

Nerve Injury Basics: Anatomy, Degeneration, Regeneration & Management

Rajiv Midha, MD, MSc, FRCS(C)

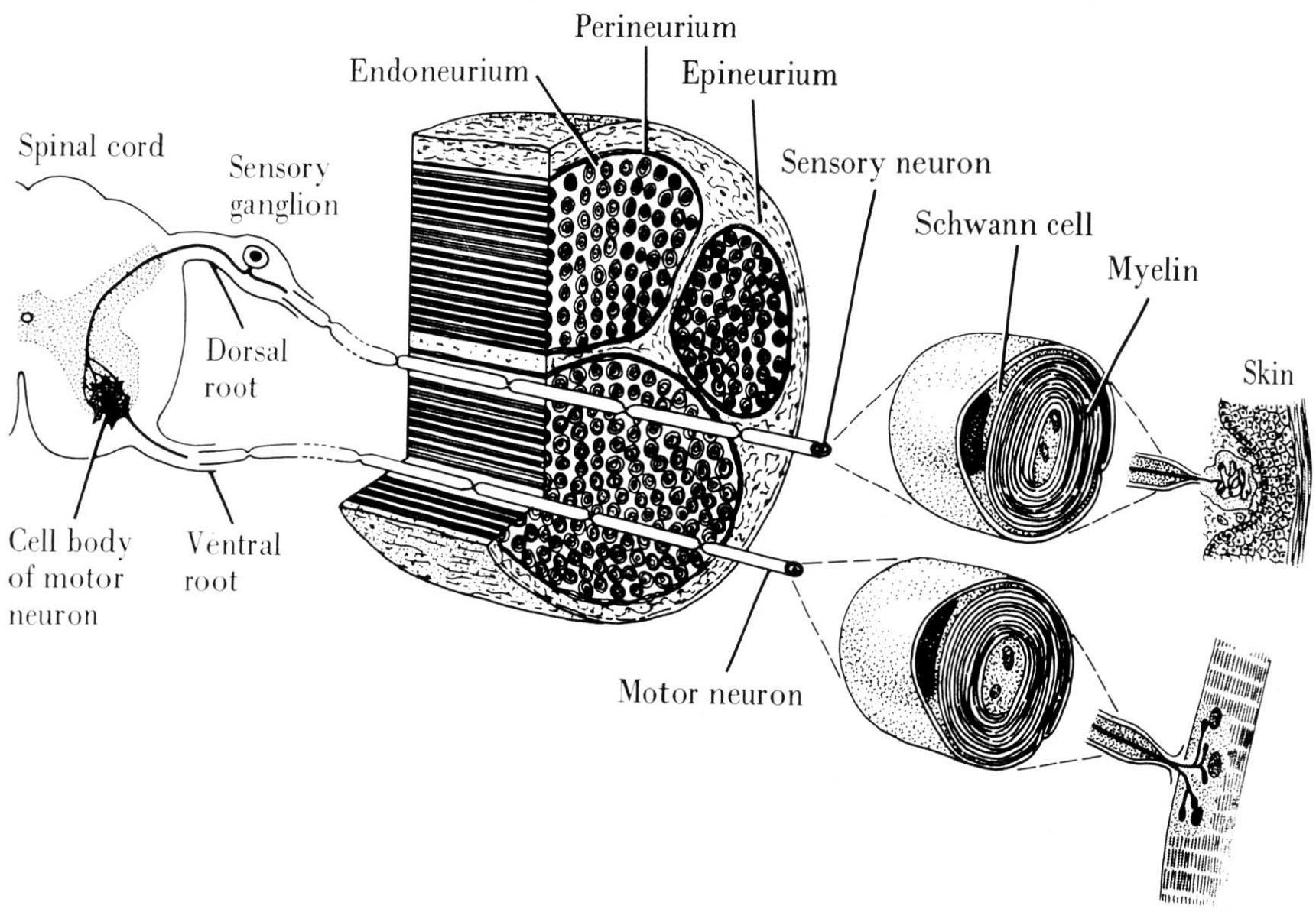
Professor, Division of Neurosurgery, Department of Clinical
Neurosciences, Hotchkiss Brain Institute
University of Calgary



Objectives

Understand:

- ✧ Anatomy and pathology of PNI
- ✧ Management of nerve injuries: selection for and timing of surgery
- ✧ Principles of operation



Spinal cord

Sensory ganglion

Dorsal root

Cell body of motor neuron

Ventral root

Perineurium

Endoneurium

Epineurium

Sensory neuron

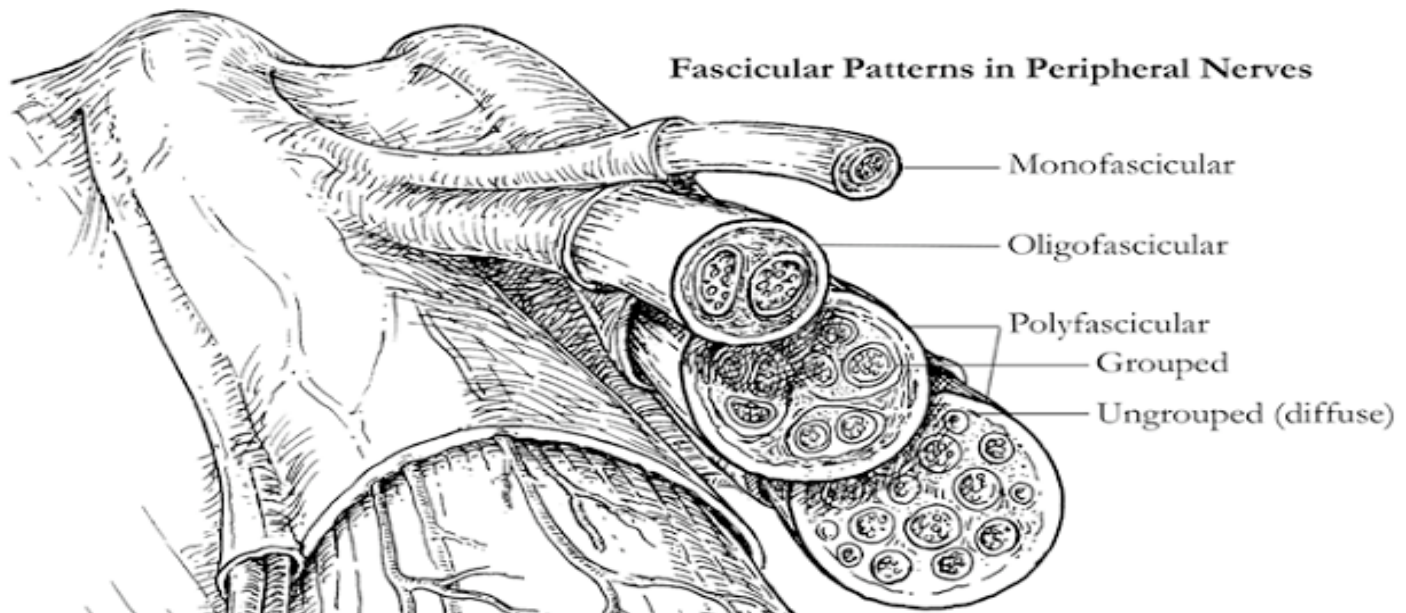
Schwann cell

Myelin

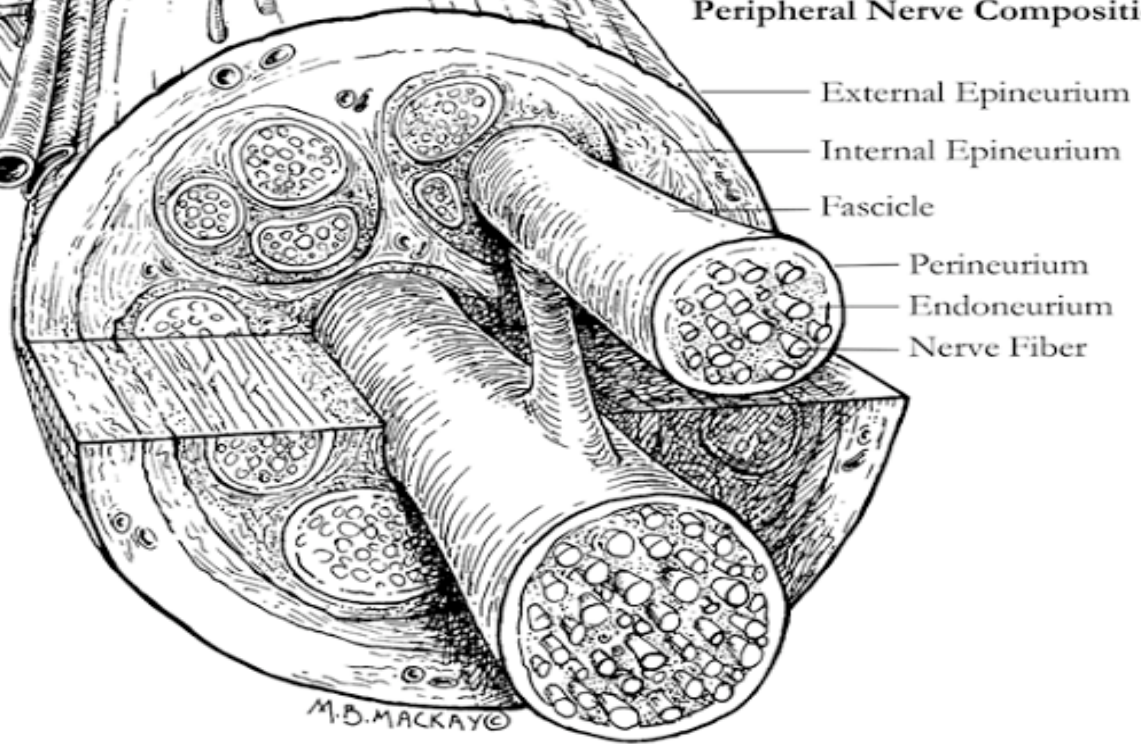
Skin

Motor neuron

Fascicular Patterns in Peripheral Nerves

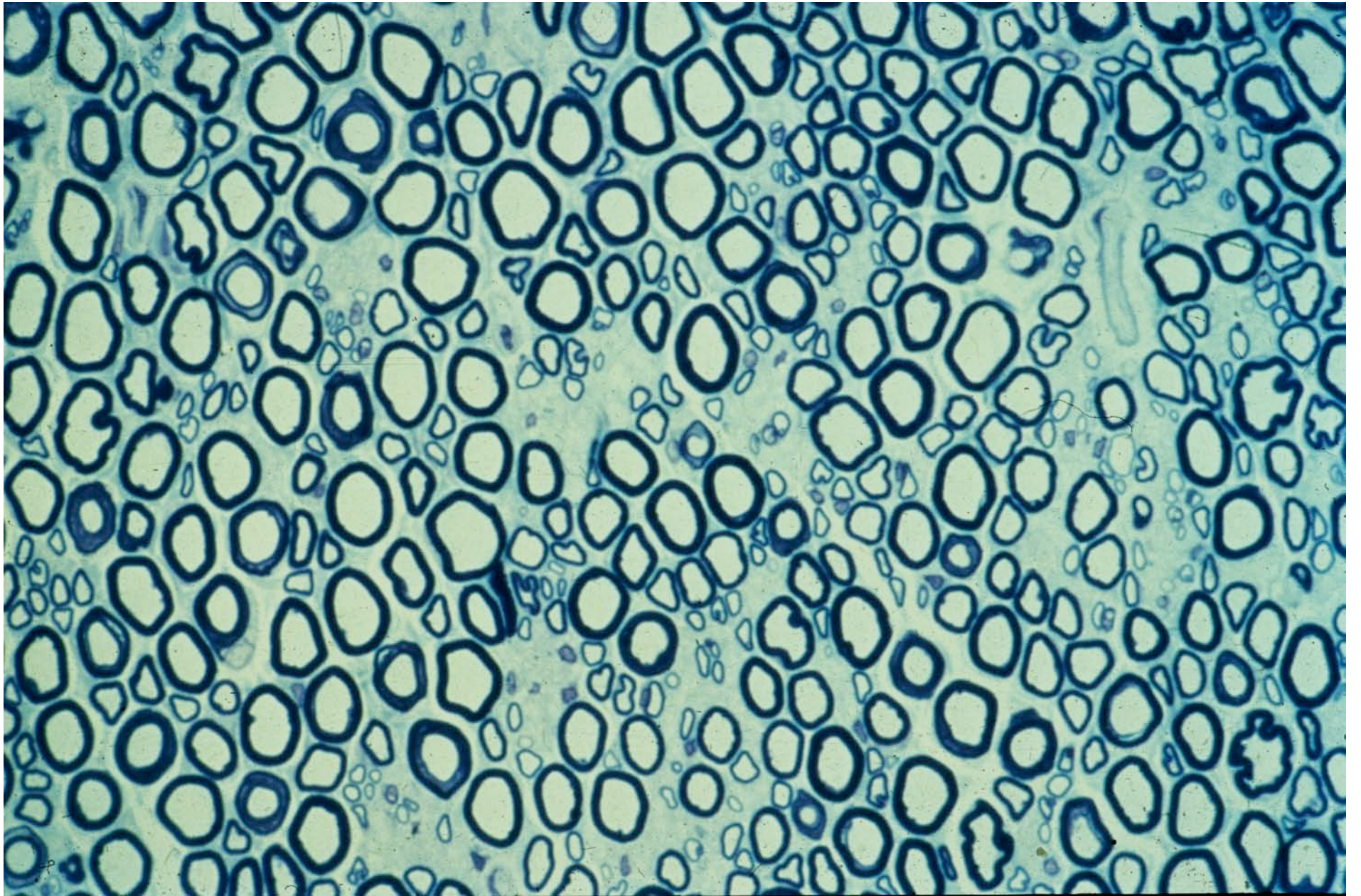


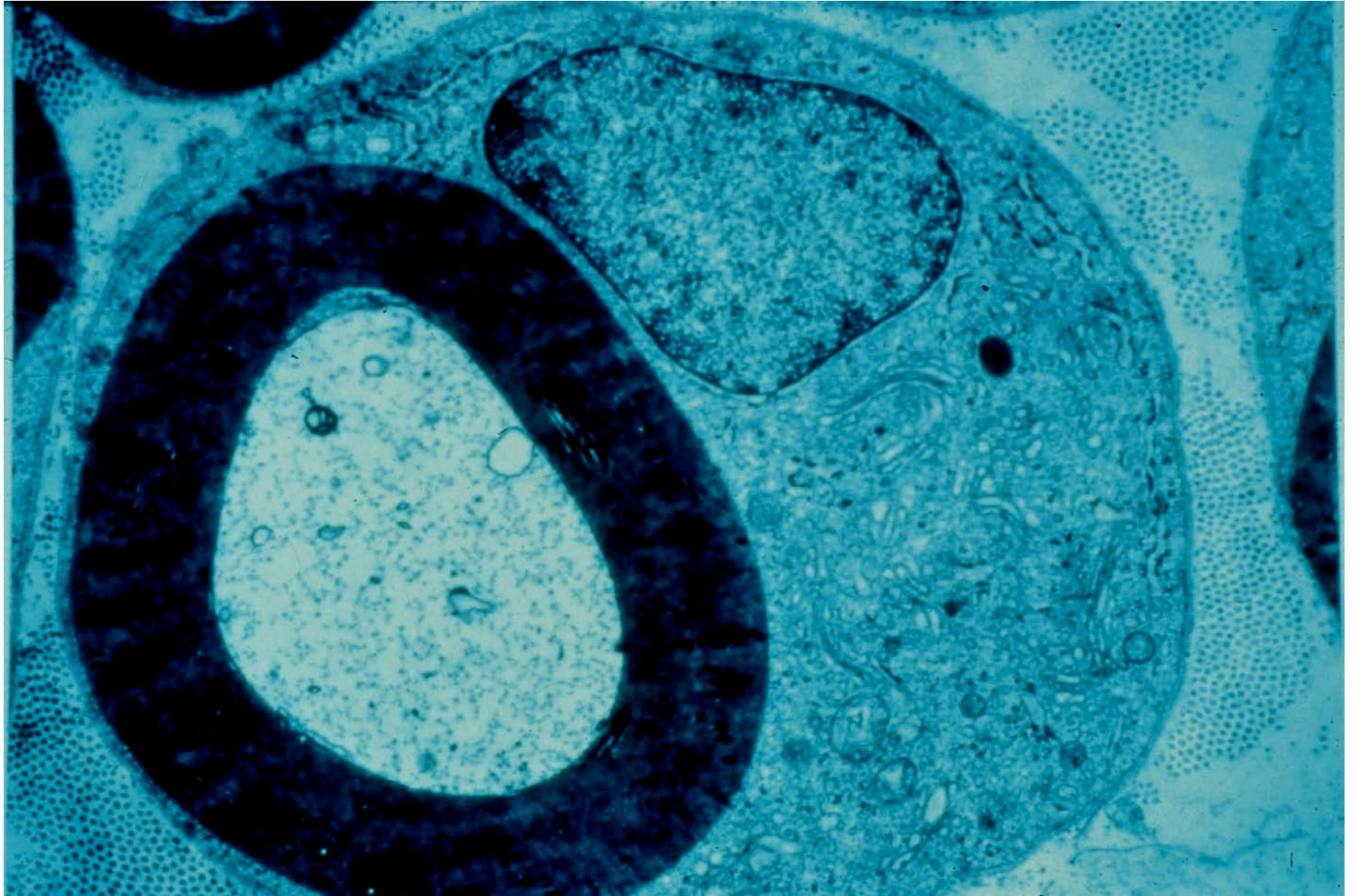
Peripheral Nerve Composition

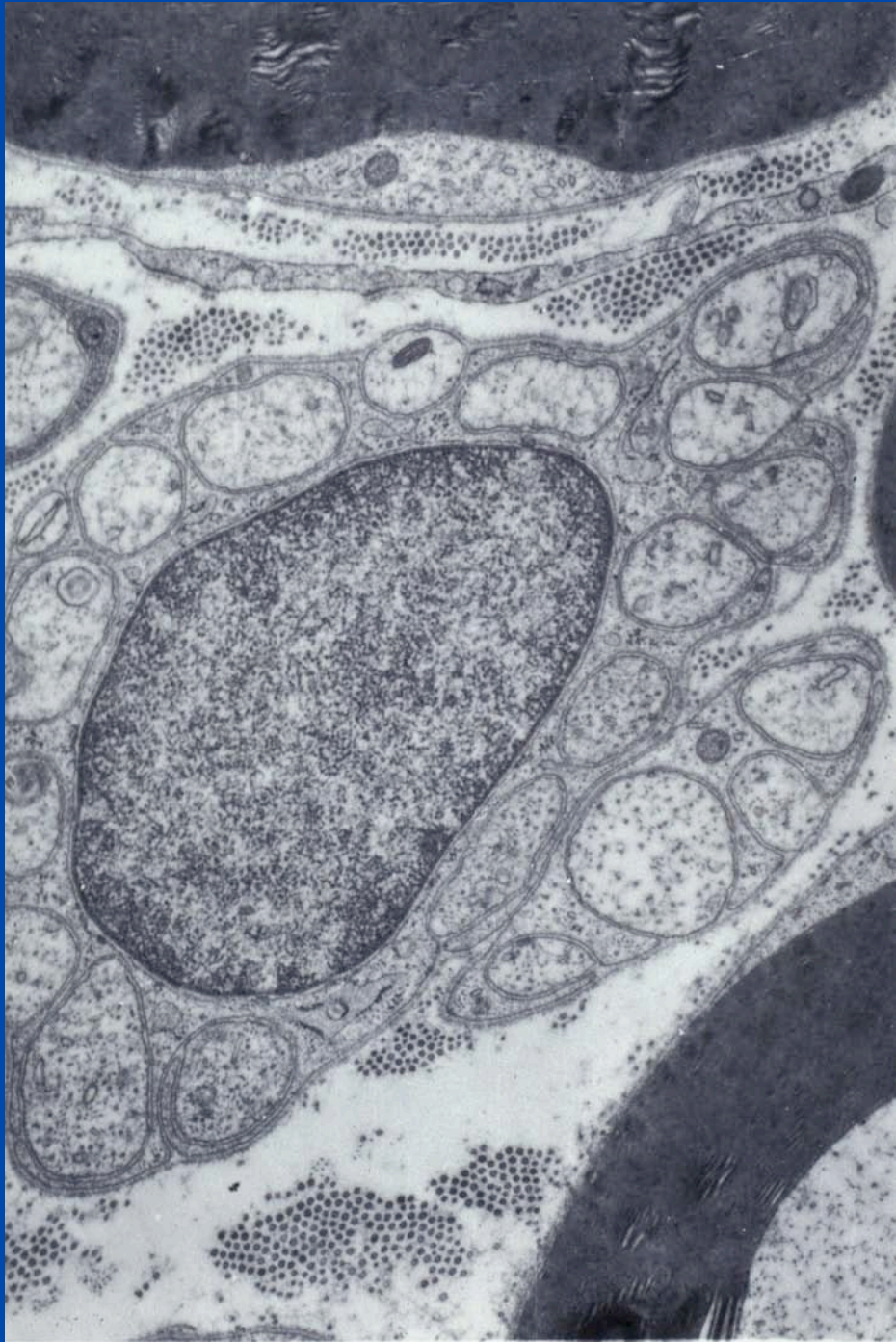


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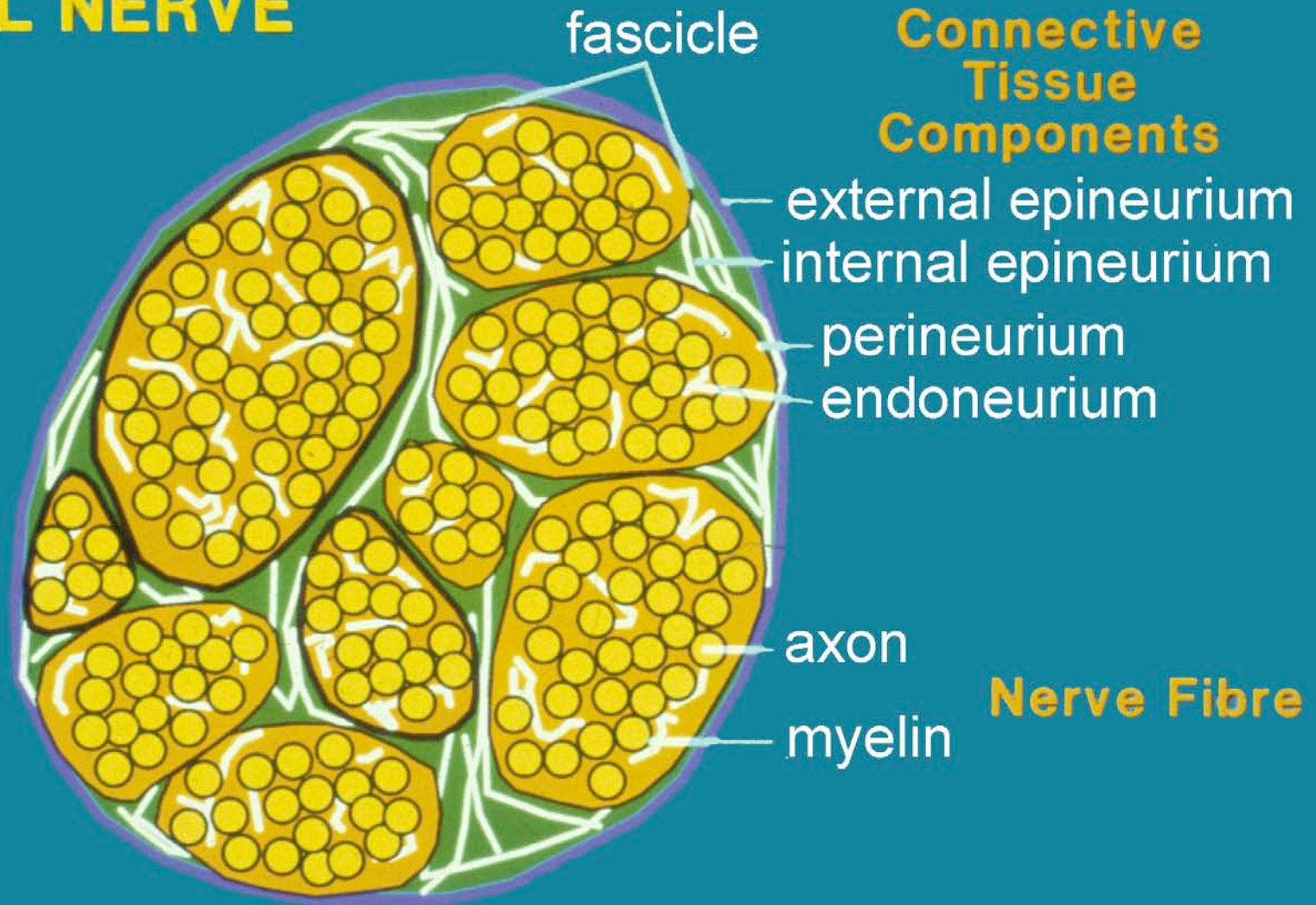




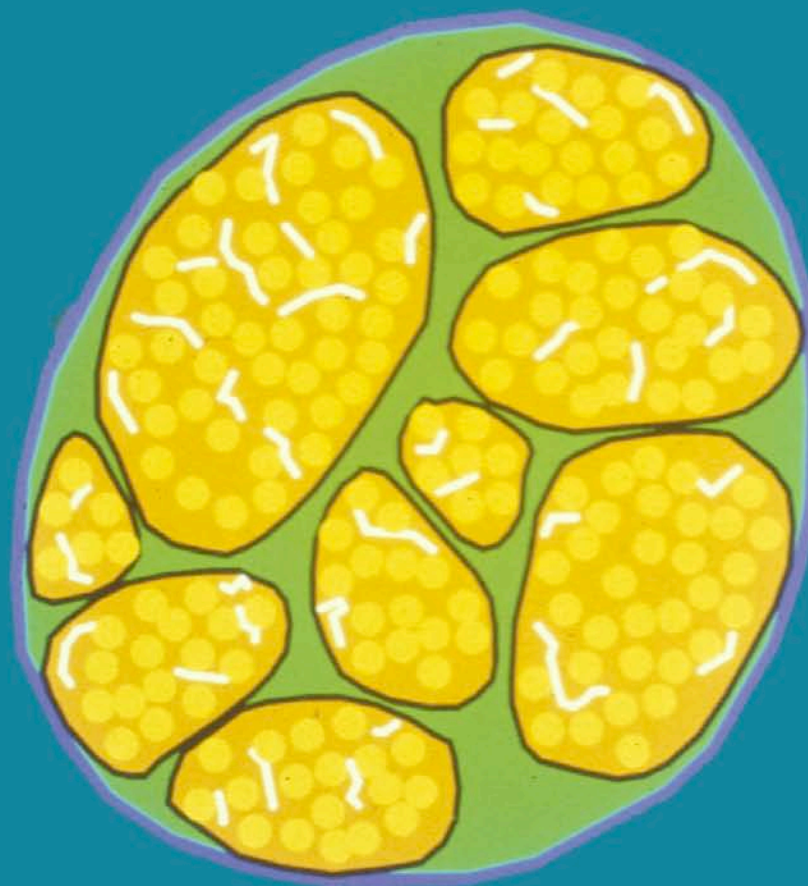




NORMAL NERVE



I NEURAPRAXIA

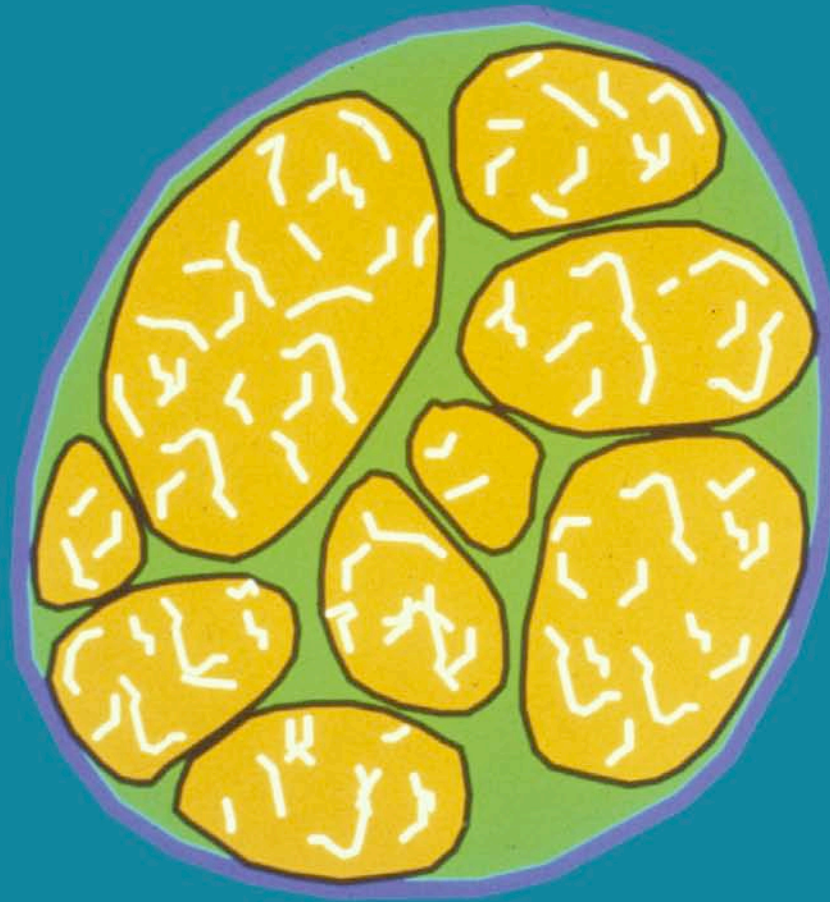


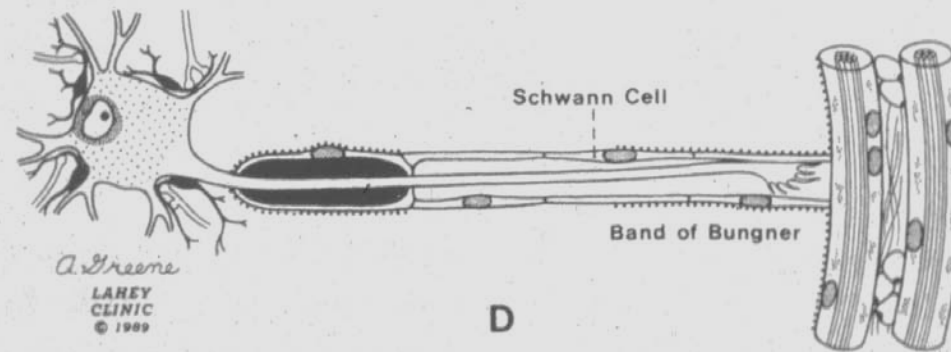
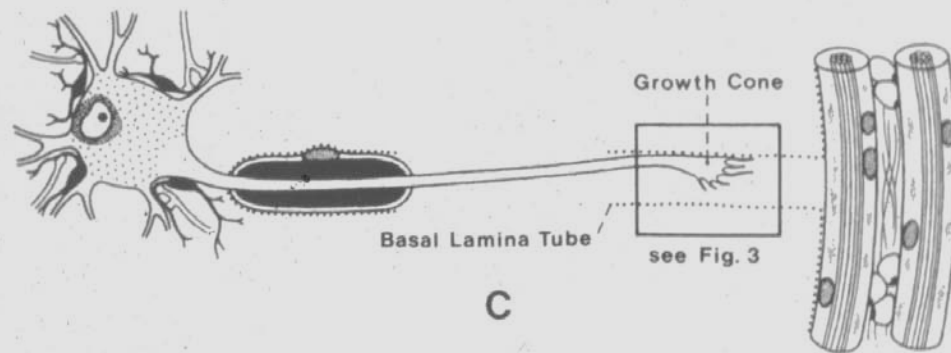
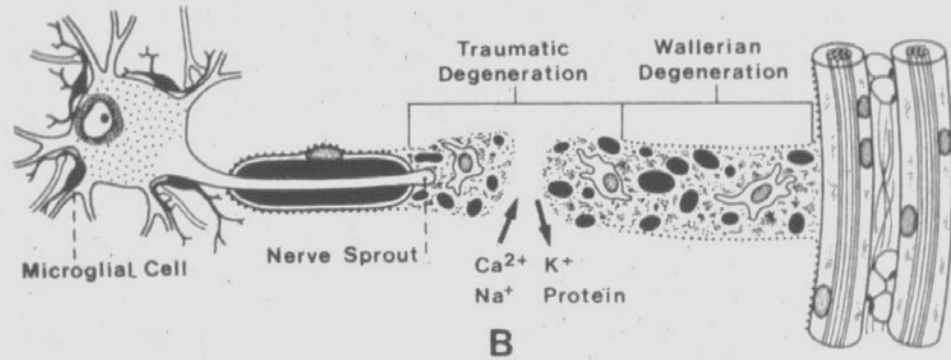
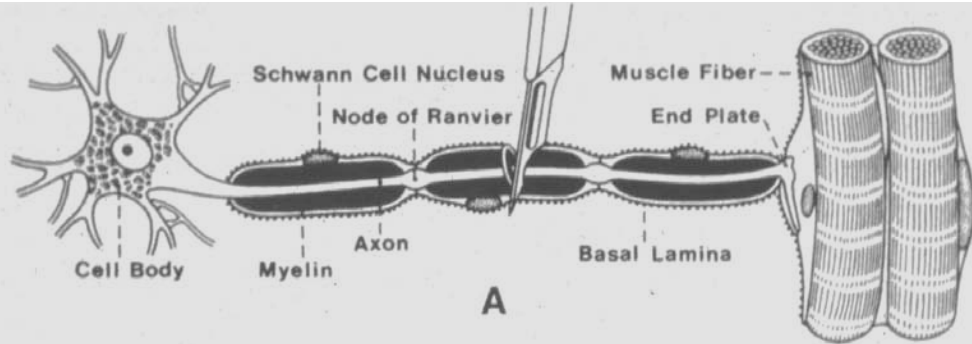
Neurapraxia

- ✧ No histological abnormality or segmental demyelination
- ✧ No Wallerian degeneration
- ✧ Conduction block in nerve; no denervation
- ✧ Complete deficit at outset, characterized by complete recovery in days to weeks
- ✧ Examples: Saturday night palsy, tourniquet paralysis, some fracture associated nerve injuries



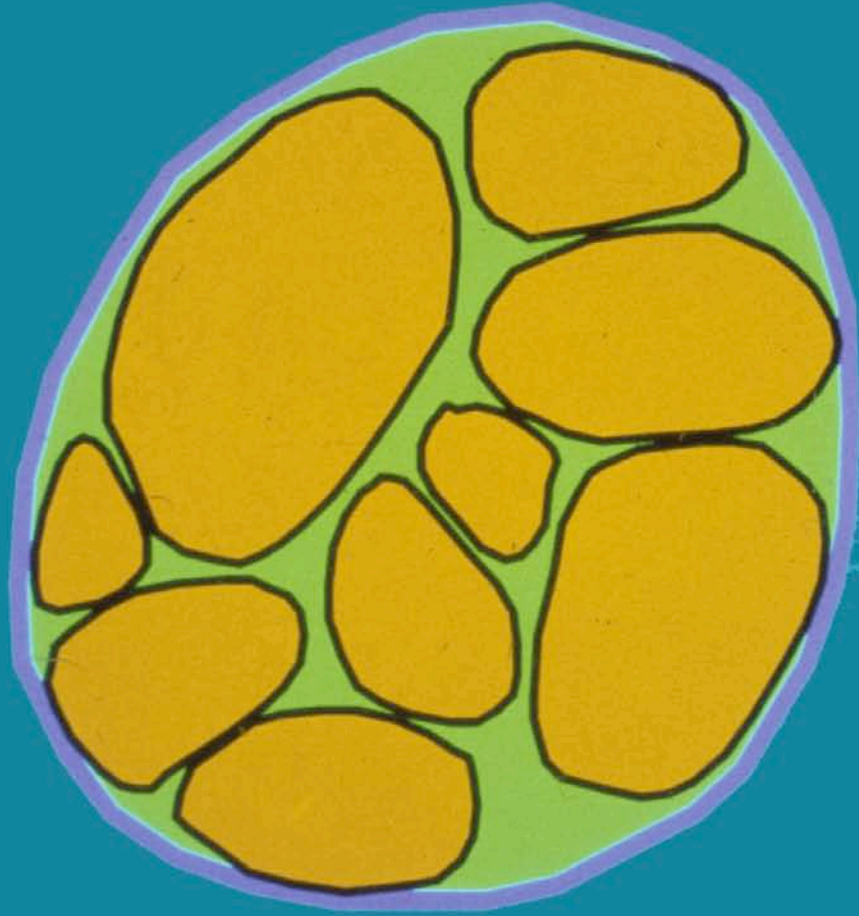
II AXONOTMESIS



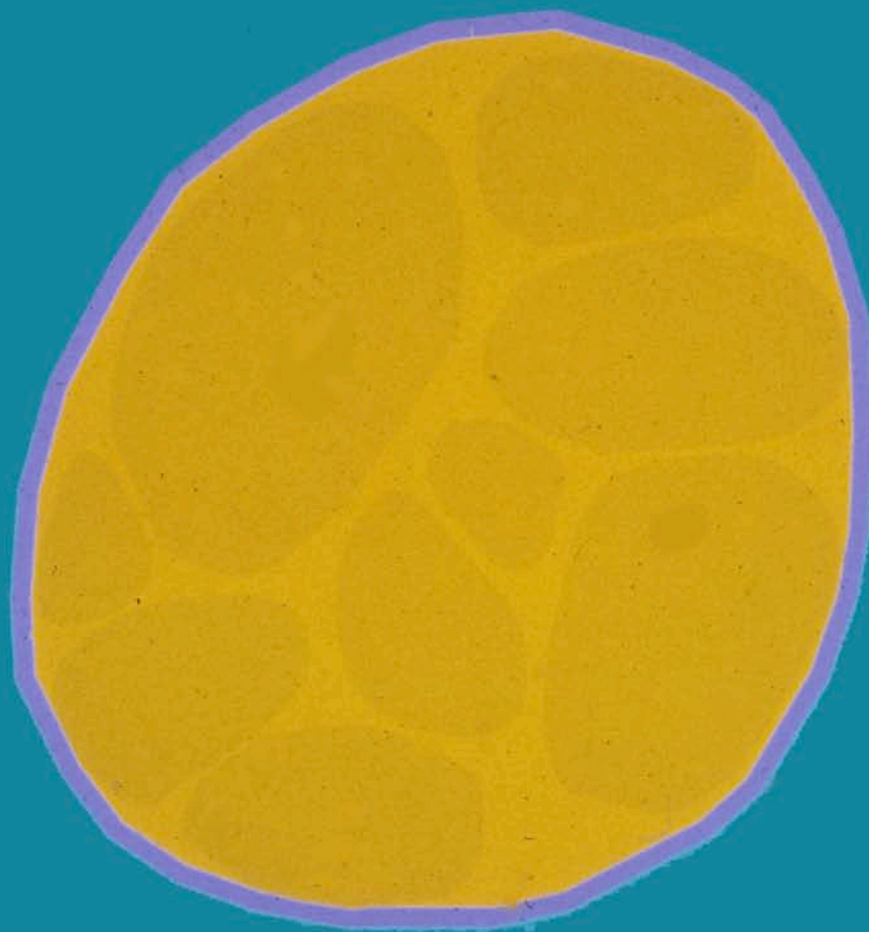


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III



IV NEUROMA IN CONTINUITY

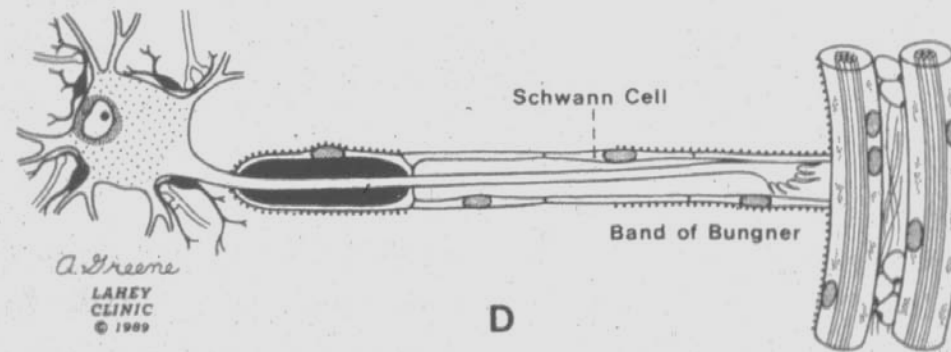
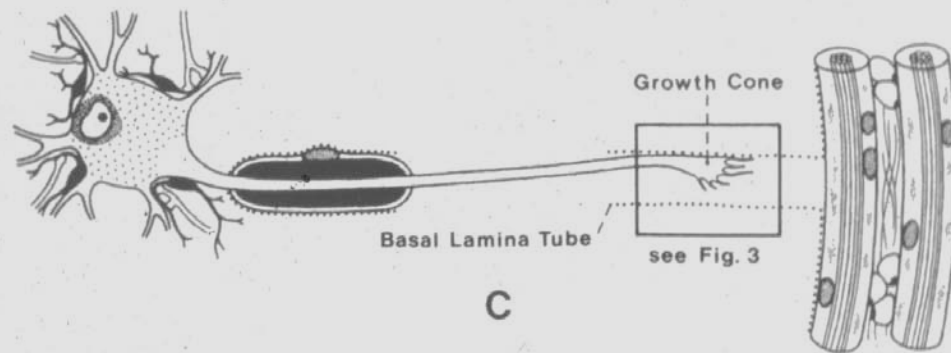
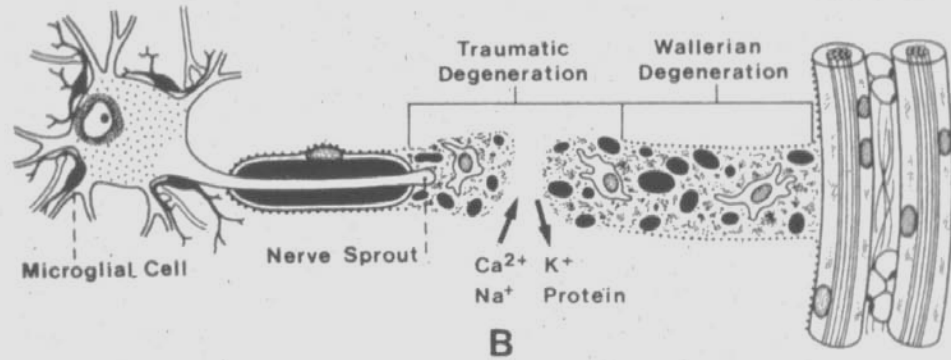
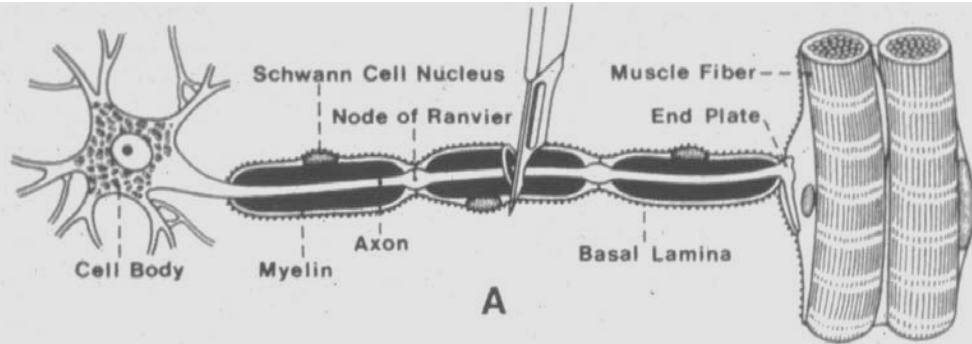


V

Overview: Nerve Injury

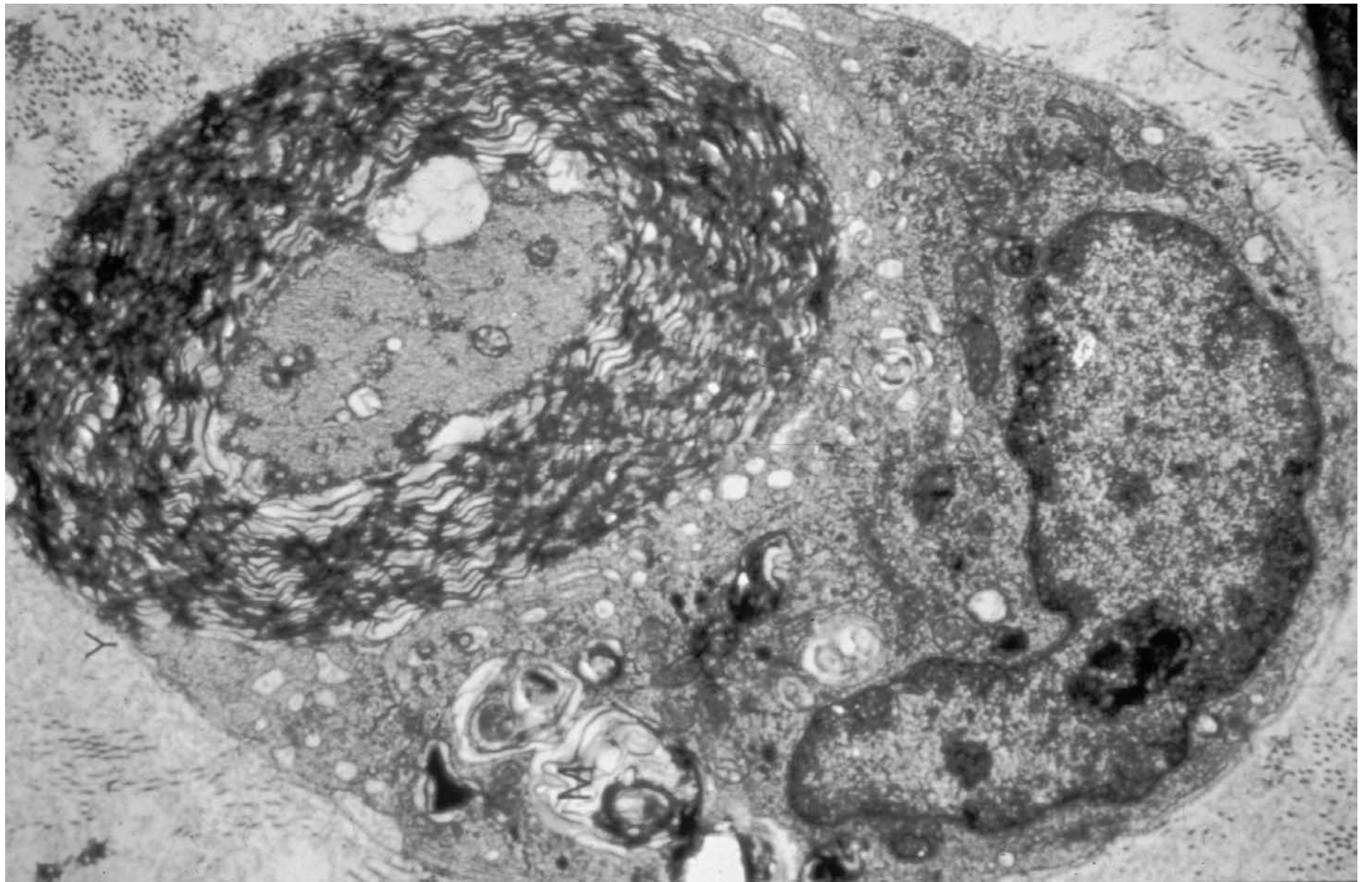
In response to nerve fiber injury (axotomy):

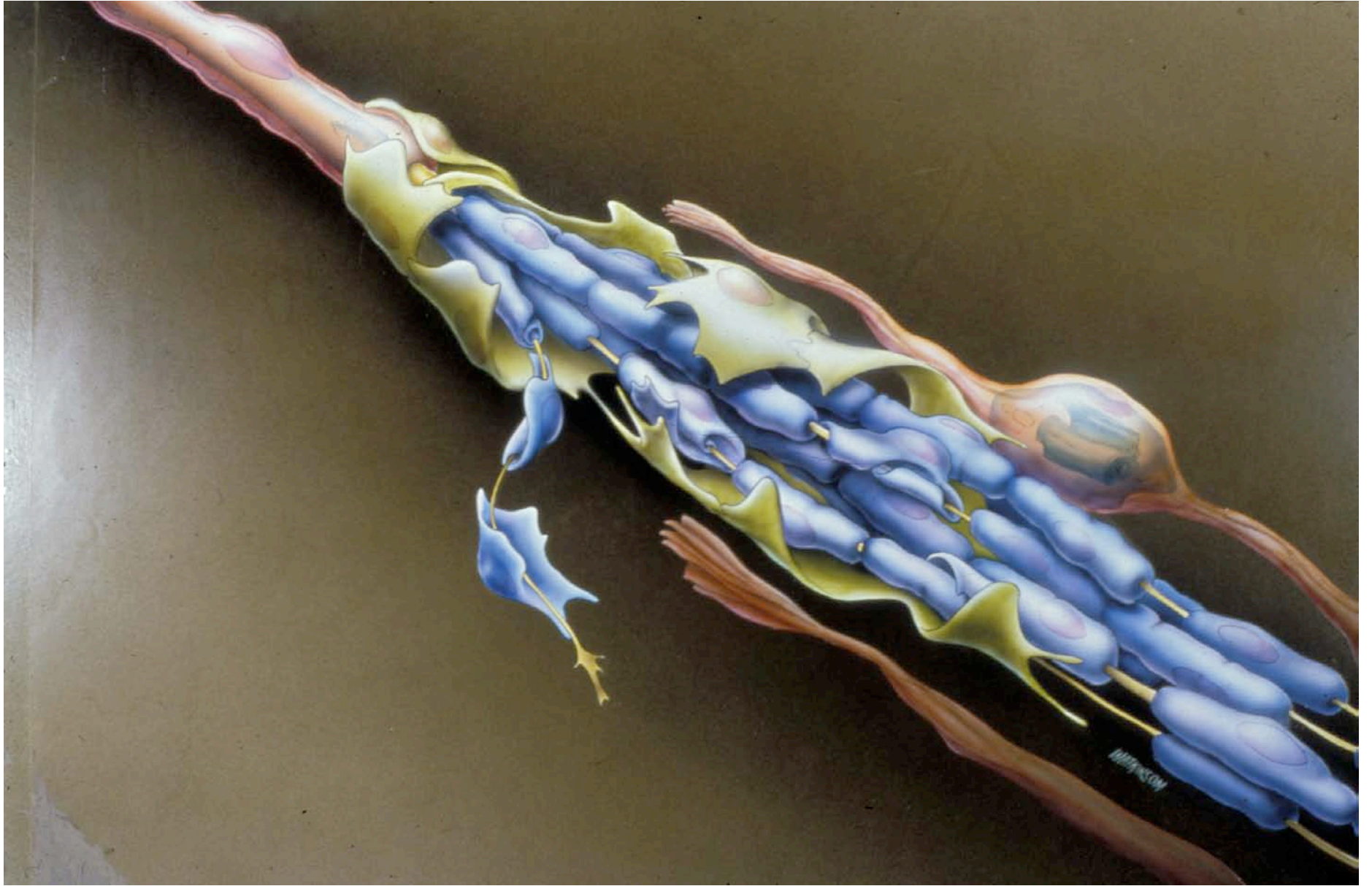
- ① Neuronal (cell body) reaction:
 - cell death
 - chromatolysis
- ② Distal segment: Wallerian degeneration
- ③ Proximal stump:
 - die-back
 - regenerative response
- ④ Regeneration
 - trophic factors, ECM molecules, axon-environment interactions and guidance mechanisms
- ⑤ End-organ
 - denervation and long-term changes

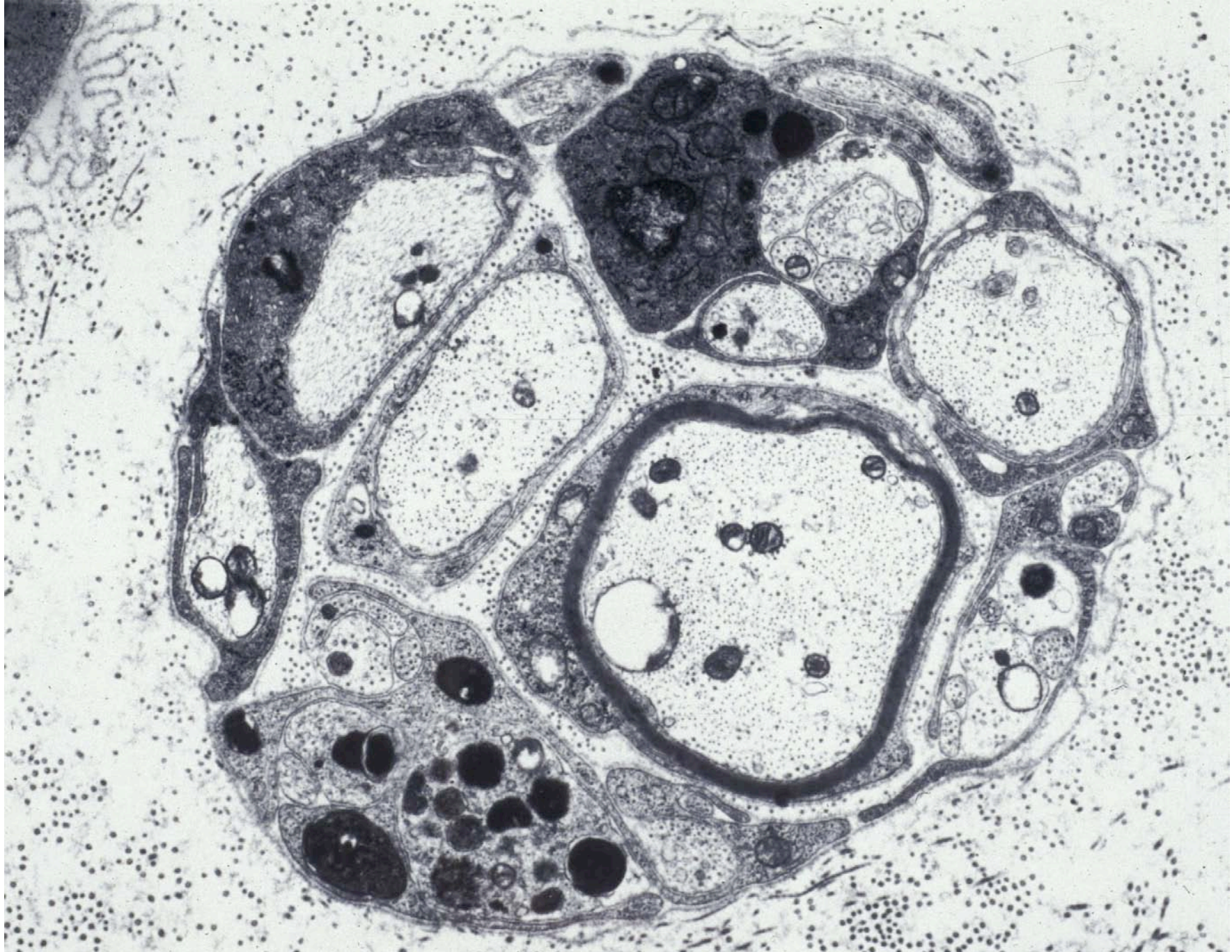


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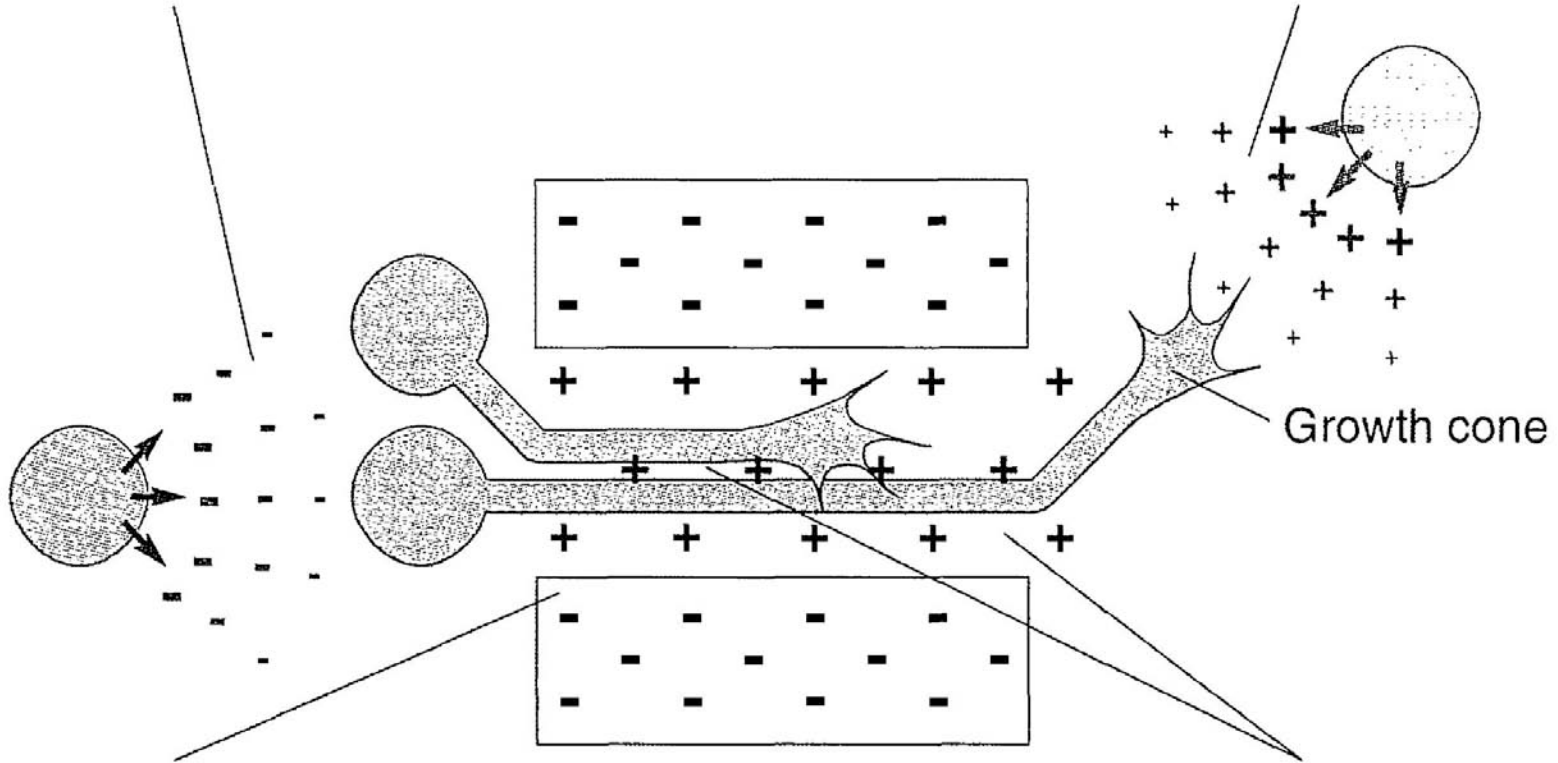
Semaphorins
(secreted)
Netrins

Long-range cues

Netrins

Chemorepulsion

Chemoattraction



Contact repulsion

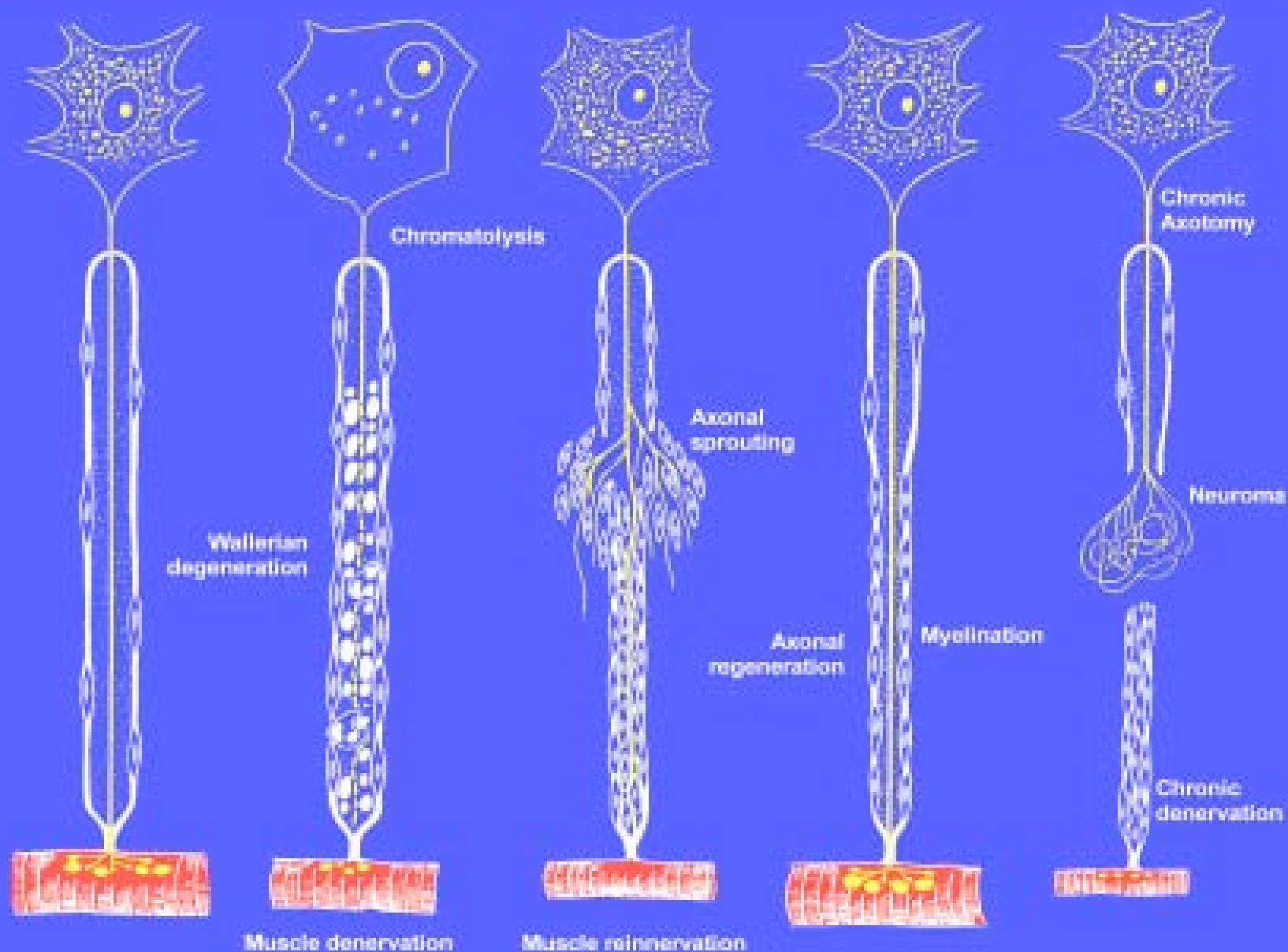
Contact attraction

Eph ligands
Semaphorins
(transmembrane)
ECM (for example, tenascins)

Short-range
cues

Ig CAMs
Cadherins
ECM (for example, laminins)

RESPONSE OF THE INJURED MOTOR UNIT



Rate of Regeneration

- ✧ Varies from species to species
 - 3-5 mm/day after rodent nerve crush
 - 2-4 mm/day after rodent nerve cut & repair
 - 1-2 mm/day in primates
- ✧ Humans:
 - rate decreases with increasing distance from cell body
 - above elbow/knee is 3 mm/day
 - between elbow and wrist or knee and ankle is 1.5 mm/day
 - below wrist or ankle is 0.5 to 1 mm/day

Human Nerve Injury Mechanisms

- ✧ Stretch
- ✧ Contusion (soft tissue injury; fracture related)
- ✧ Compression (acute >> chronic)
- ✧ Crush
- ✧ Laceration (sharp vs. blunt)
- ✧ Penetrating injury (GSW)
- ✧ Iatrogenic

- ✧ Majority of nerve injuries (>70 %) leave the nerve in gross continuity

Sunderland Grading Scale (*Seddon)

| Injury grade | Myelin | Axon | Endo | Peri | Epi |
|------------------------------|--------|------|------|------|-----|
| <i>I (Neuropraxia)*</i> | +/- | | | | |
| <i>II (Axonotmesis)*</i> | + | + | | | |
| <i>III</i> | + | + | + | | |
| <i>IV</i> | + | + | + | + | |
| <i>V (Neurotmesis)*</i> | + | + | + | + | + |

| | Neuropraxia | Axontemesis | Neurotemesis |
|-----------------------------|---|--|---|
| Pathoanatomy/ physiology | Metabolic, ischemic, compression. Nerve appears normal, or demyelination | Axon severed, nerve in continuity. Variable extent of endo/perineurial damage. Wallerian degeneration | Entire nerve severed. Laceration injury. Nerve in discontinuity. Wallerian degeneration |
| Electrophysiology | Conduction block | No conduction (axon degenerated) after few days. EMG +ve for denervation in 3 weeks | |

Neuropraxia

Axontemesis

Neurotemesis

Natural History

Recovery in days-weeks, rarely months

Regeneration 1 mm/day. Recovery most variable, depending on extent of connective tissue damage in the nerve, location and type of nerve

No hope for spontaneous recovery

Treatment

Expectant, virtually all recover

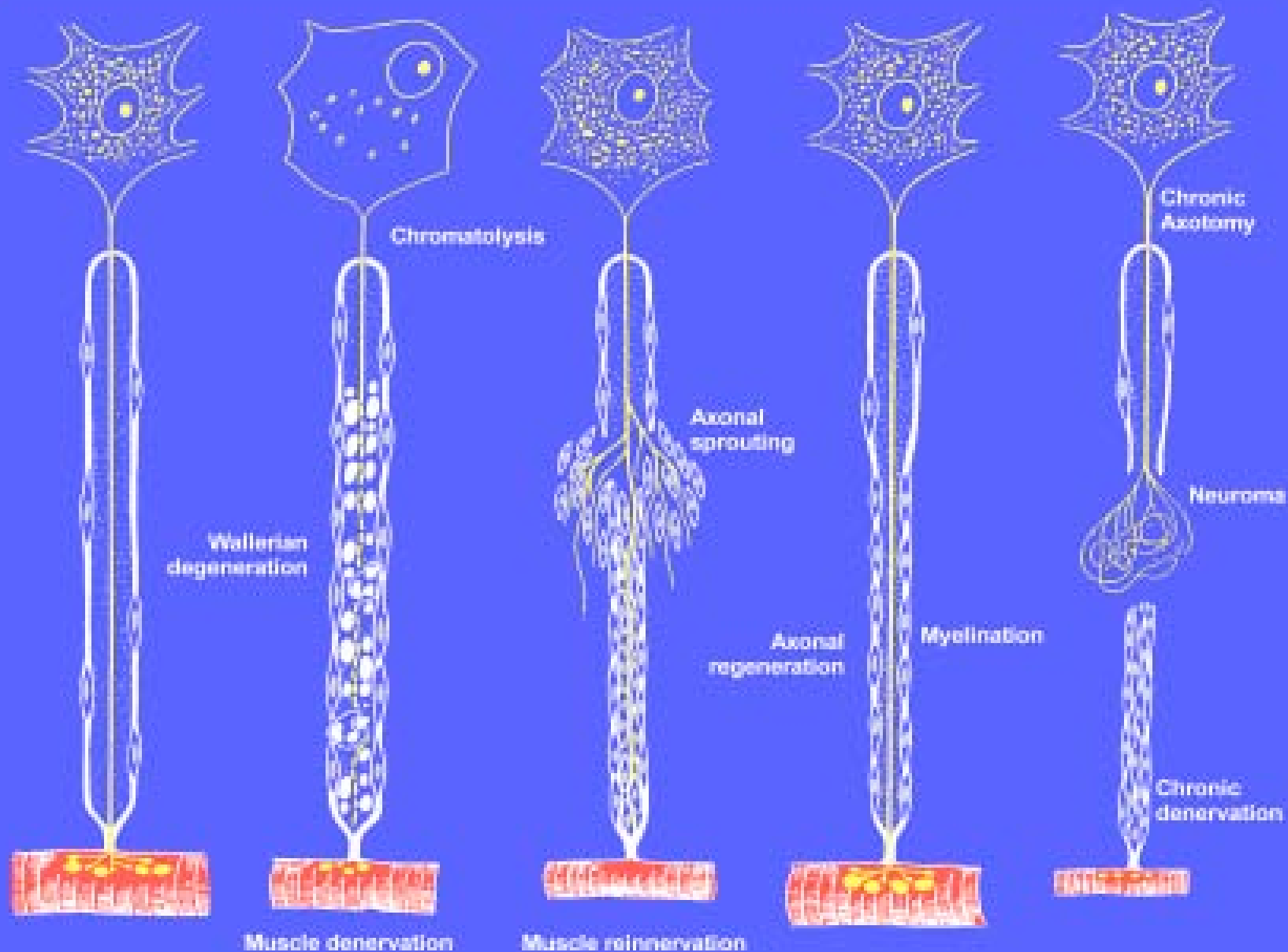
Follow clinically and electrically in serial fashion; expect recovery. If not forthcoming over 3-6 months: explore +/- repair

All need repair, timing depends on mechanism. Sharp laceration: immediately. Blunt: delayed weeks

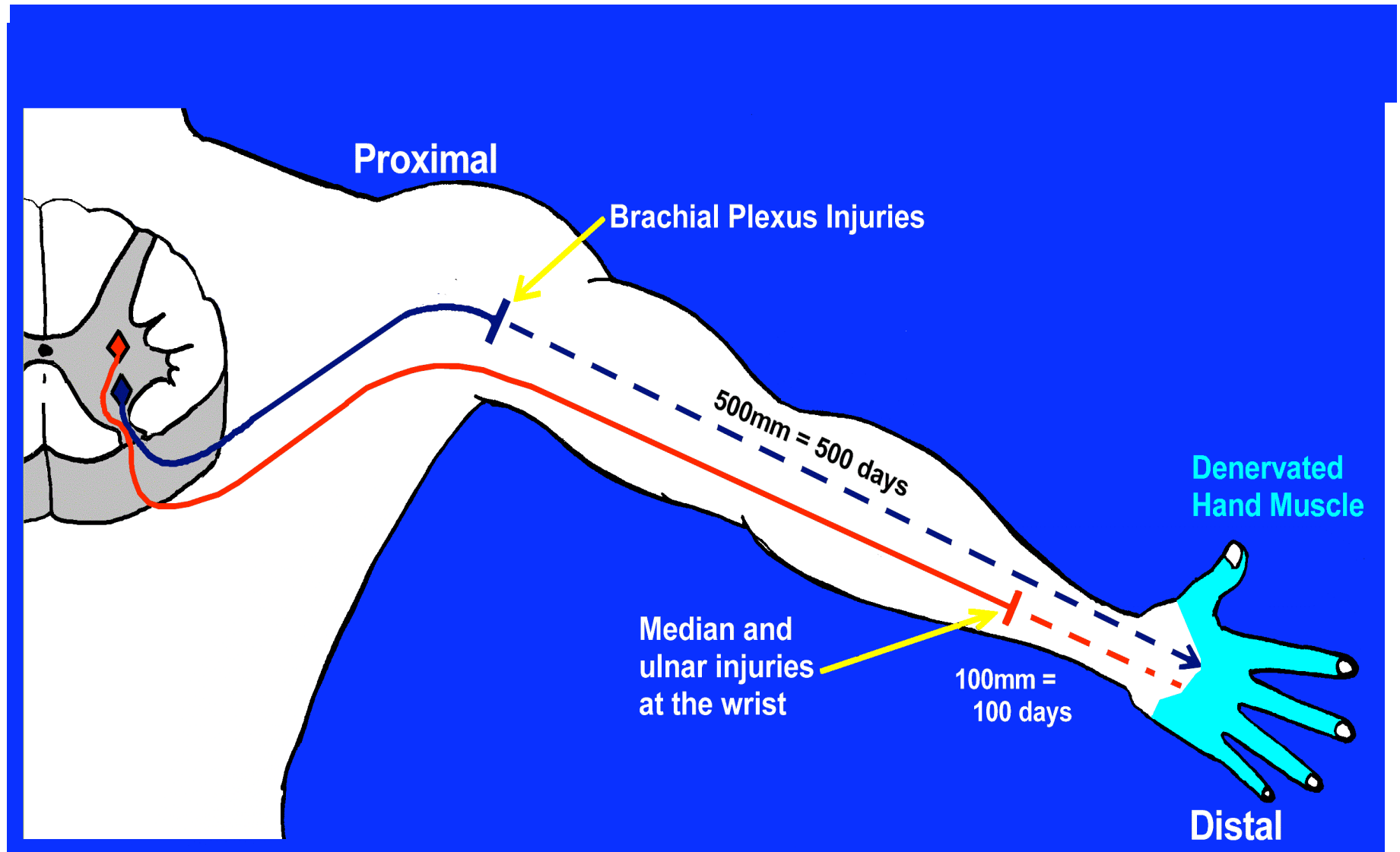
Recovery of Function

- ◇ Neuropraxic injury
 - 8-12 weeks
- ◇ Axonotmetic injury
 - 1mm/day
 - 1 inch / month
 - N.B. Short focal injury
- ◇ Neurotemetic injury
 - Failed recovery

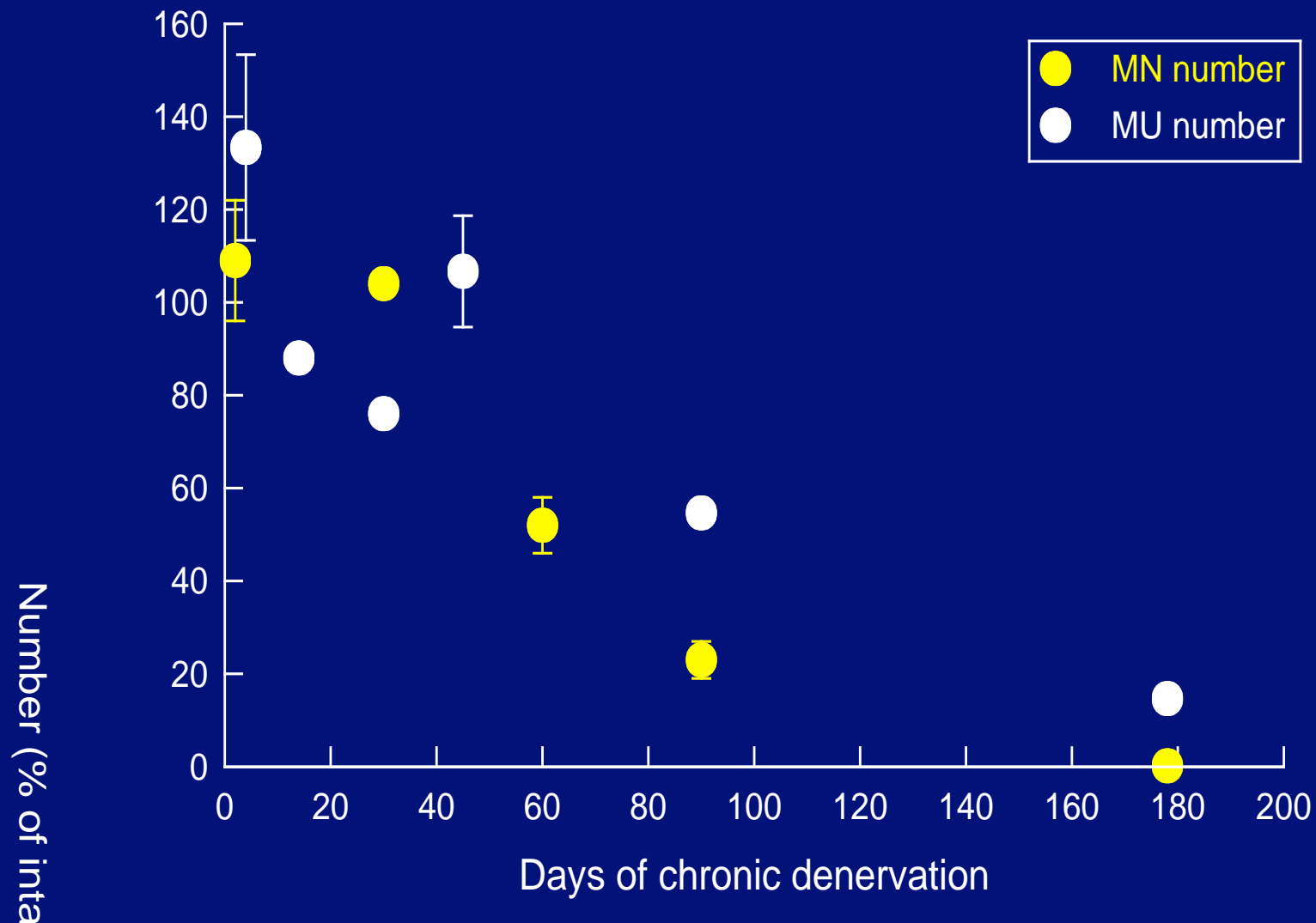
RESPONSE OF THE INJURED MOTOR UNIT



Axonal Regeneration Over Long Distances In The Limbs



Reduced motor axon regeneration after chronic denervation



Nerve Injuries In-Continuity

- ✧ Majority of clinical nerve injuries
- ✧ Sunderland Grade II-IV
- ✧ Propensity for regeneration and functional recovery good for Grade II, variable for III and poor for Grade IV
- ✧ Initial management is expectant: baseline evaluation, serial clinical and electrical follow-up
- ✧ For patients failing to improve over a few months, offer exploration and reconstruction as appropriate



Lacerative Nerve Injuries

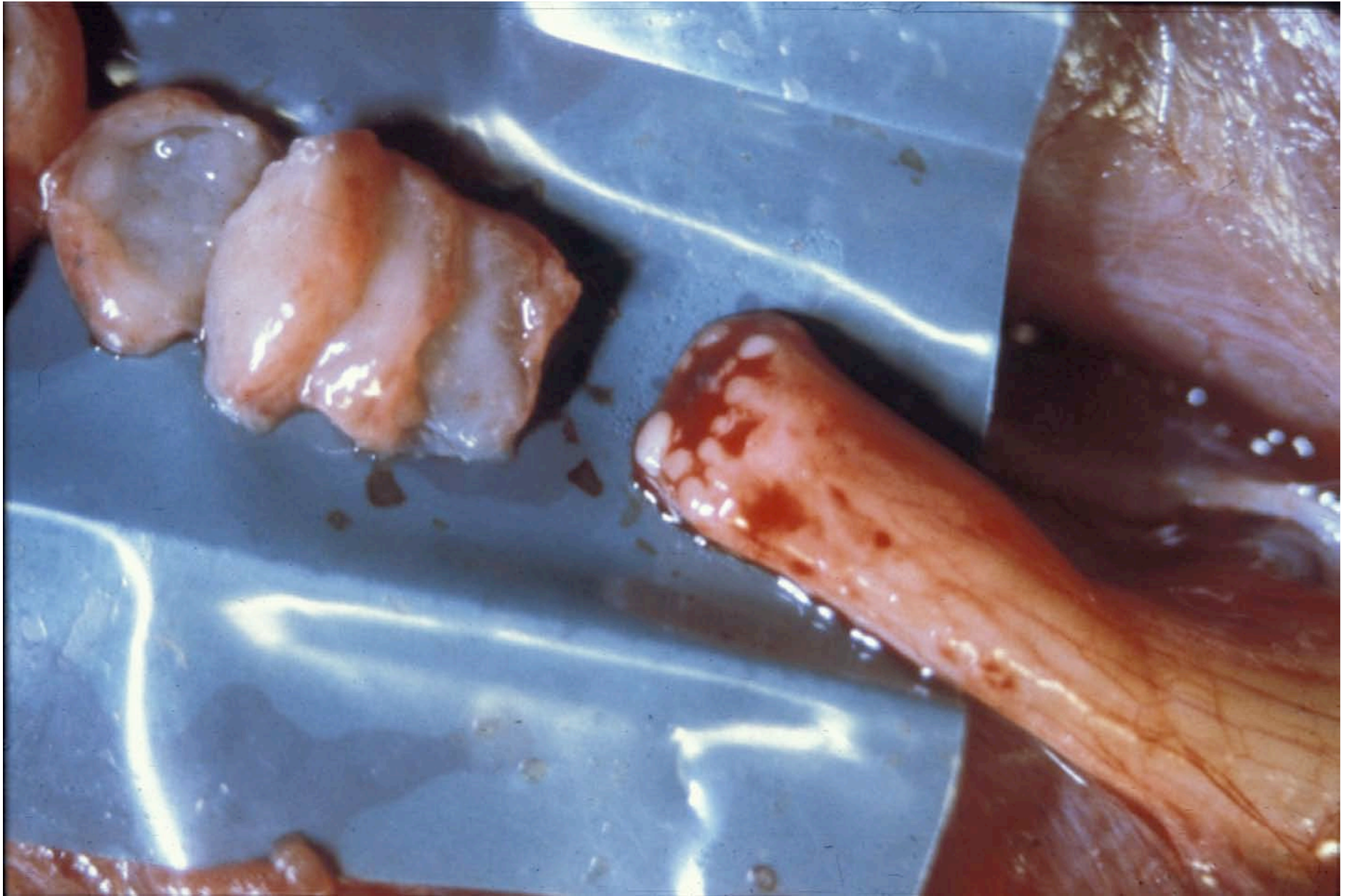
- ✧ Neurotmesis, Sunderland Grade V
- ✧ Will not recover unless repaired
- ✧ Timing of repair dictated by mechanism:
 - sharp, clean (glass, knife, scapel): immediate to urgent (within 72 hours) repair. Usually end-end.
 - contaminated or blunt (chainsaw): debride, identify and tag ends, suture to surrounding fascial tissue to maintain length. Delayed repair (weeks) to allow healthy non-contused ends to declare/demarcate. Repair often needs a graft.

Timing of Nerve Exploration (Repair): Rule of 3's

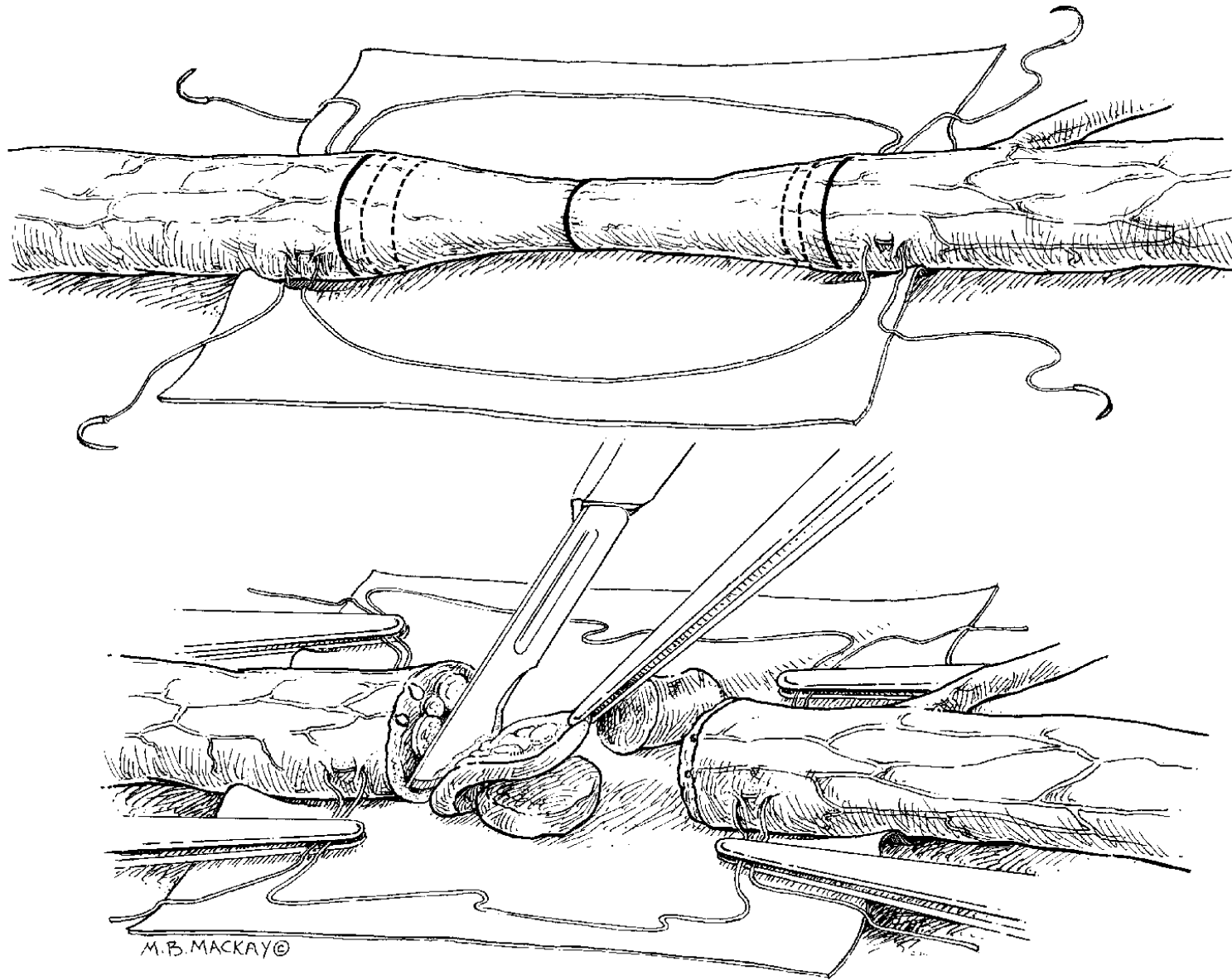
- ✧ (Within) 3 Days: Sharp clean lacerations
- ✧ 3 Weeks: Blunt lacerations
- ✧ 3 Months: Injuries in continuity

Nerve Repair Principles

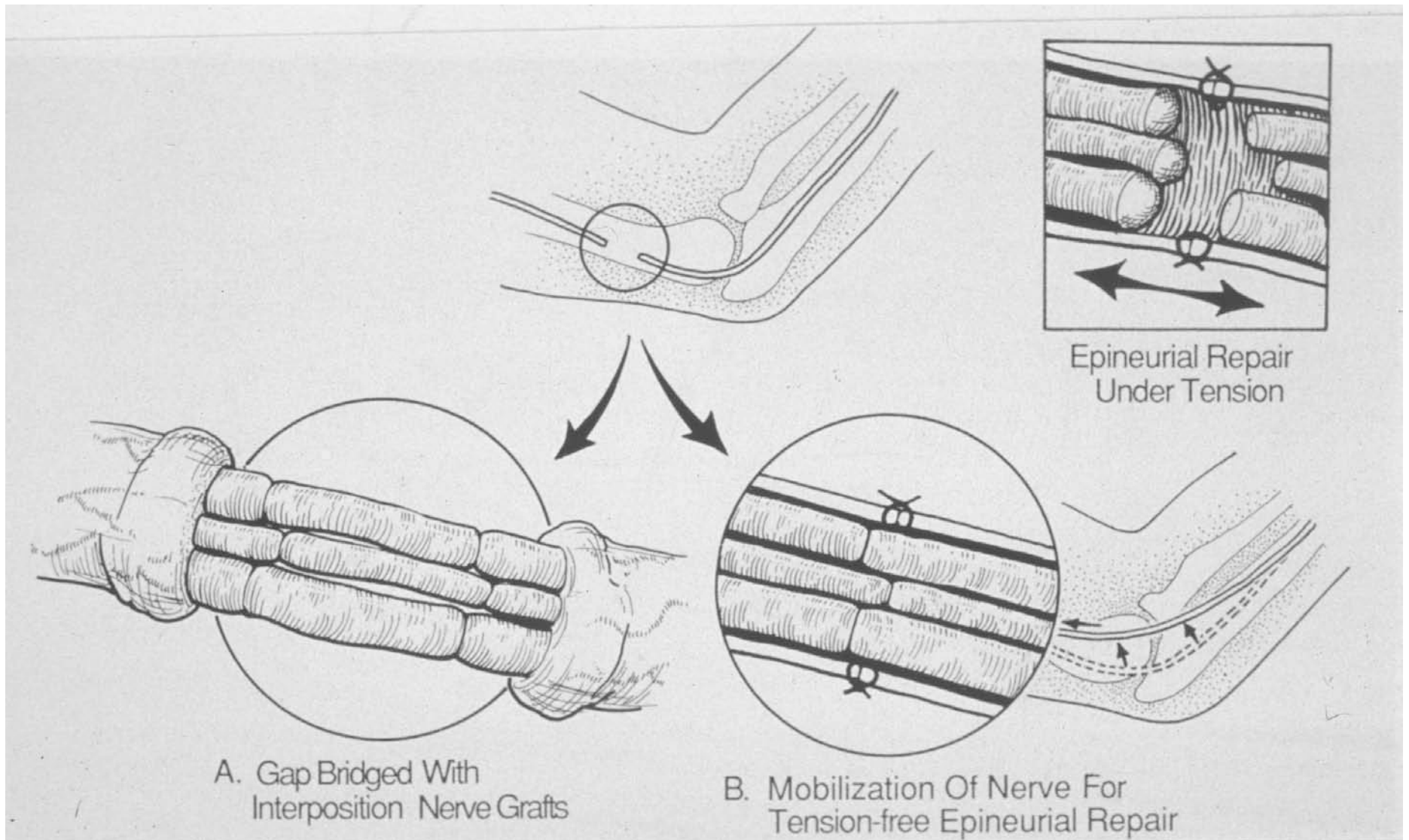
- ✧ Trim back to healthy (fascicular) tissue
- ✧ Tension-free coaption
- ✧ Match surface landmarks: topographic specificity
- ✧ Magnification (microinstruments)
- ✧ Use minimum number of microsutures
- ✧ Consider use of fibrin glue (itself or to reinforce)
- ✧ Avoid overriding of fascicles
- ✧ Consider use of epineurial, grouped fascicular and fascicular repairs depending on circumstances
- ✧ Use maximal amount of graft: ensure optimal cross-sectional coverage of nerve stumps



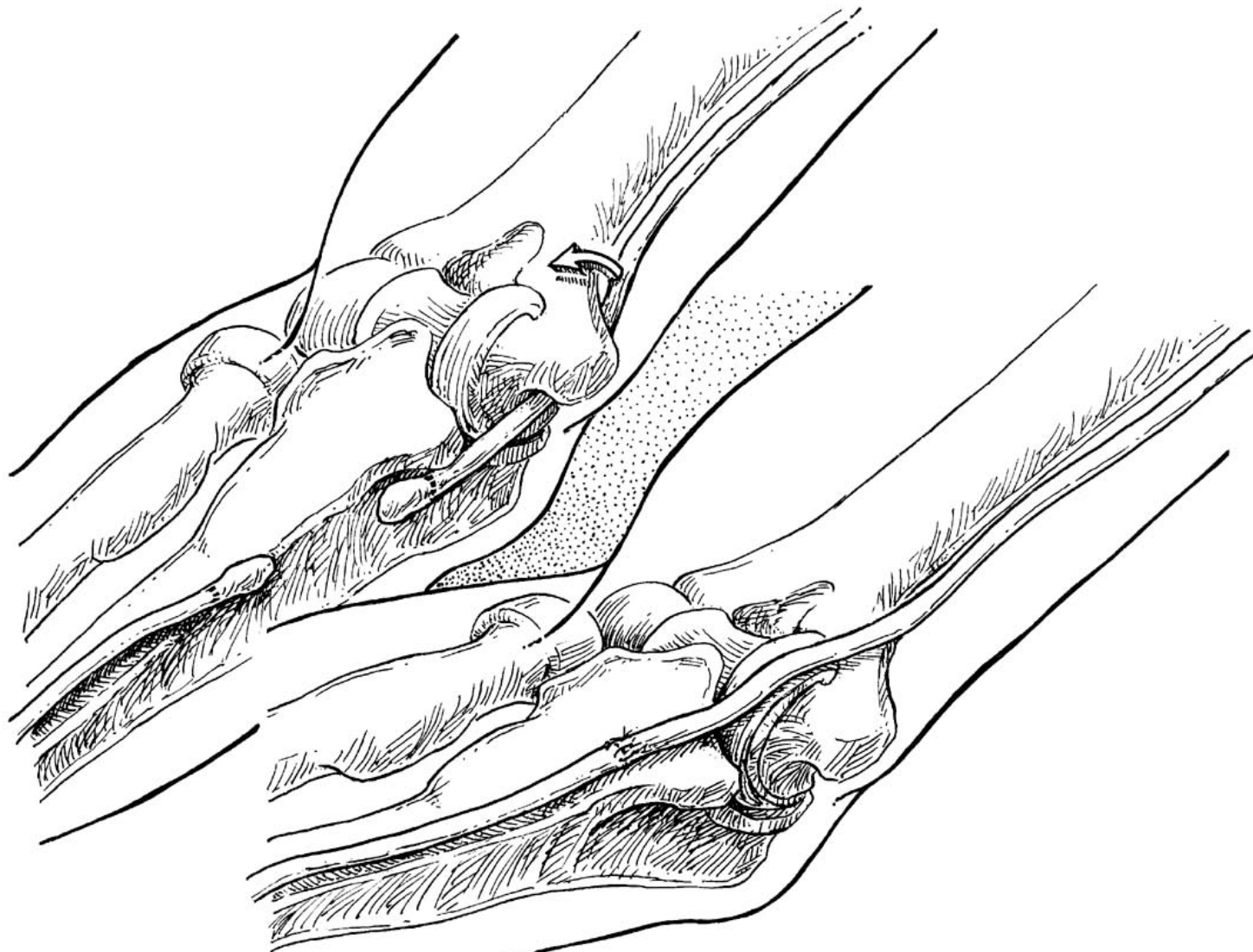
Trimming back to healthy fascicular tissue



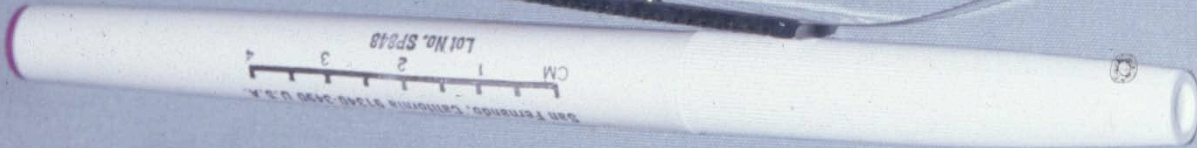
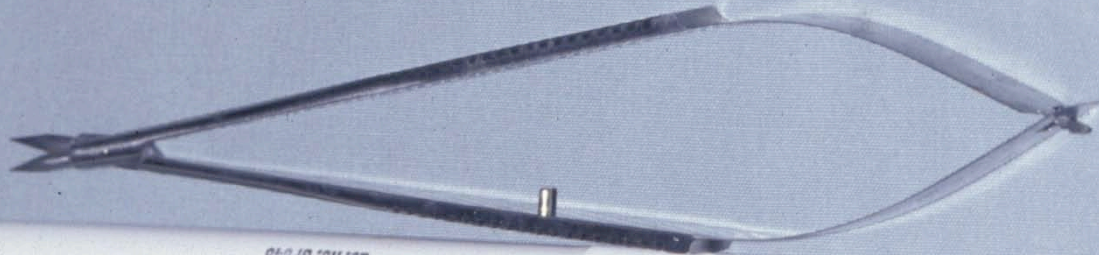
Maintaining topographic specificity (alignment)



Avoiding tension at repair

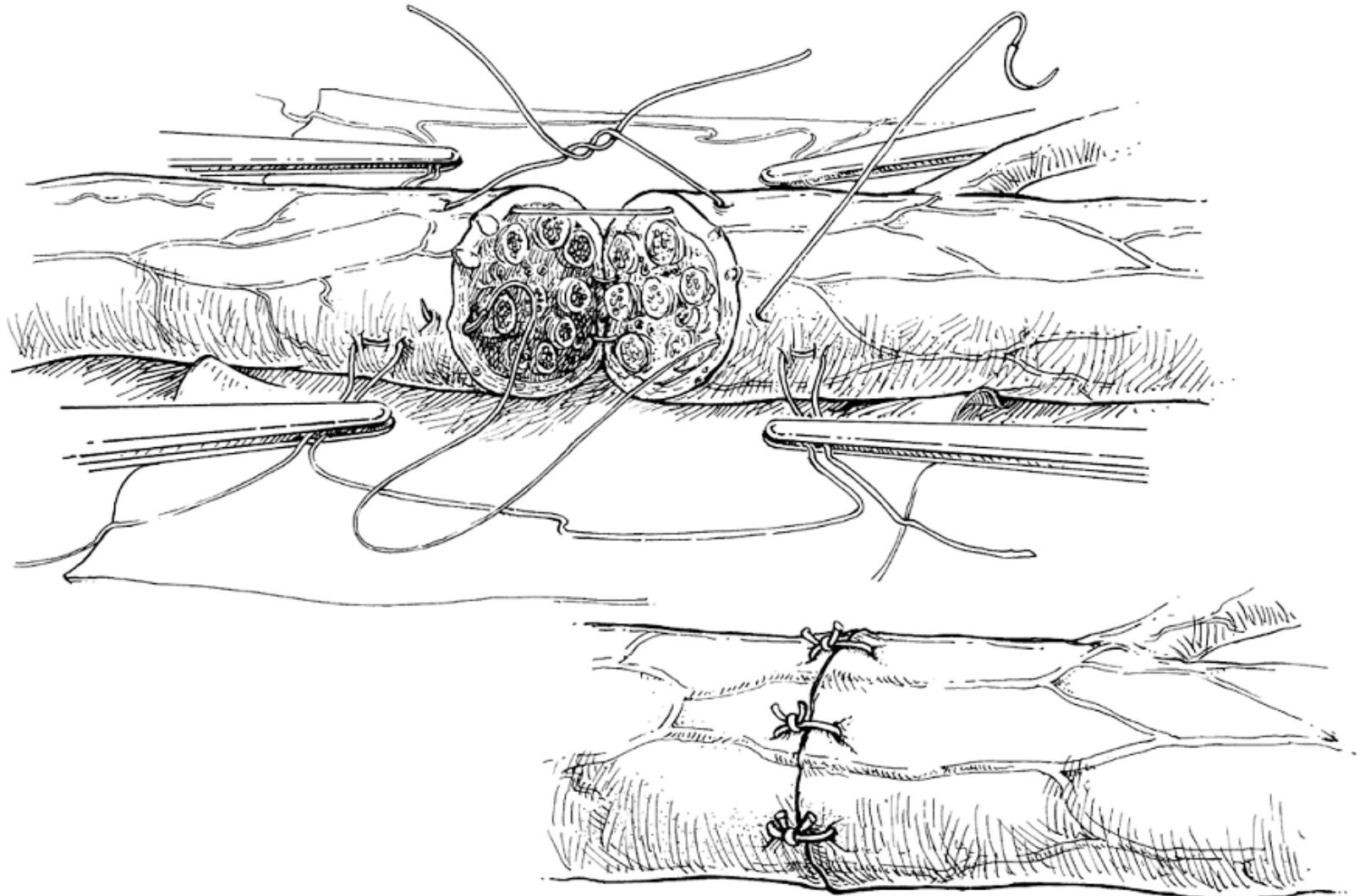


Consider transposition

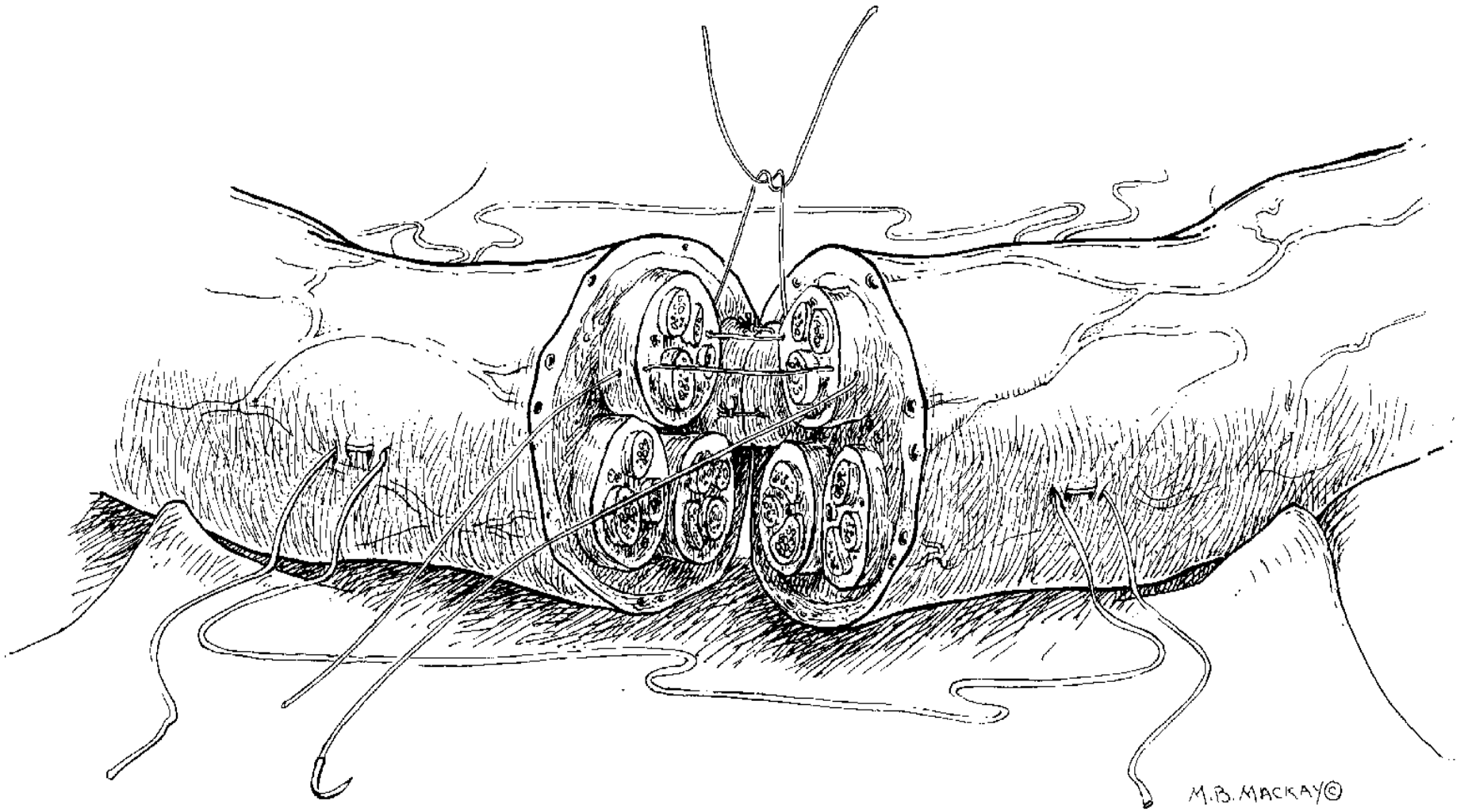


Nerve repair techniques

- ✧ Epineurial
 - ✧ Grouped fascicular
 - ✧ (Interfascicular grafts)
 - ✧ Perineurial
- ✧ No convincing difference in outcome, as long as tension avoided



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