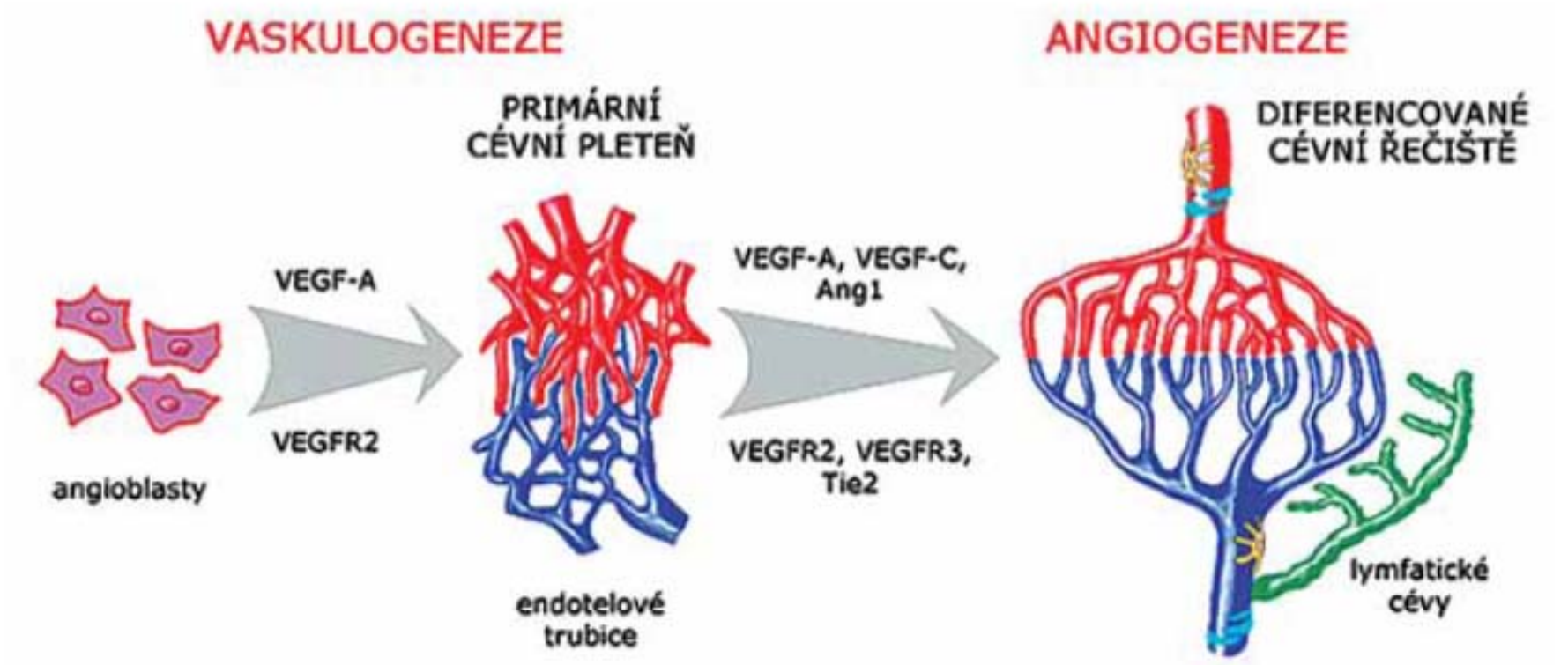






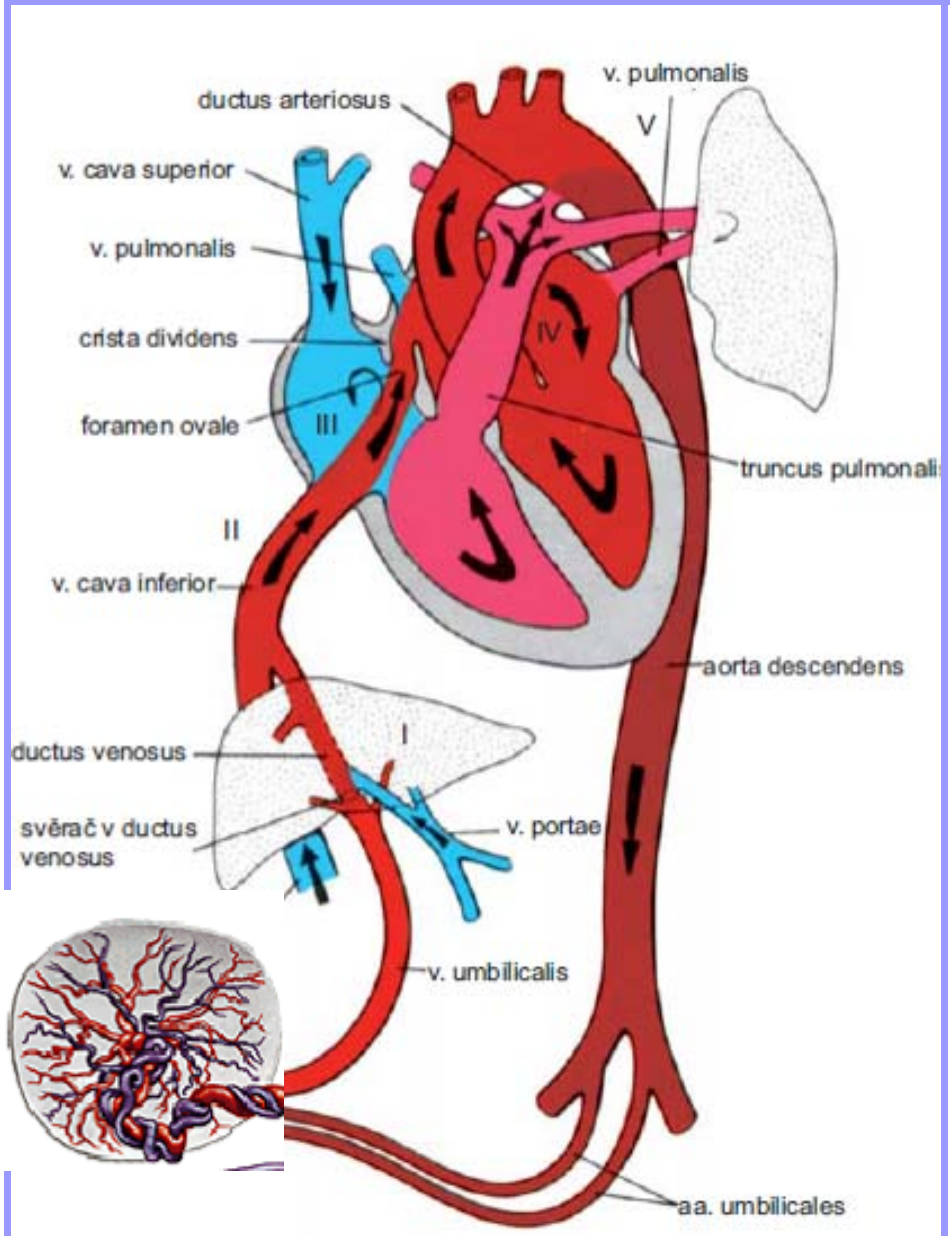


Venous valves

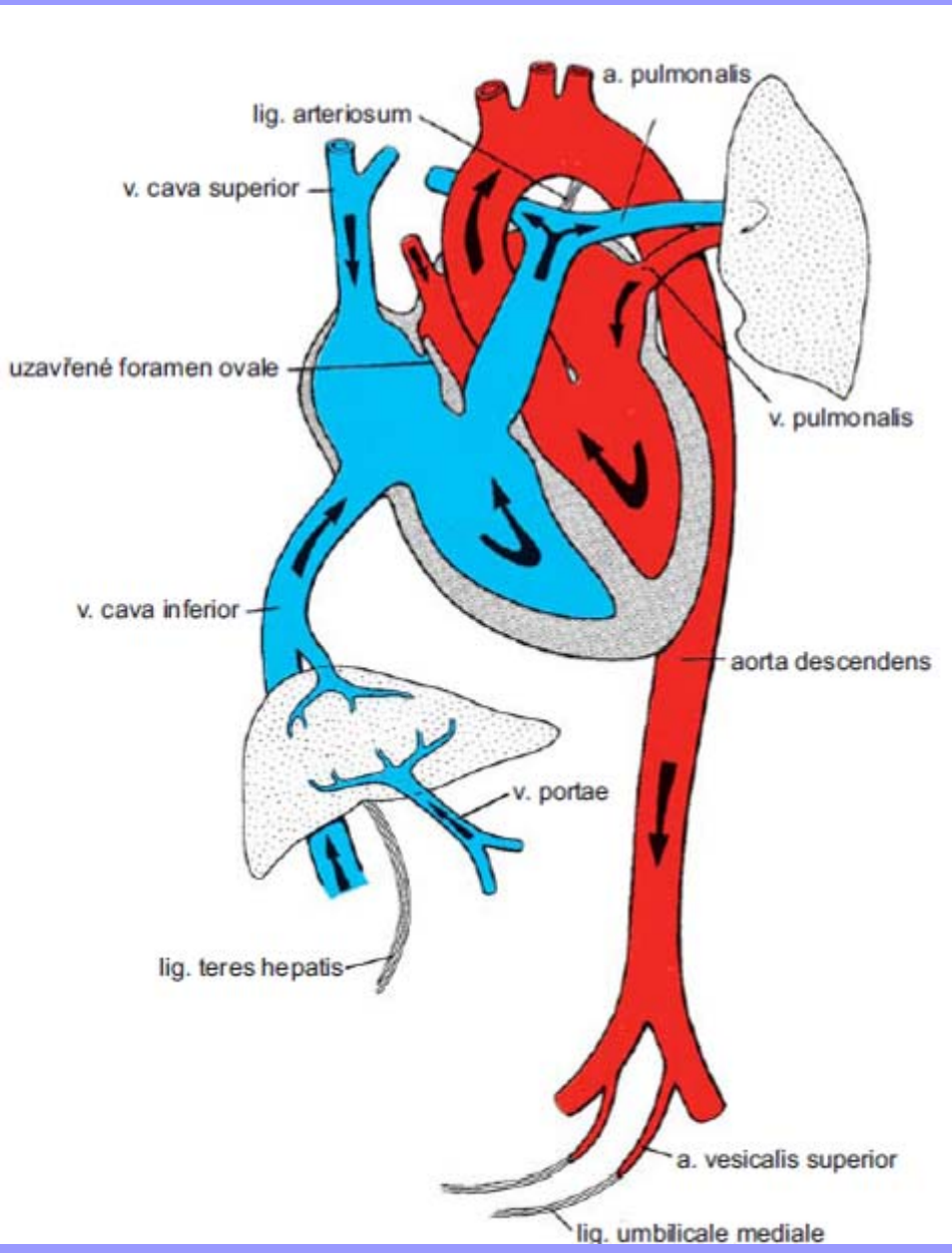


Obr. 1. Schéma vývoje krevních a lymfatických cév
Primární cévní pleteně vznikají procesem vaskulogeneze z angioblastů pod vlivem růstového faktoru VEGF. Termínem angiogeneze je označován vznik diferencovaného řečiště remodelací a růstem primárních pletení. Ve stěně větších cév se objevují pericyty a hladké svalové buňky. Lymfatické cévy vznikají většinou pučením z venózního endotelu. Zkratky jsou vysvětleny v textu článku.

Fetal circulation before birth



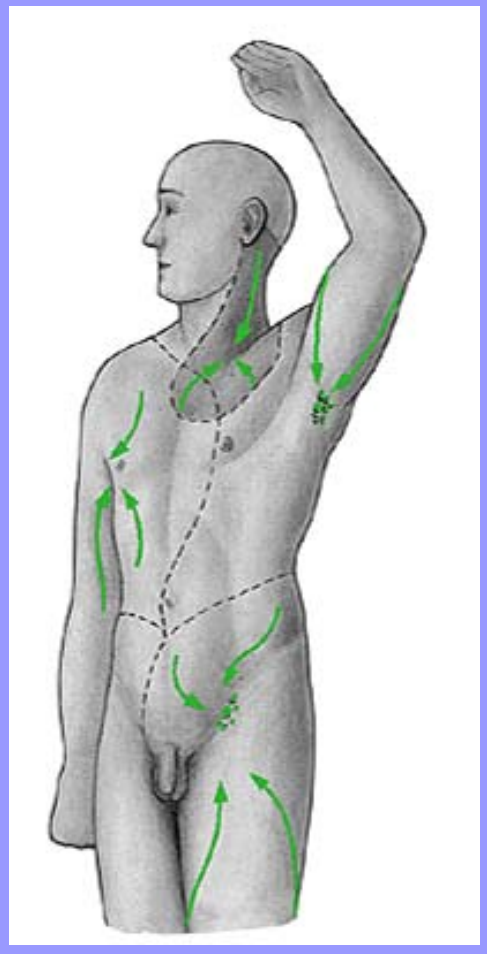
Circulation after birth

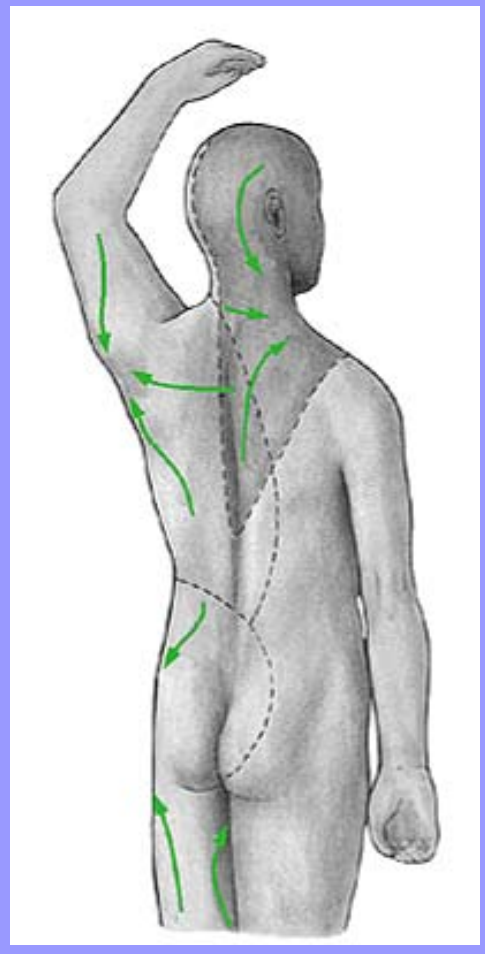


7. Terms of general anatomy of lymphatic system

lymphatic vessels, lymph, lymphatic trunks and ducts, lymph nodes

Lymph node, lymph tissue in the organs, main lymphatic trunks





Literature:

Platzer: Color Atlas and Textbook of Human Anatomy – Vol.1 Locomotor System, Thieme 2003
Kahle, Frotscher: Color Atlas and Textbook of Human Anatomy – Vol. 3 Nervous System and Sensory Organs, Thieme 2000
Netter: Atlas of Human Anatomy, Icon 2003
Sobotta: Atlas of Human Anatomy Vol.1+2, Williams and Wilkins 2000
Moore, Perssaud: The developing human
Carlson: Human embryology and developmental biology
Different original publications in scientific journals
Author´s own figs. and illustrations

Sources of used illustrations:

Gray´s Anatomy,

Sobotta: Atlas der Anatomie des Menschen

Grim, Druga: Základy anatomie, 5. díl

Benninghoff, Drenckhahn: Anatomie I., II.

Moore, Perssaud: The developing human

Carlson: Human embryology and developmental biology

Čihák: Anatomie 1

Different original publications in scientific journals

Author´s own figs. and illustrations