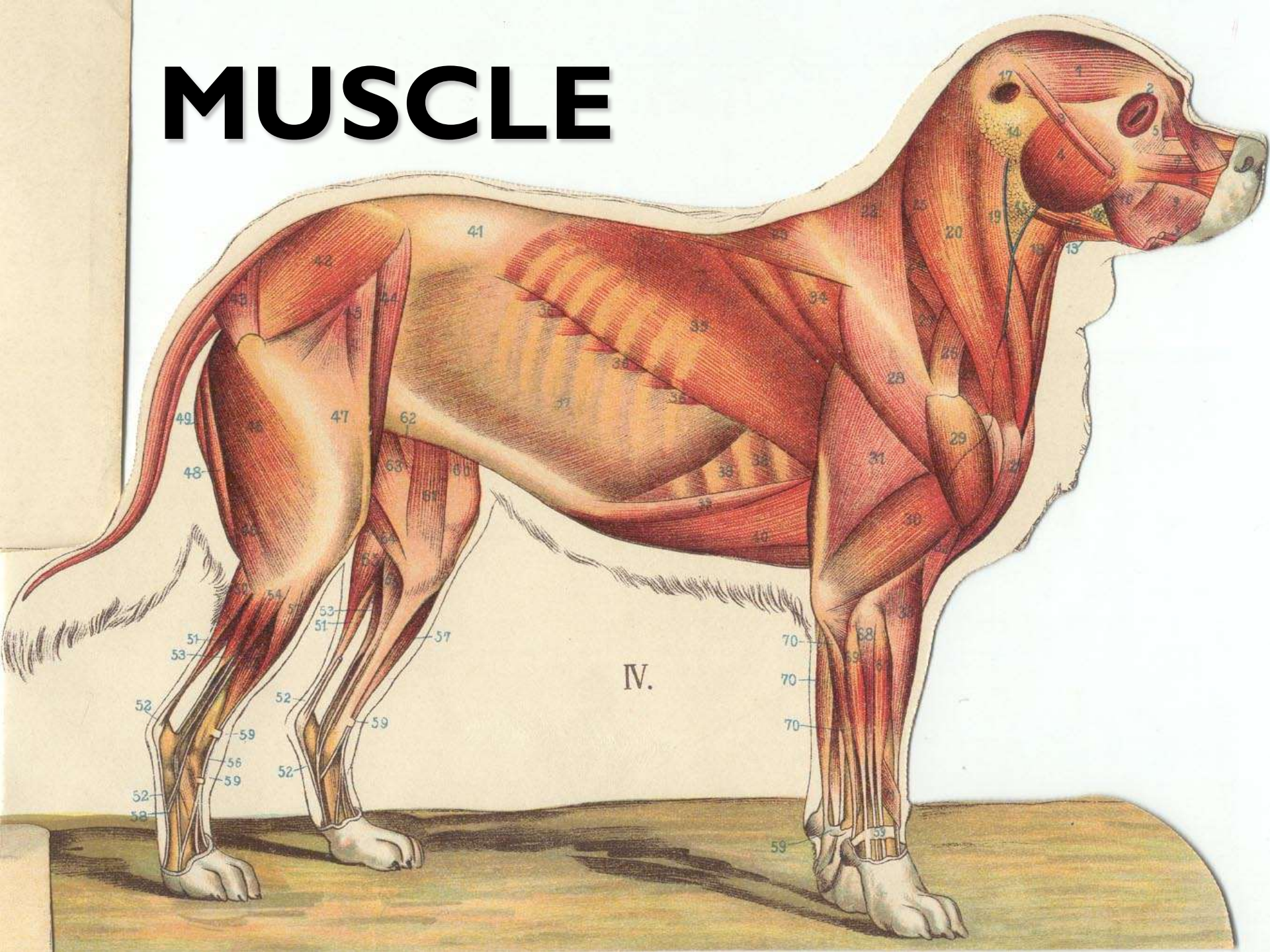
MUSCLE



MUSCLE IS A BASIC TISSUE

- **DEFINITION:** Muscle is *a tissue specialized for contraction and transmission of impulses*
- Extreme example of specialization and differentiation for limited, specific functions
- Always associated with CT's
- Almost always associated with nervous tissue

THINGS COMMON TO *ALL* MUSCLE TYPES

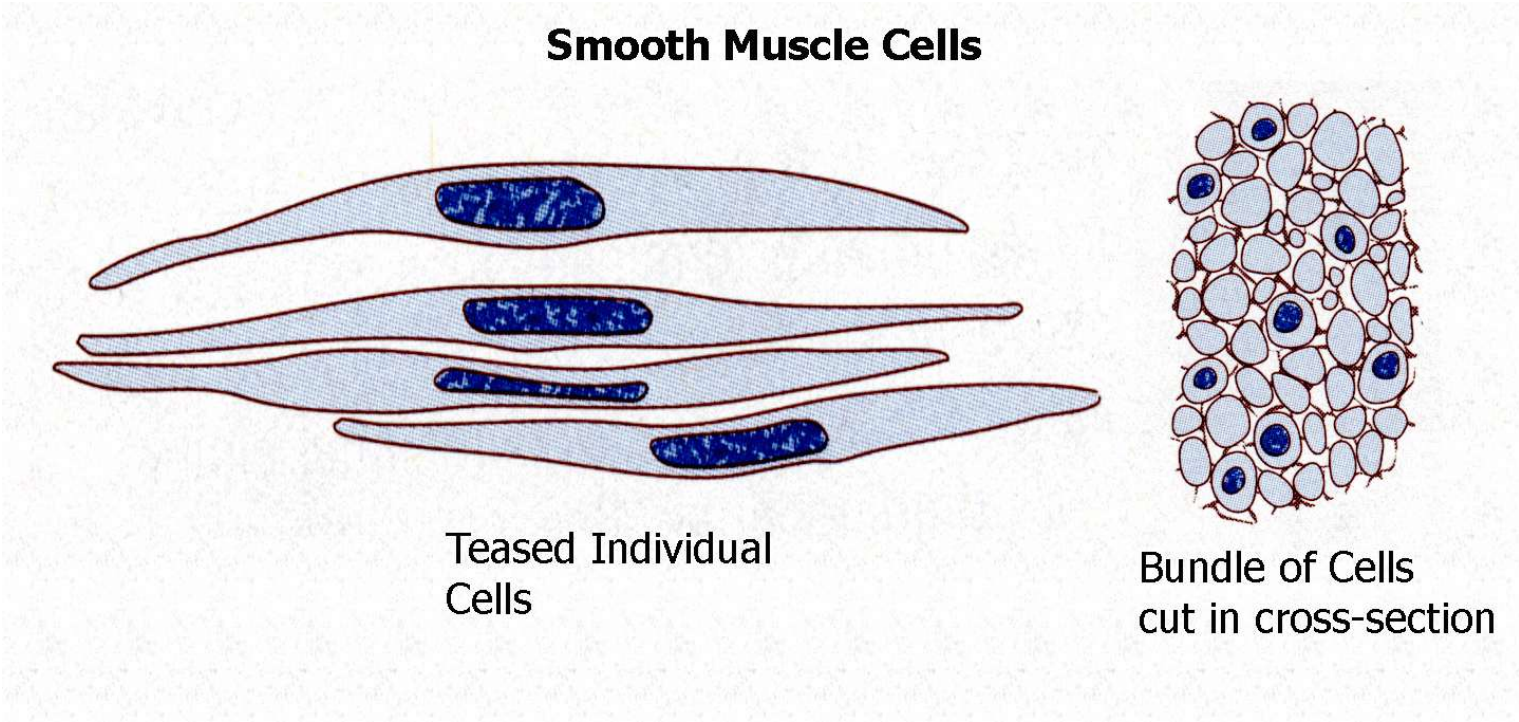
- Contraction is due to ACTIN and MYOSIN microfilaments
- Contraction is an "all or none" response
- Force of contraction is transmitted through a network of collagenous fibers
  - Always associated with CT!
- Origin is from embryonic mesoderm
- Specialization has caused loss of other capabilities
  - Loss of ability to divide

SMOOTH MUSCLE

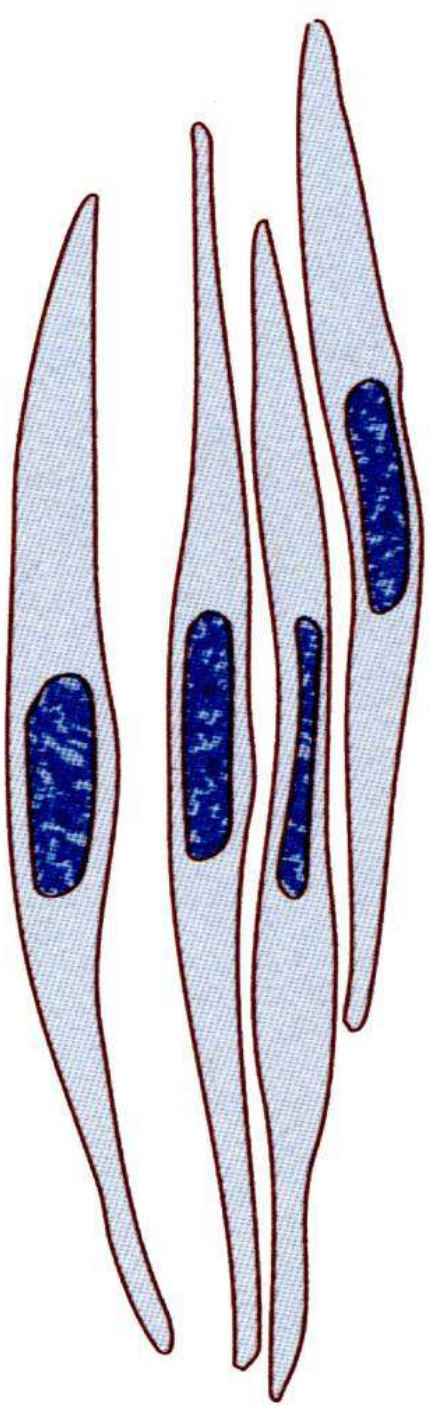
- Hormonal, nervous, and physical stimuli
  - *Prolactin*: uterine smooth muscle
  - *Responsive contraction* in intestine
  - *Nervous stimulation* via sympathetic and parasympathetic routes
- Contractions usually strong, sustained, and slow
- "Involuntary" or "visceral" designation not always accurate
  - Occurs widely in most organs and in fibrous CT's
- Can be single cells, small aggregates or large sheets
- Also in skin & eye, among other places

SMOOTH MUSCLE CELLS

- **"Spindle shaped"**
- **Lie adjacent to each other in sheets**
- **Single central nucleus**
- **Nuclei are blunt-ended or "cigar" shaped**
- **EM shows microfilaments & pinocytotic vacuoles**

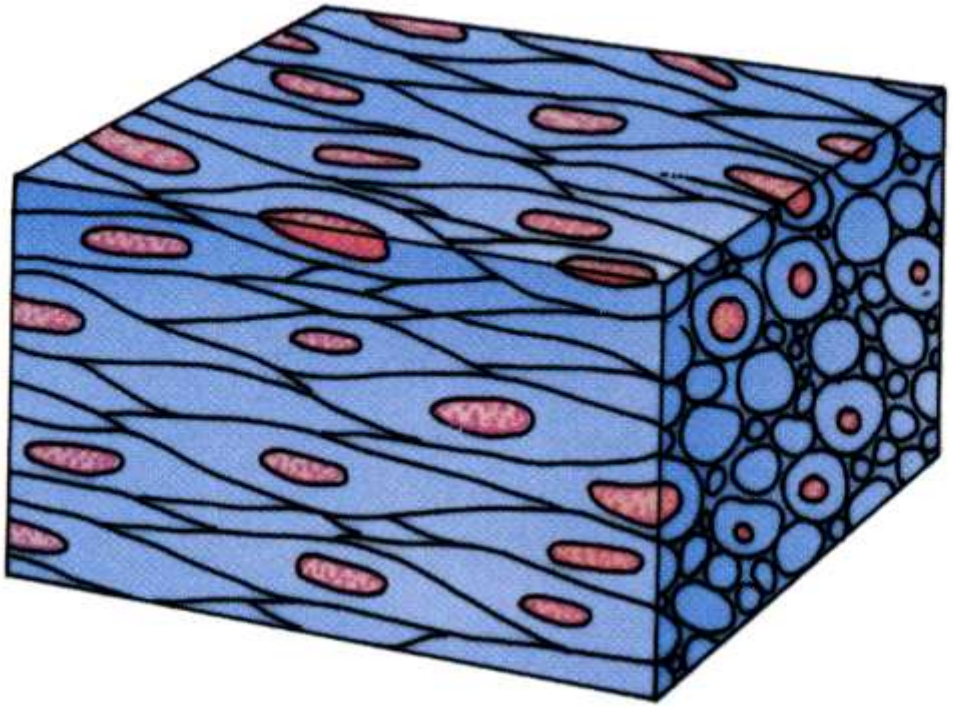


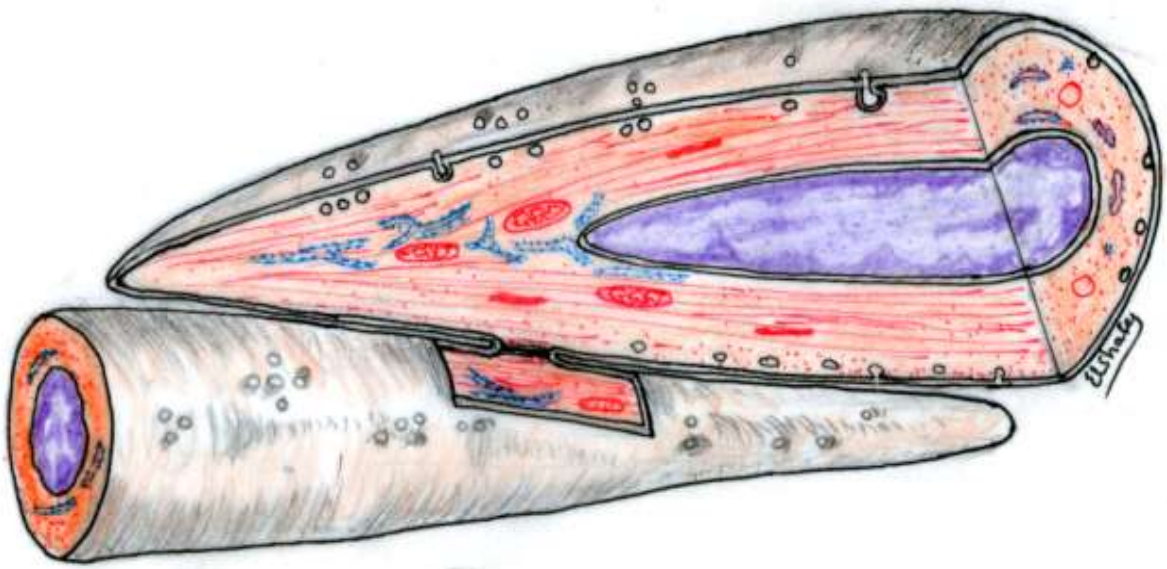

Spindles
Spindles



ASSOCIATION OF SMOOTH MUSCLE CELLS

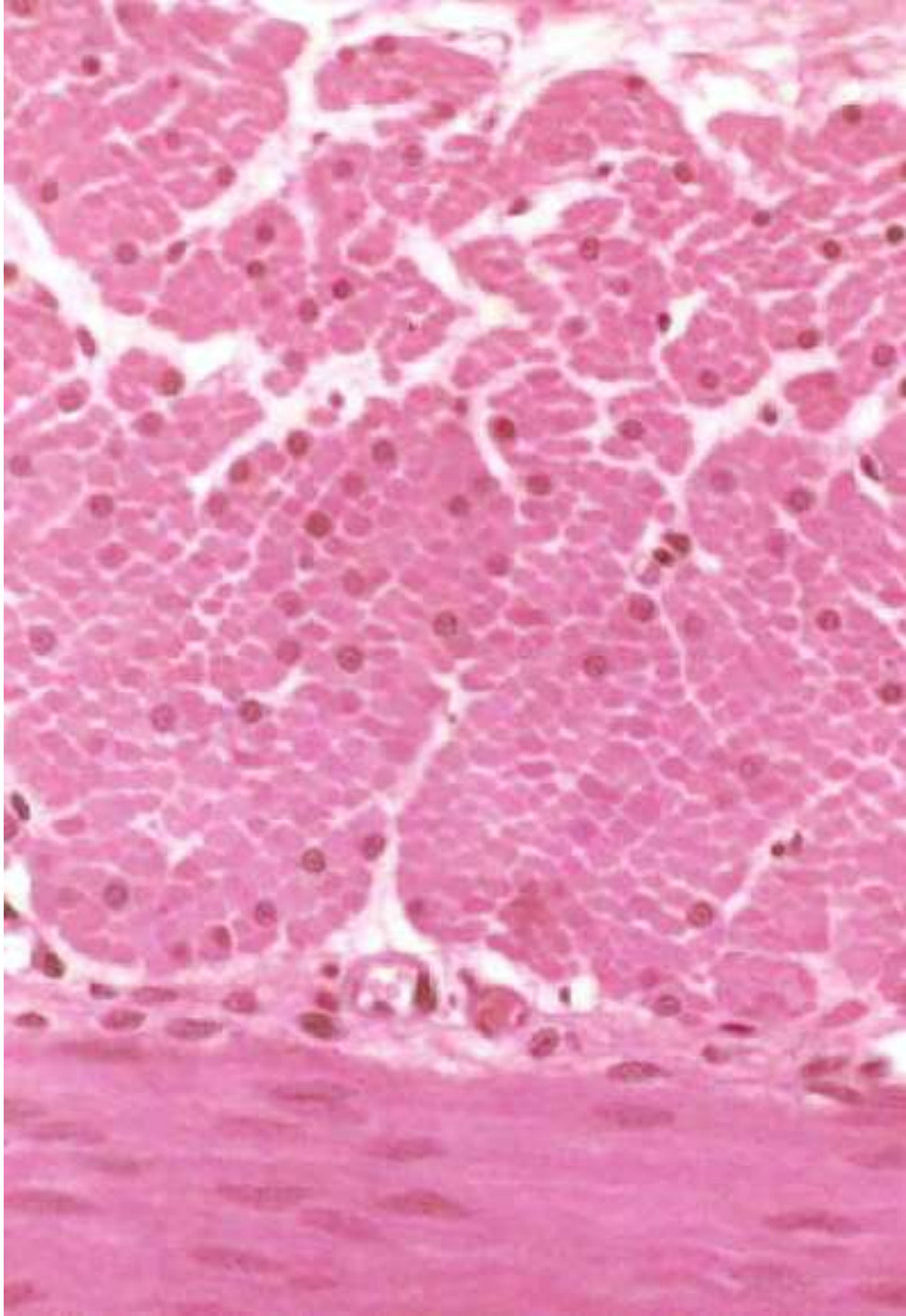
- **Adjacent cells have *gap junctions* to communicate**
- **Pinocytotic vesicles present**
  - **Ingestion of hormones, neurotransmitters, etc.**

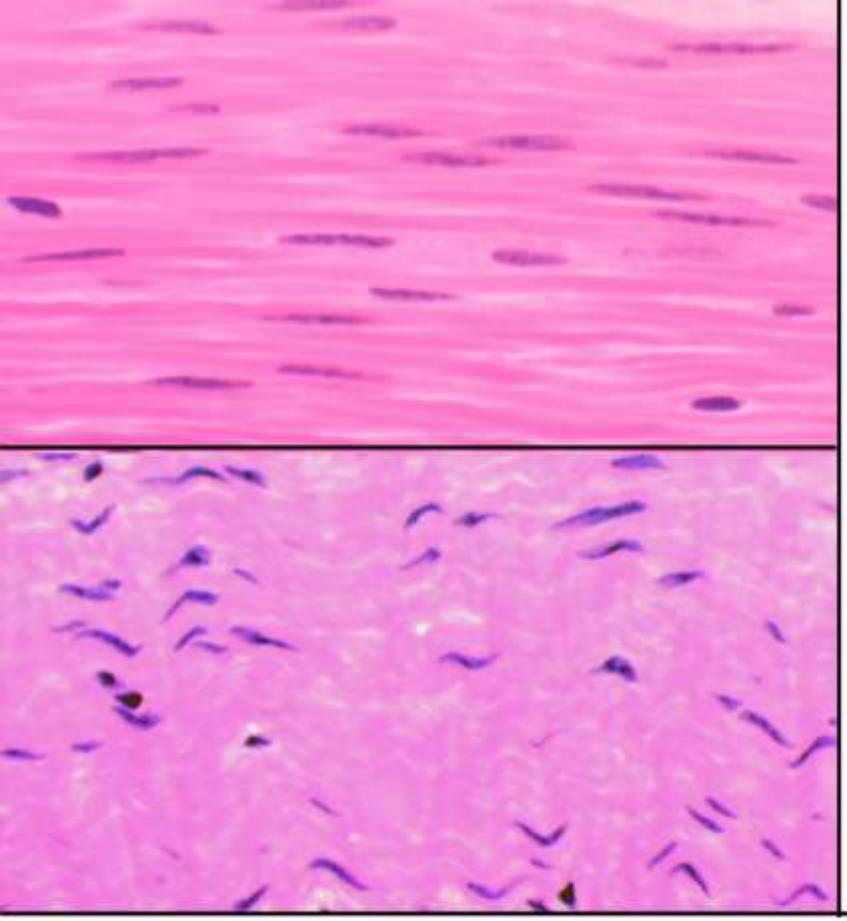




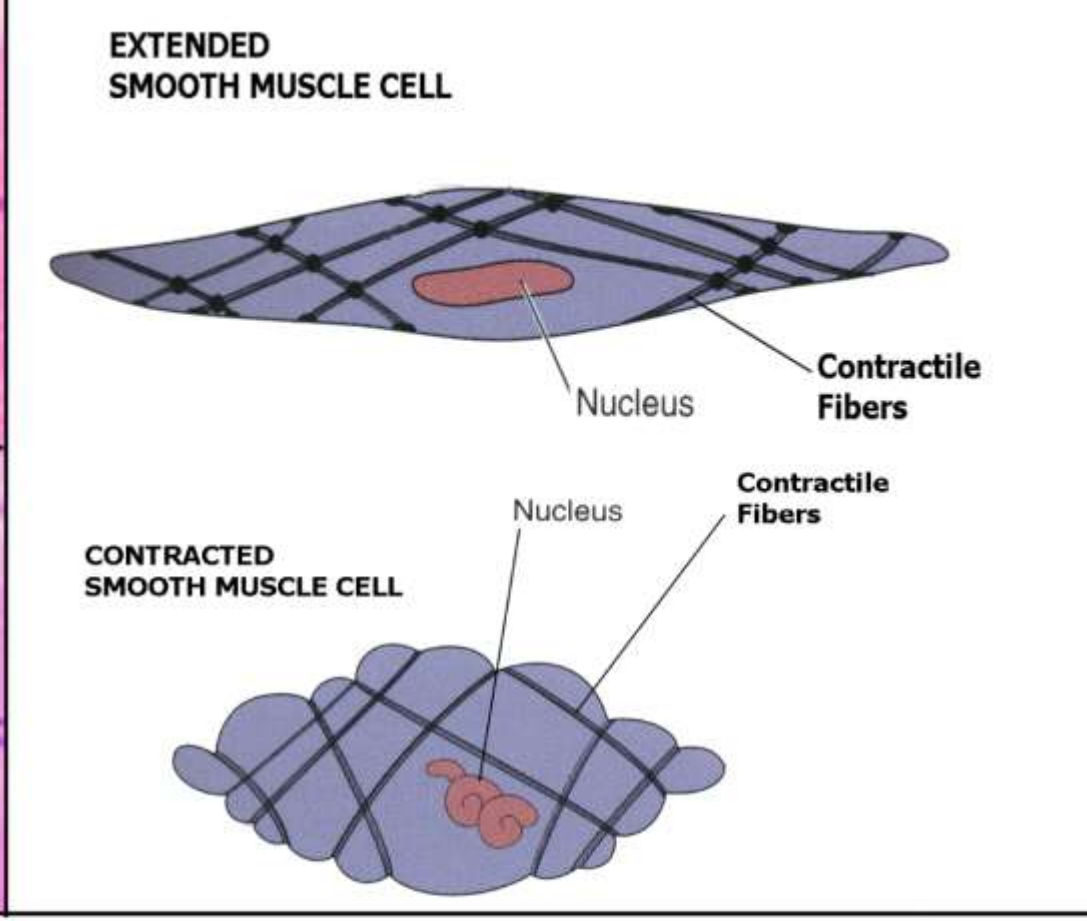
HISTOLOGY OF SMOOTH MUSCLE

- Cross sections have characteristic appearance
- Longitudinal sections easily mistaken for CT
- Tonus causes nuclei to "wrinkle" or "corkscrew" in LS





Histology of Smooth Muscle
In the Extended State (top)
In the Contracted State (bottom)



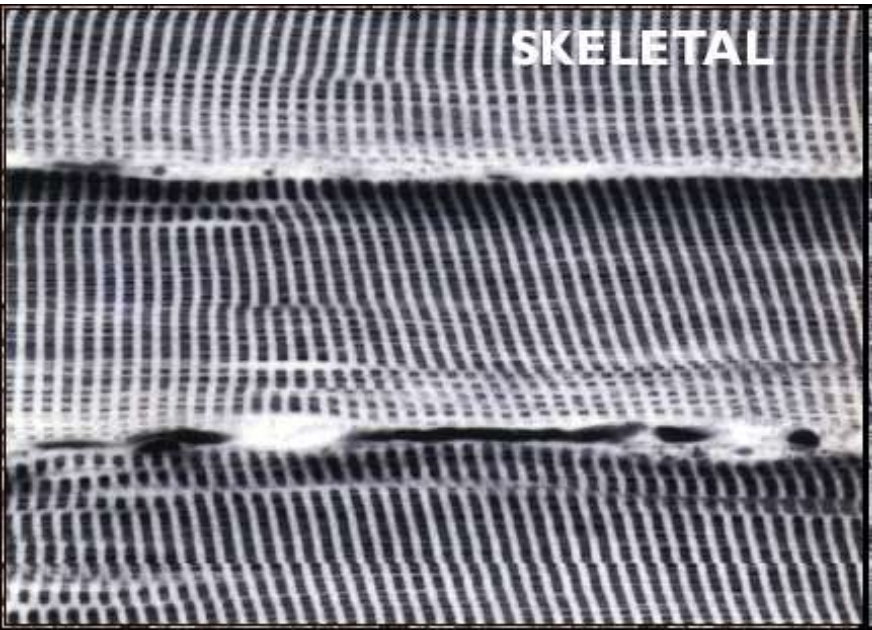
Contraction causes "corkscrew" appearance of the nuclei

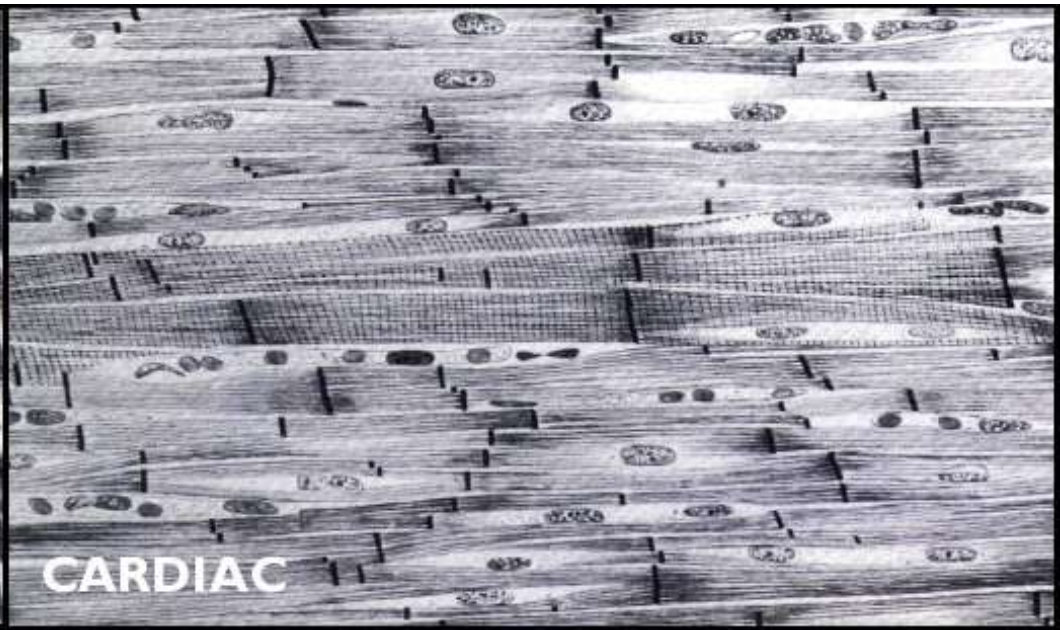
HISTOLOGY OF SMOOTH MUSCLE

- **State of contraction affects appearance!**

STRIATED MUSCLE

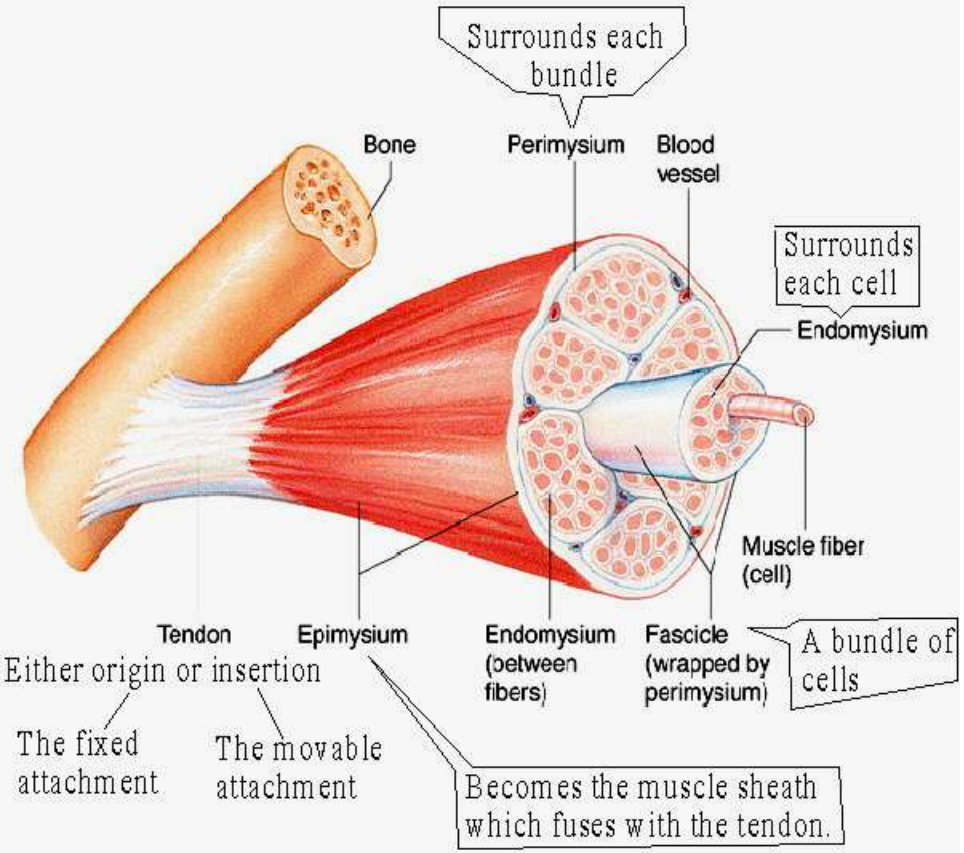
- **Two types: SKELETAL and CARDIAC**
- **More similar than they are different**
- **Skeletal muscle the archetype for both**





"Muscle" vs "Muscles"

- **Anatomic muscles can be considered *organs***
  - **All have names**
- **Principal *tissue* in them is muscle**
  - **CT is also present**
  - **Blood vessels, etc., also present**
- **Terminology of levels of organization is hierarchical**
  - **Terminology reflects different levels of activity**

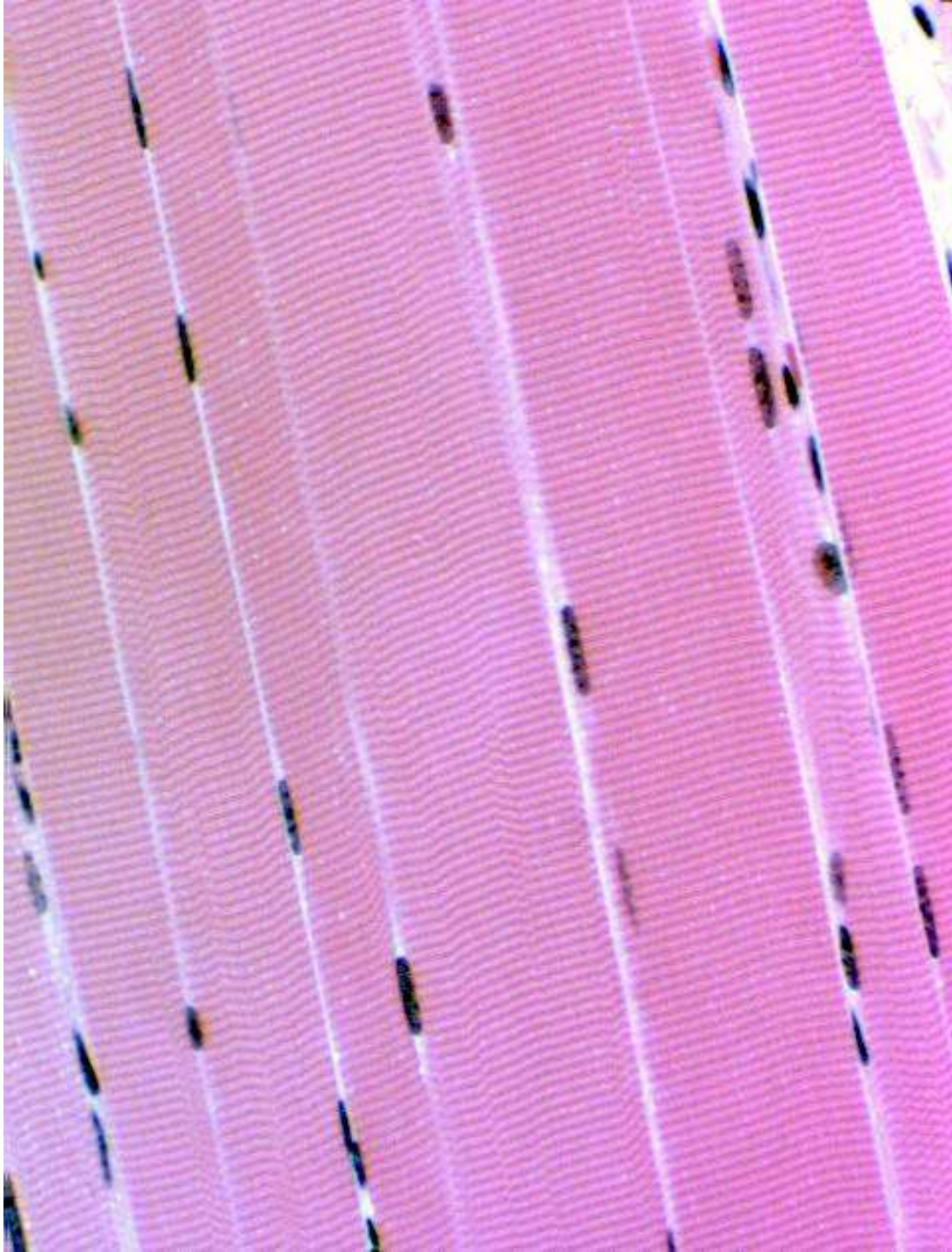


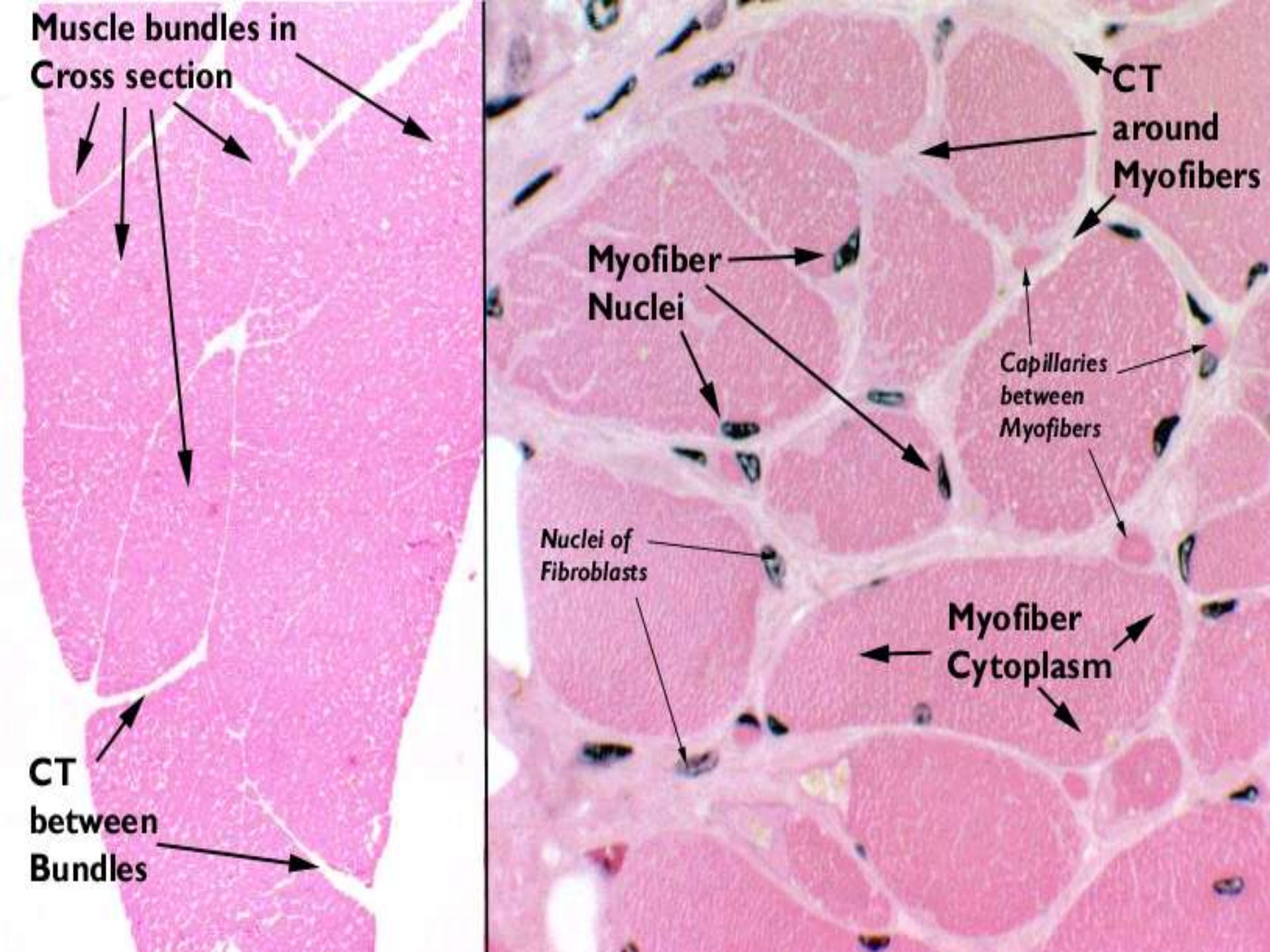
ORGANIZATION IN SKELETAL ANATOMIC MUSCLES

- CT bundles demarcate FASCICLES
- Fascicles composed of MYOFIBERS
- Myofibers are cells
- Myofibers contain MYOFIBRILS
  - Orderly arrays of filamentous subunits
- Myofibrils are made of MYOFILAMENTS
  - Actin and Myosin

SKELETAL MUSCLE

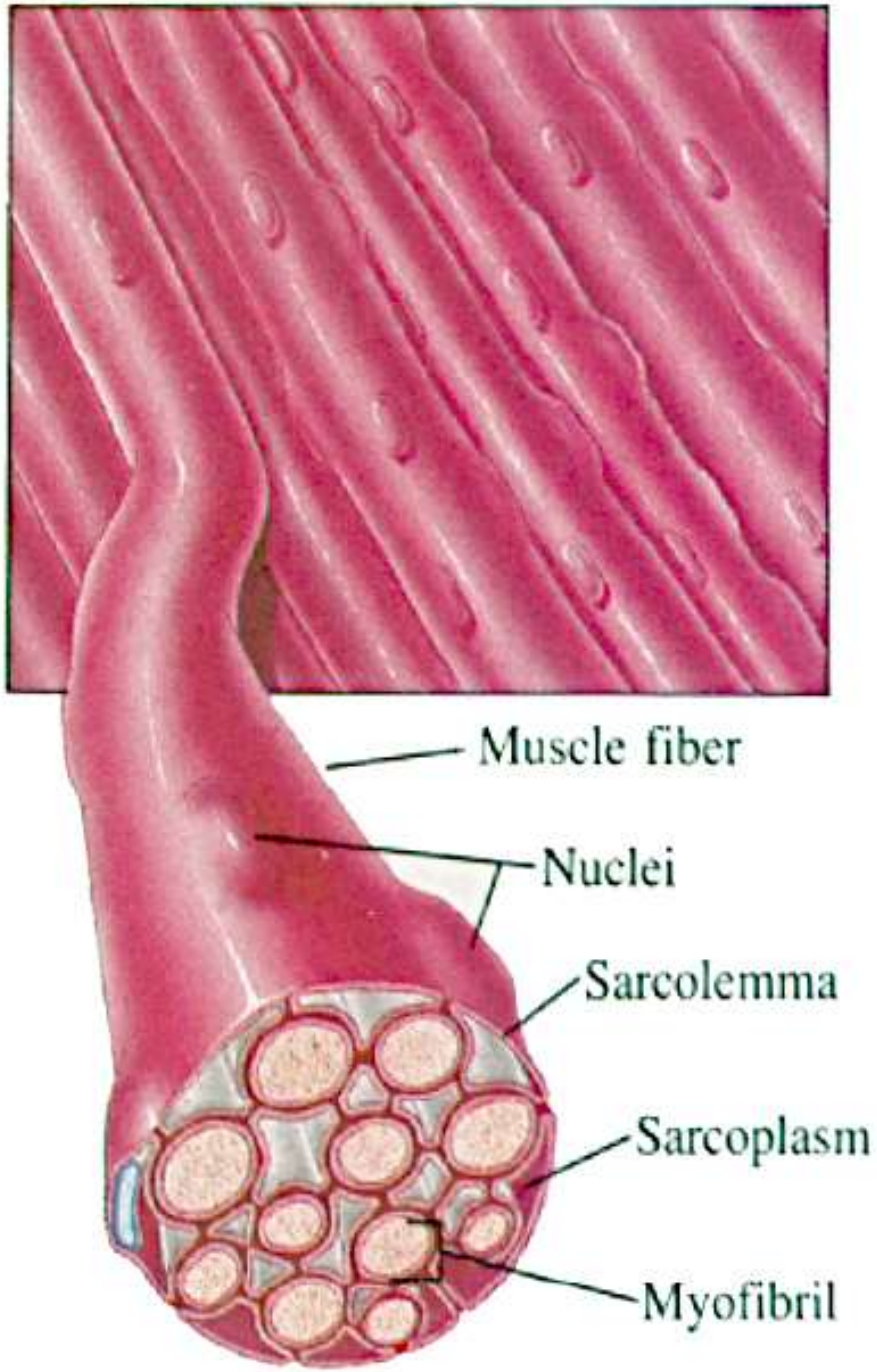
- **"Voluntary" i.e., *usually* under conscious control**
  - **Intimate, *absolutely necessary* interaction with nervous tissue**
  - **Responds *only* to nervous stimuli**
- **Most abundant form**
- **Function to provide for movement**
- **Affected by hormones, nutrition, disease, etc.**
- **Cross striations are hallmark**
  - **Very large cells**
  - **Blood vessels between**

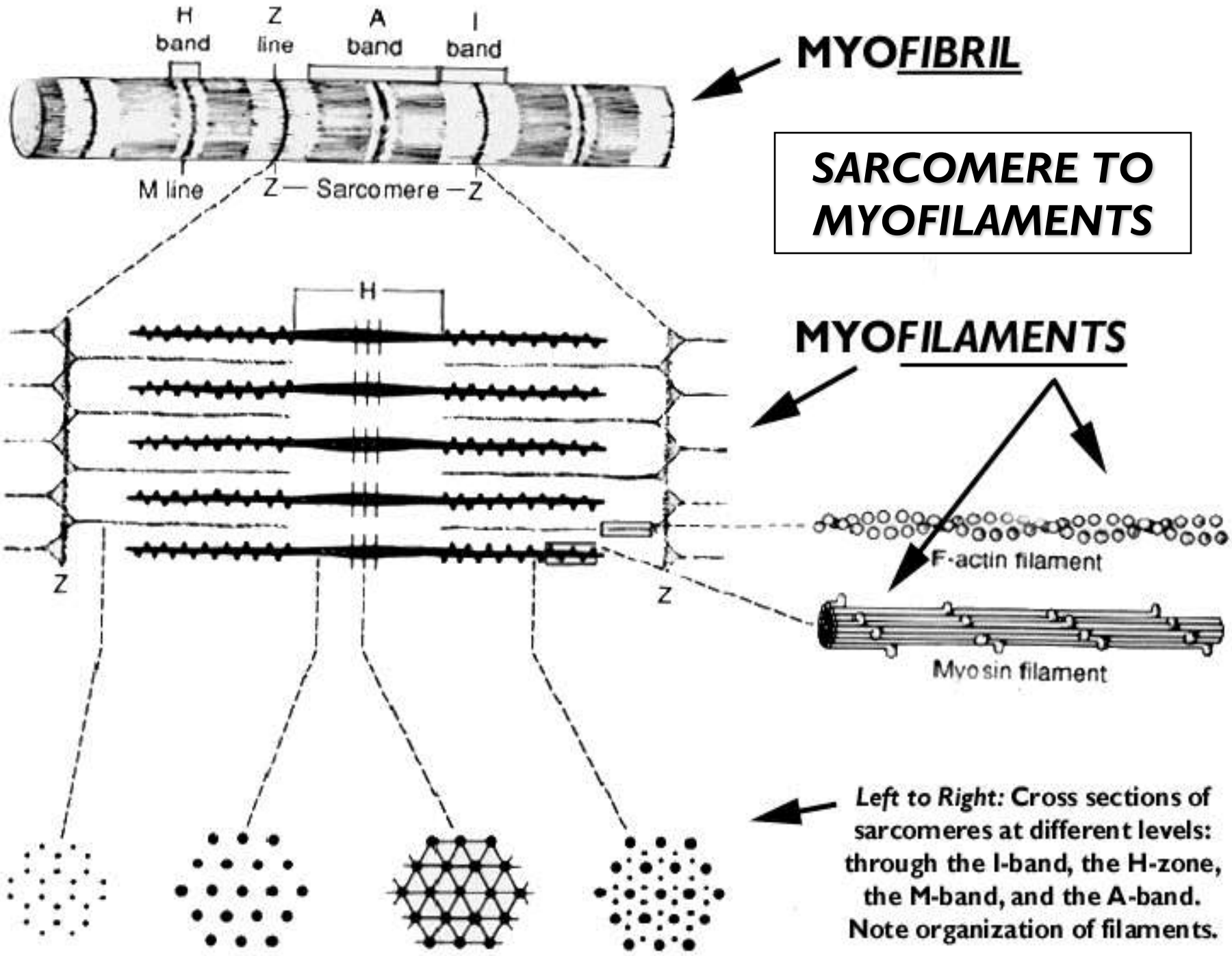


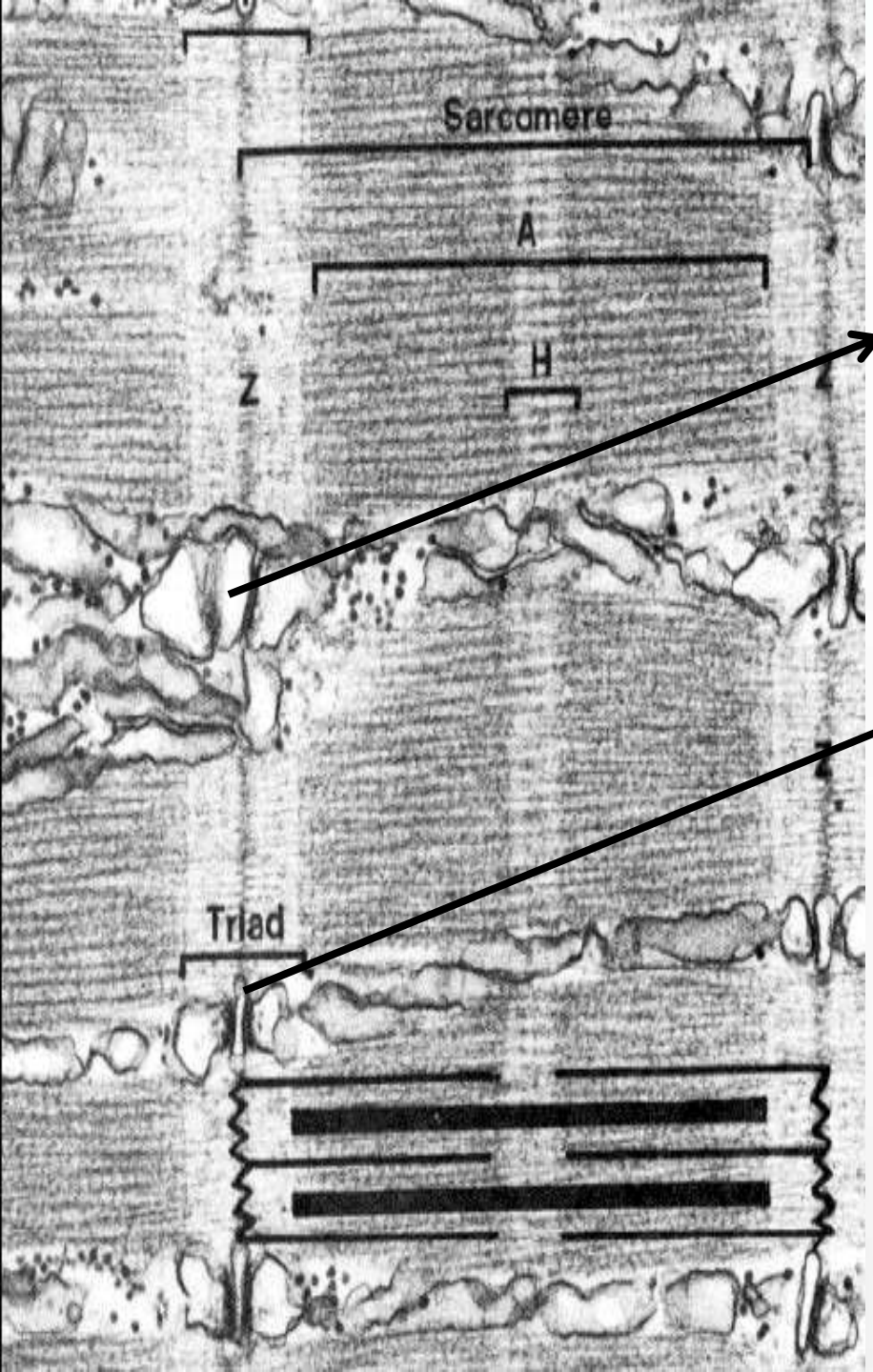

Muscle bundles in Cross section
CT between Bundles
CT around Myofibers
Myofiber Nuclei
Capillaries between Myofibers
Nuclei of Fibroblasts
Myofiber Cytoplasm

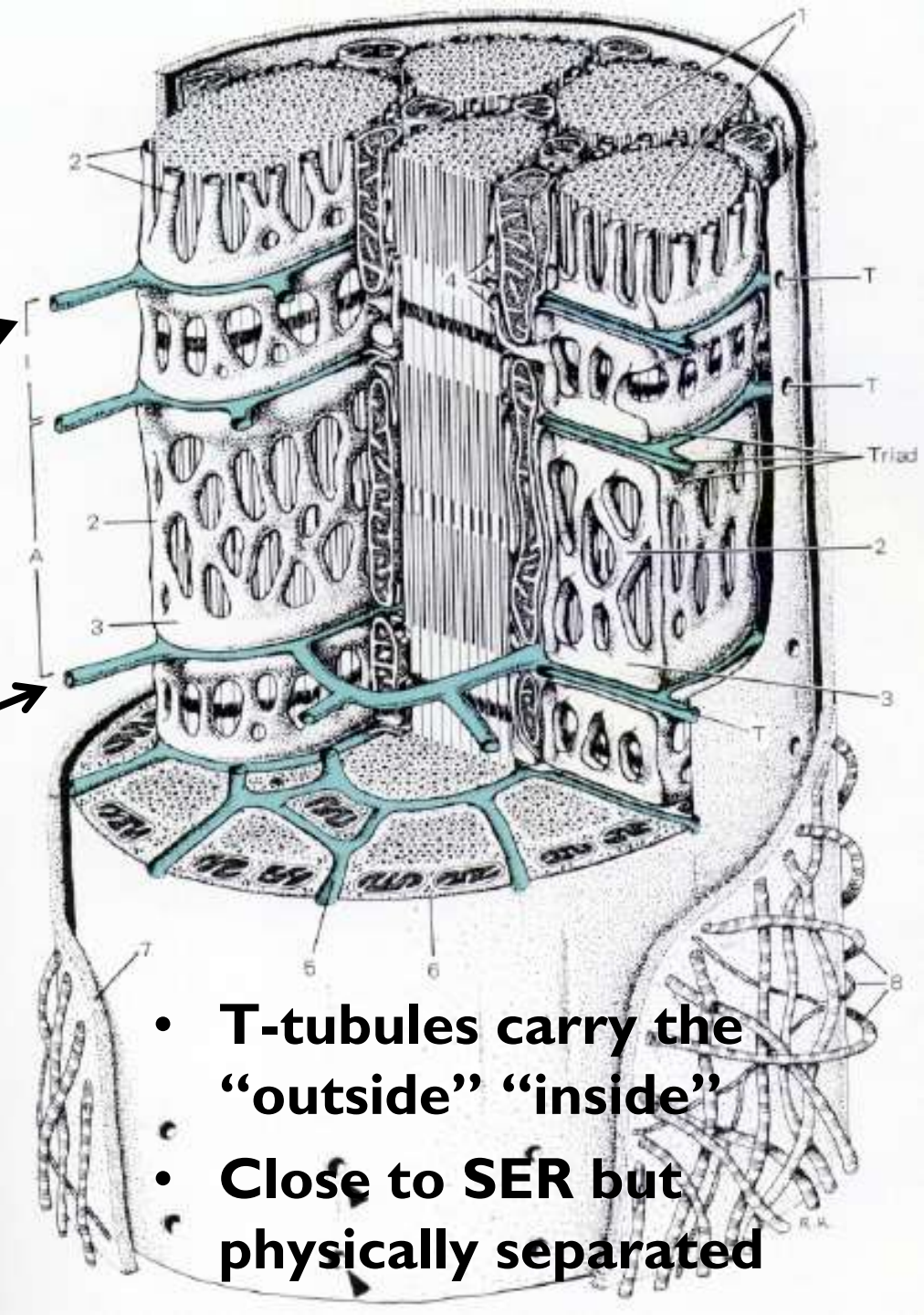
MYOFIBER

- **Basic cell of skeletal muscle**
  - **EACH myofiber is a SINGLE CELL**
- **Packed with contractile elements in PARALLEL and in REGISTER with each other**
  - **Cytoplasm almost wholly contractile material**
  - **Sarcomeres laid end to end like railroad cars**
  - **Each myofibril is anchored at the ends of the myofiber**




H band
Z line
A band
I band
MYOFIBRIL
M line
Z — Sarcomere — Z
SARCOMERE TO MYOFILAMENTS
H
MYOFILAMENTS
Z
Z
F-actin filament
Myosin filament
Left to Right: Cross sections of sarcomeres at different levels: through the I-band, the H-zone, the M-band, and the A-band. Note organization of filaments.



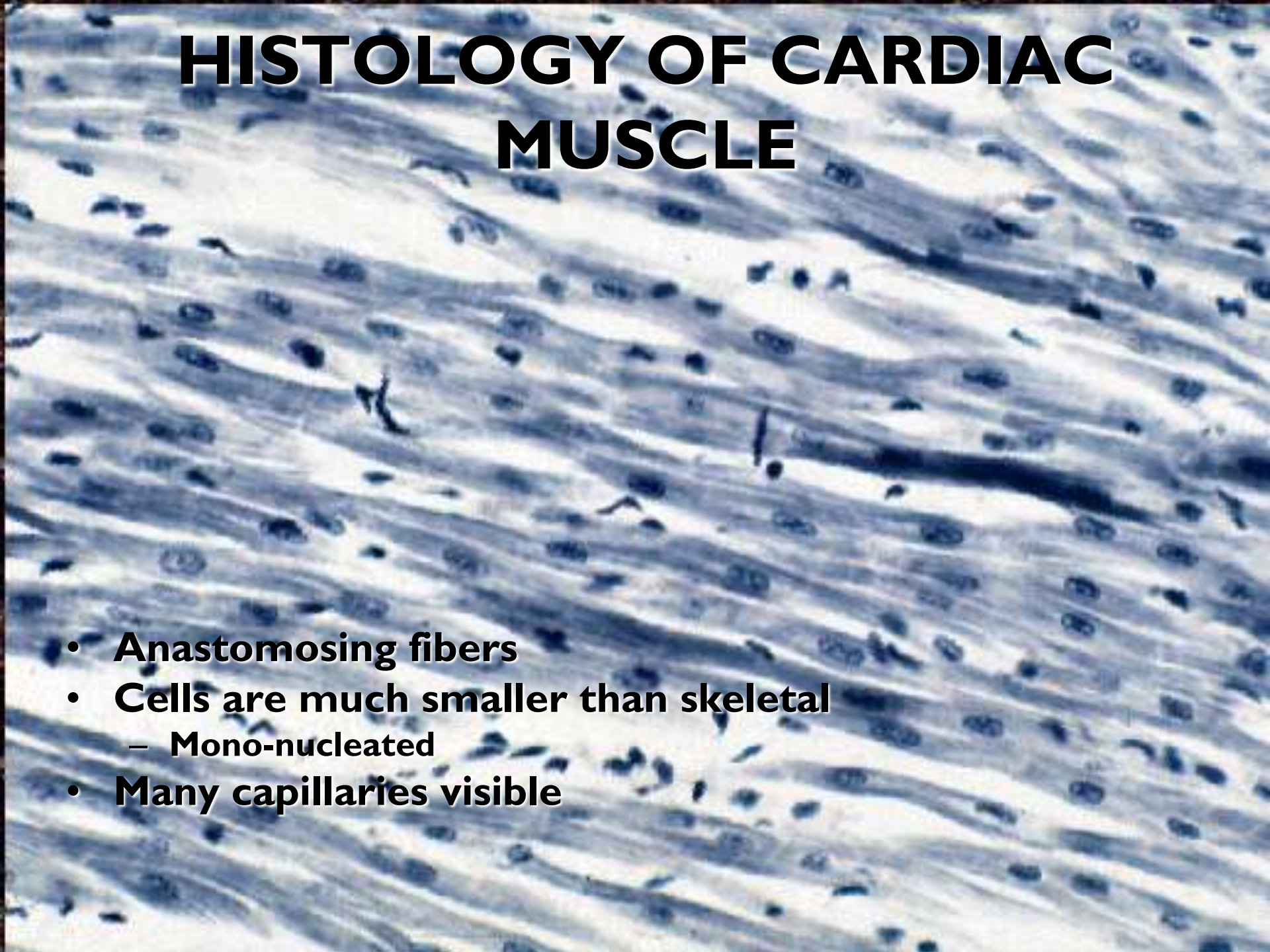


- **T-tubules carry the "outside" "inside"**
- **Close to SER but physically separated**

CARDIAC MUSCLE

- A form of striated muscle
- Found only in the heart
- Structurally similar to skeletal
  - Cells are smaller
  - Specialized communication structures
- Histology somewhat different
- Responsive to different stimuli
  - Contraction is an *inherent* property
  - No *direct* neural stimulation needed
    - *No NMJ!*

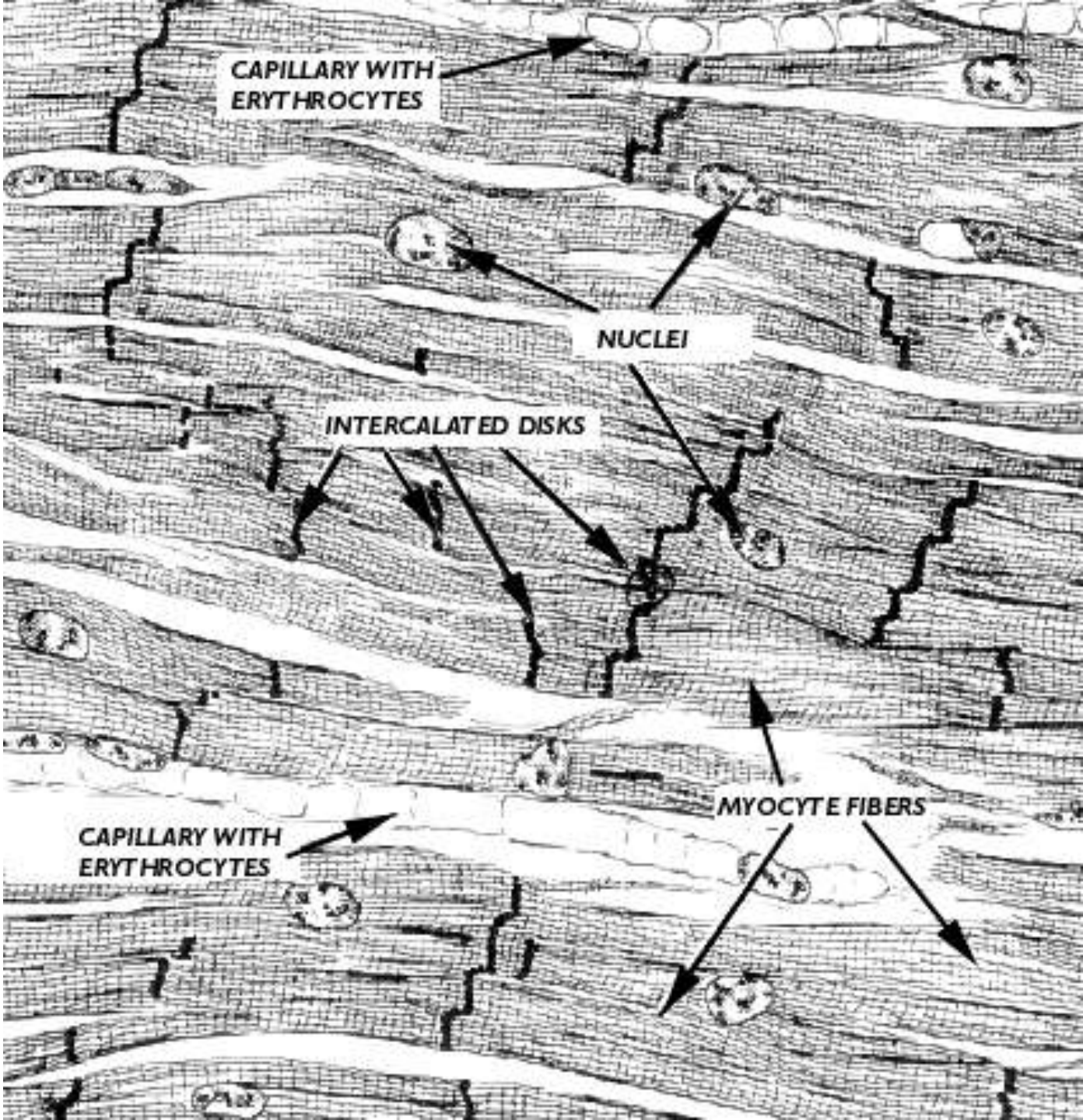
HISTOLOGY OF CARDIAC MUSCLE



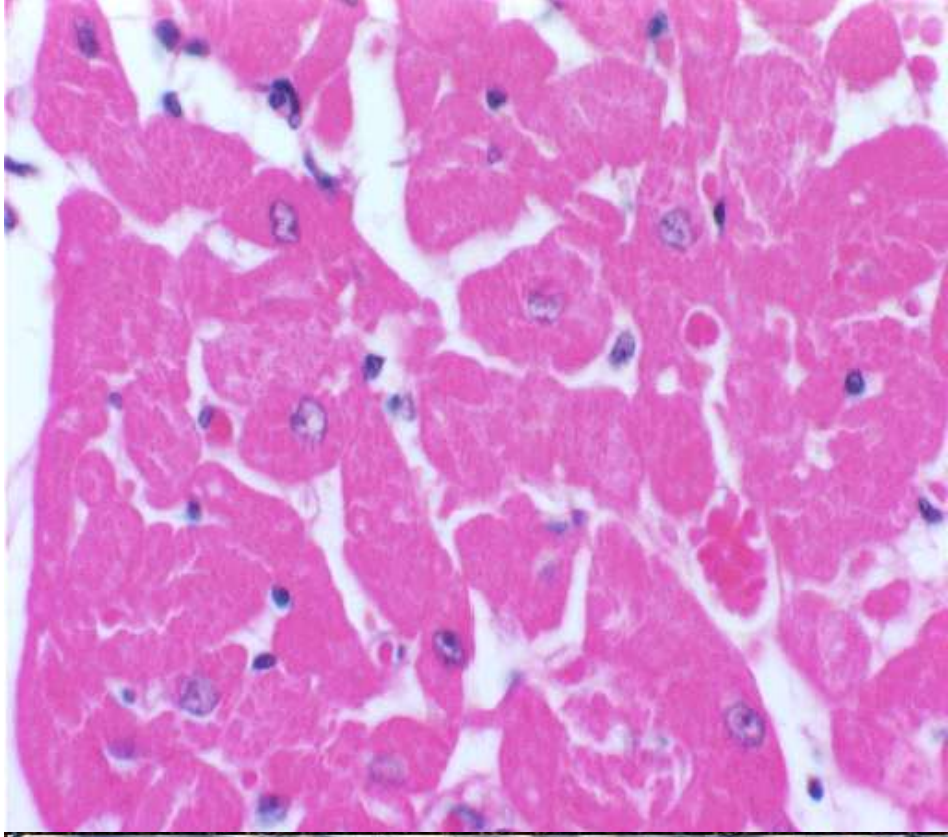
- Anastomosing fibers
- Cells are much smaller than skeletal
  - Mono-nucleated
- Many capillaries visible

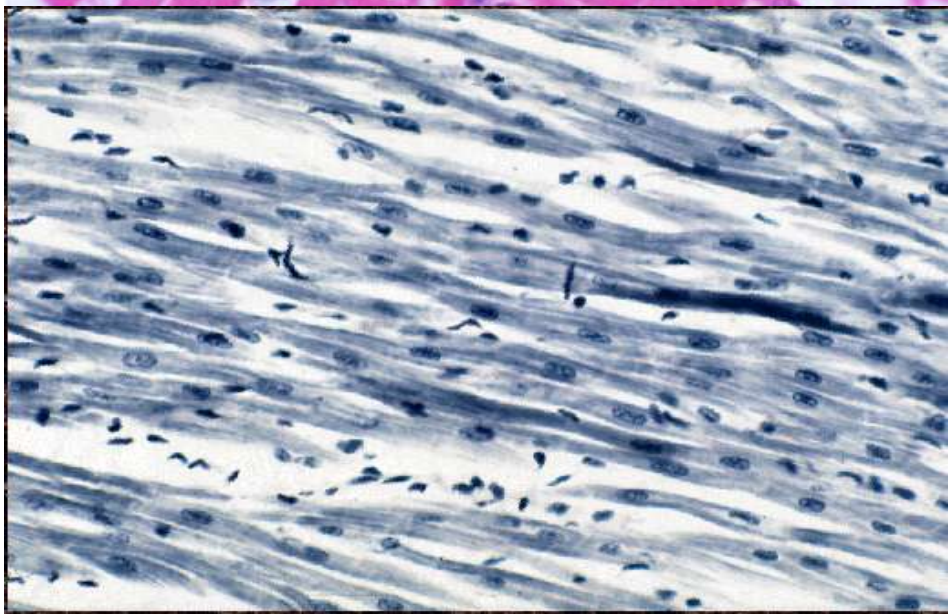
CARDIAC MUSCLE

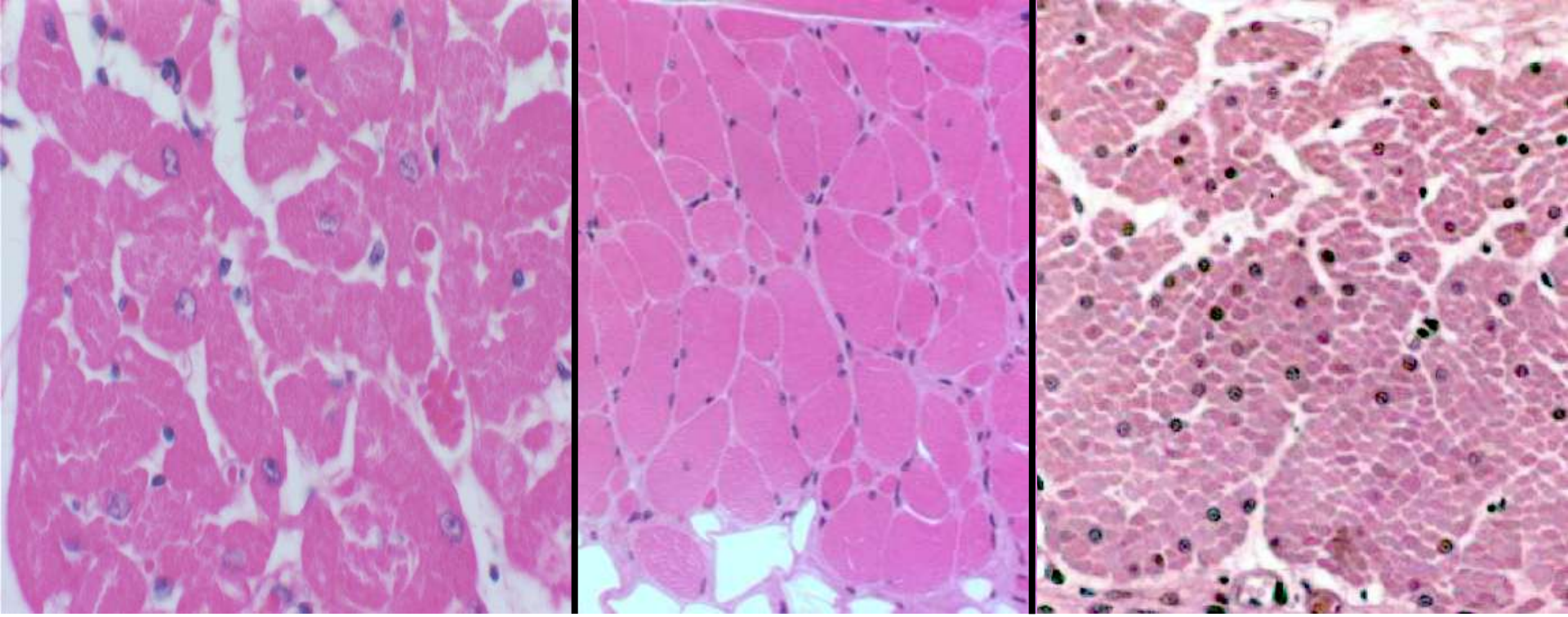
- Individual cells
  - Nucleus in center
- Striations faint
- Unique INTER-CALATED DISK
  - Diagnostic feature of CM!



- **In Cross Section:**
  - **Nuclei in CENTER of cell**
  - **Cells all about the same size**
  - **Proportionally more nuclei per unit area than Smooth muscle**







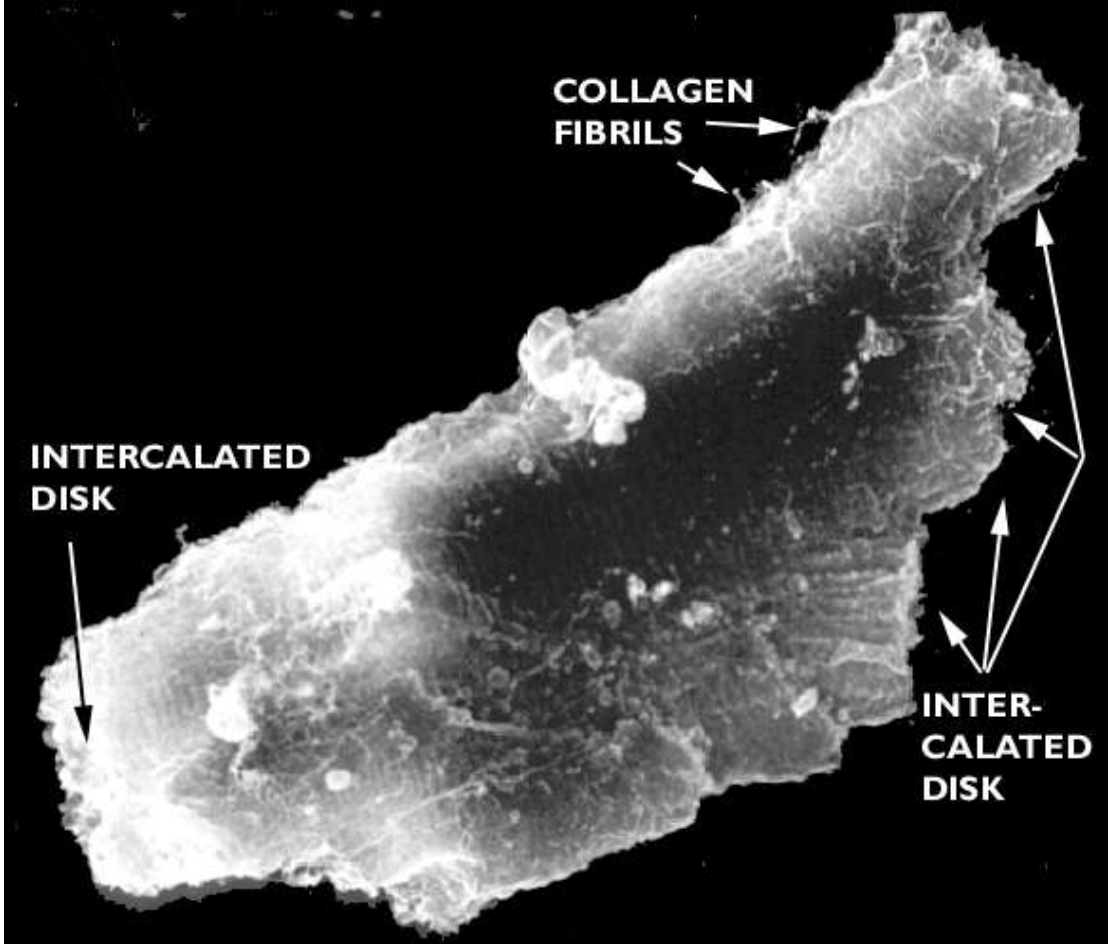
THREE CROSS SECTIONS

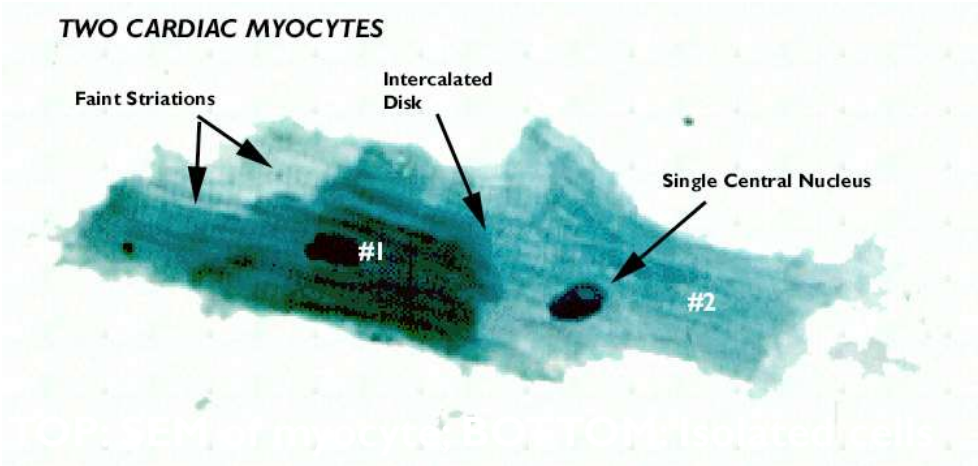
ALL AT APPROXIMATELY THE SAME MAGNIFICATION

LEFT TO RIGHT: Cardiac, Skeletal, Smooth

CARDIAC MYOCYTES

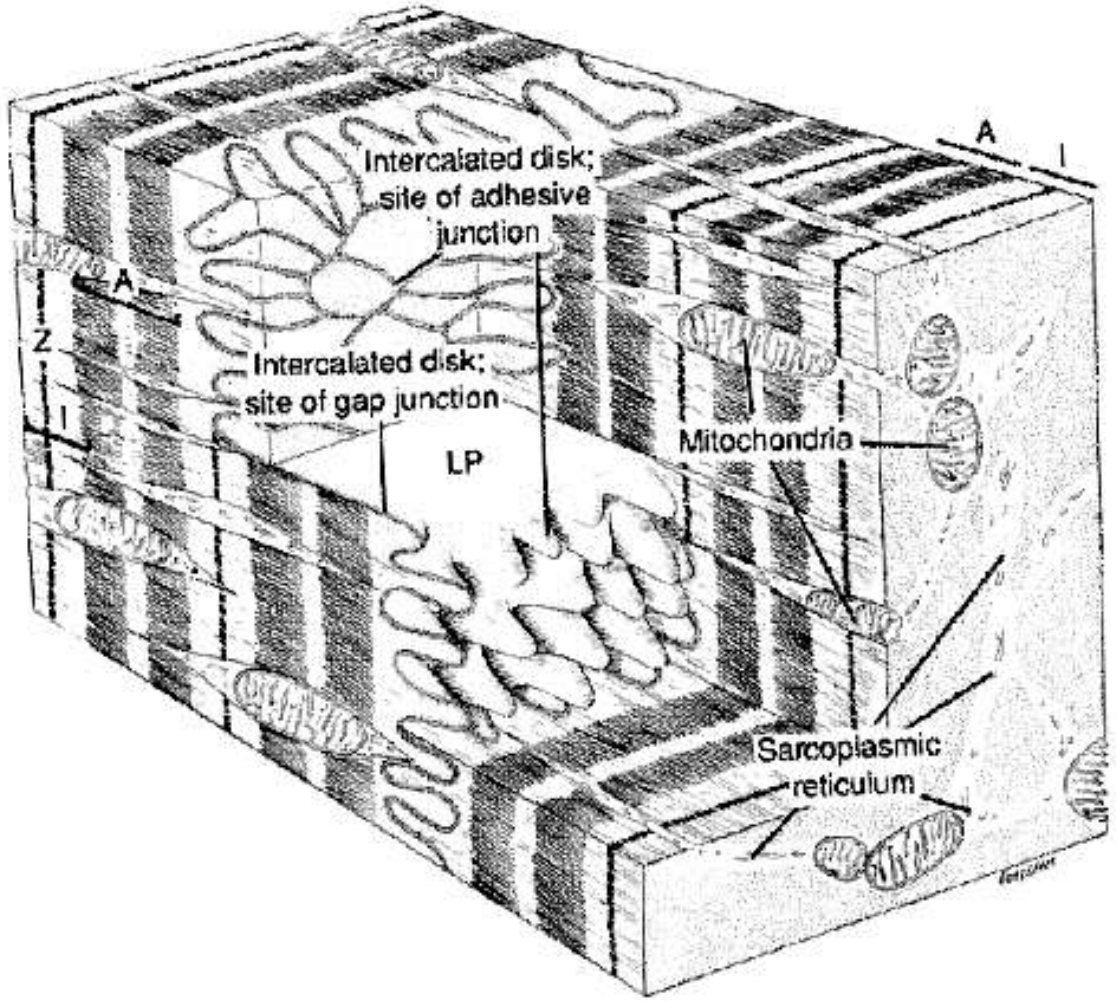
- Striations have same origin as Skeletal cells
- Length 70-100 microns
- Width 10-20 microns
  - CM Fibers composed of cells attached end-to-end!

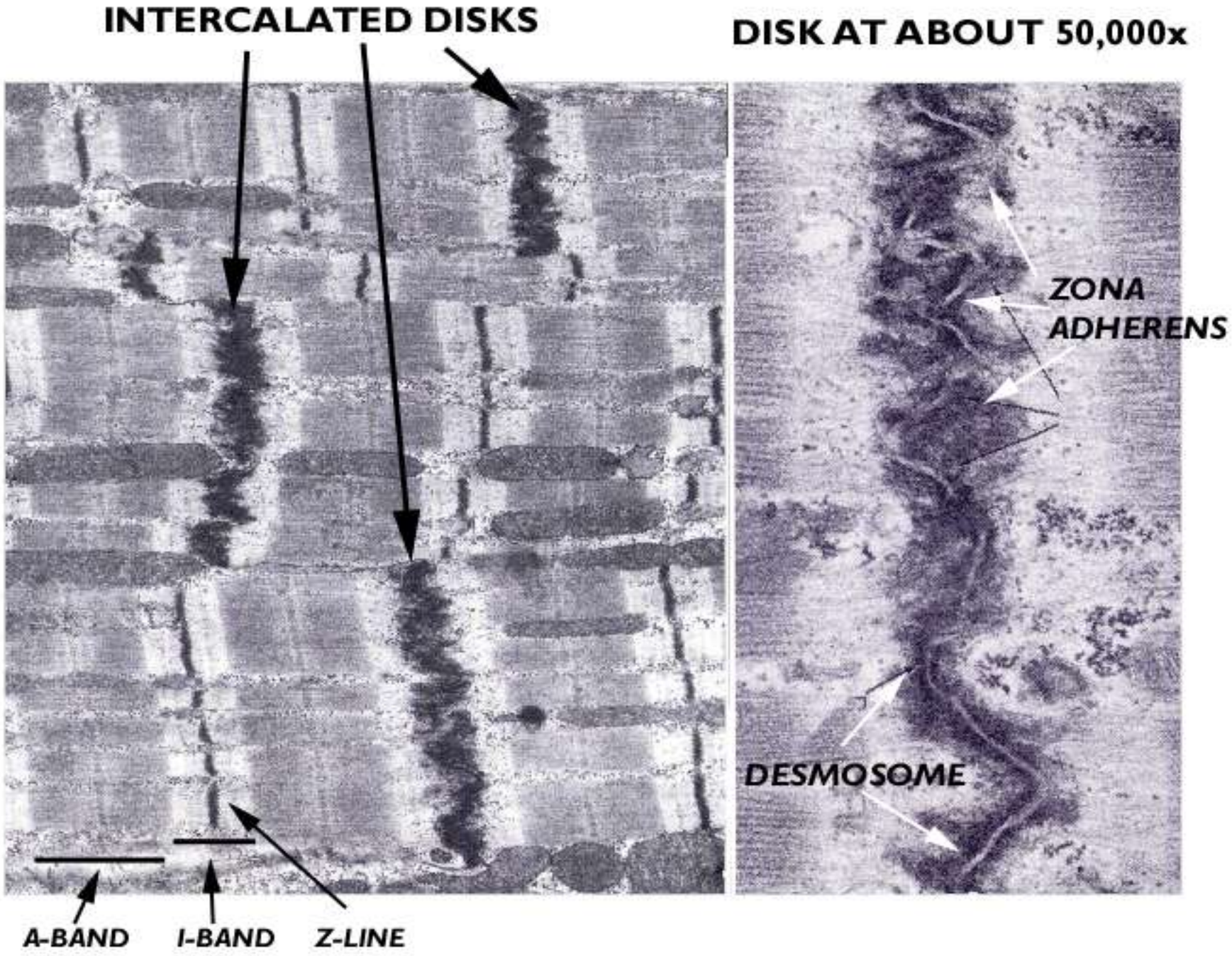




INTERCALATED DISKS

- **Special structure for COMMUNI-CATION & ADHESION**
- **3-D interlocking of adjacent cells at ends**
- **ID includes adhering junctions & gap junctions**
- **Communication & adhesion site for CM**



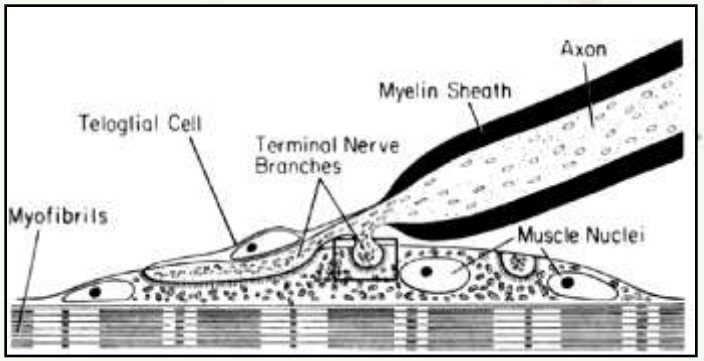

INTERCALATED DISKS
DISK AT ABOUT 50,000x
ZONA ADHERENS
DESMOSOME
A-BAND
I-BAND
Z-LINE

NEURAL RELATIONSHIPS IN MUSCLE

- Vary with type
  - SKELETAL muscle most elaborate
  - SMOOTH muscle simple but direct
  - CARDIAC muscle controlled by non-neural network & internally
- Control is monitored closely by CNS
  - Structures exist for this purpose

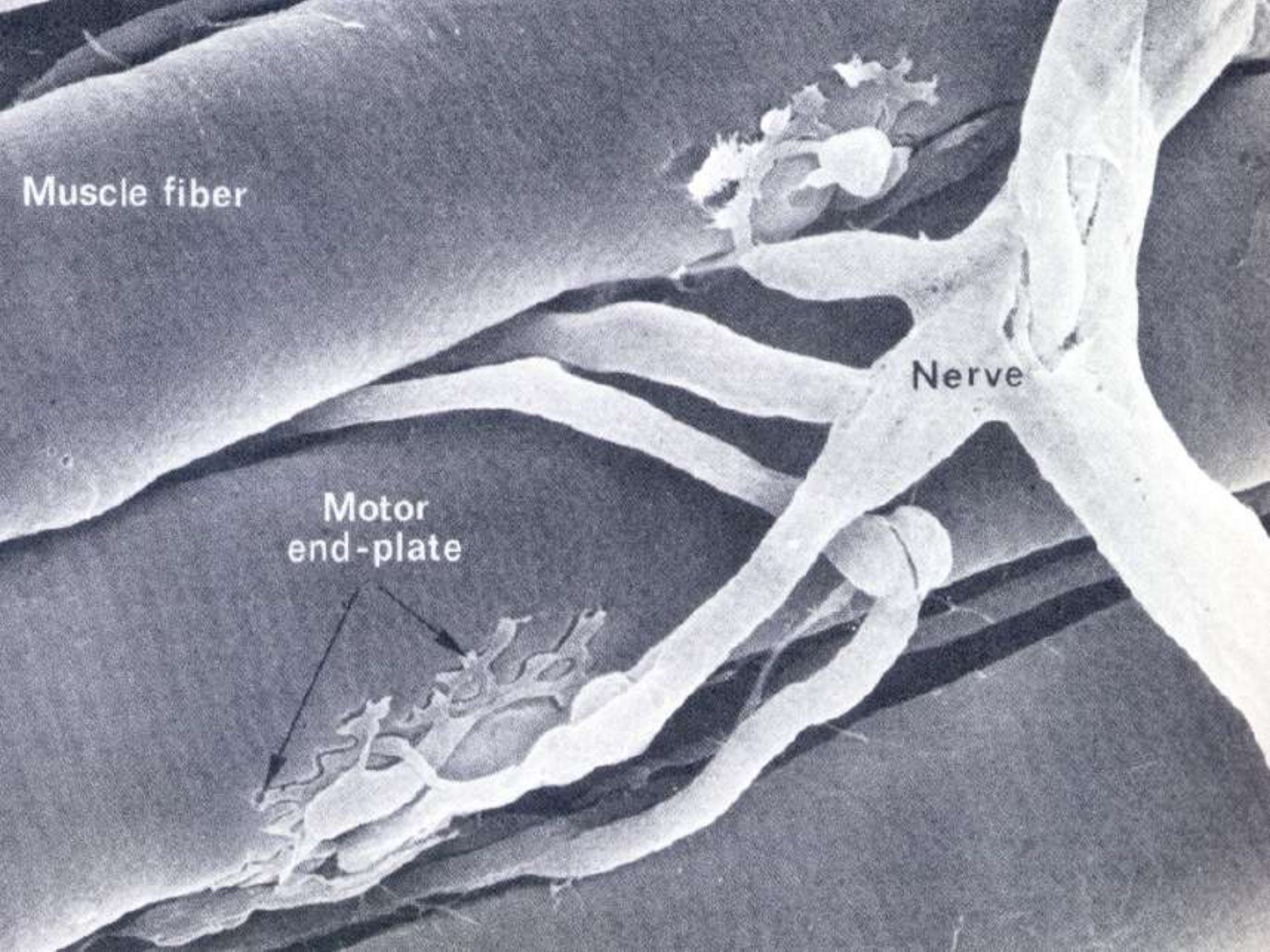
MOTOR END PLATE

- **Skeletal muscle ONLY**
- **Lacking in smooth and cardiac muscle**
- **Transmission of signal from nervous system to muscle is chemical in nature**
- **Specialized structure in PM of myofiber**
- **ONE AND *ONLY ONE* NMJ ON ANY GIVEN MYOFIBER**

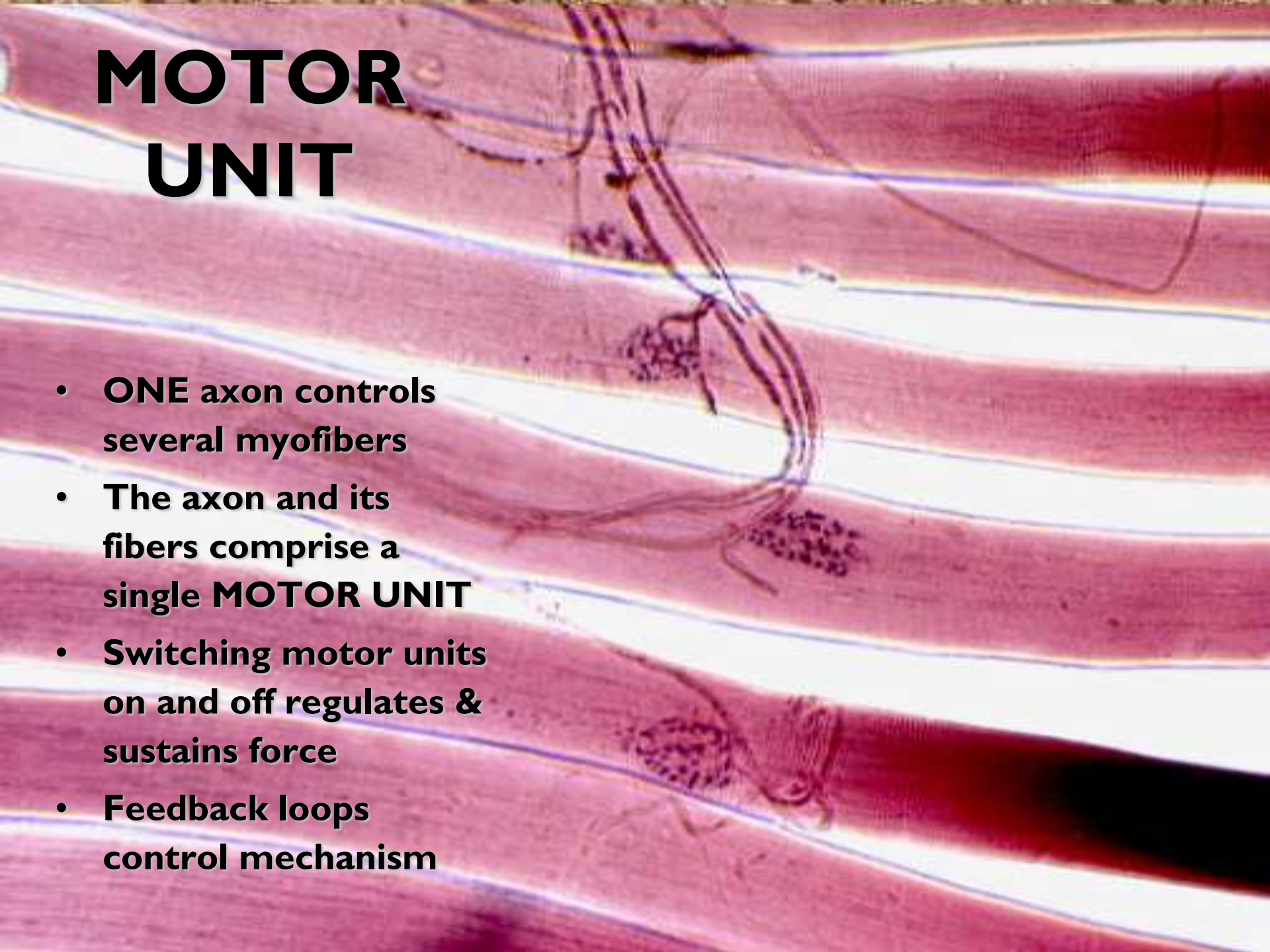


Motor End Plate

Muscle Fiber


Muscle fiber
Nerve
Motor
end-plate

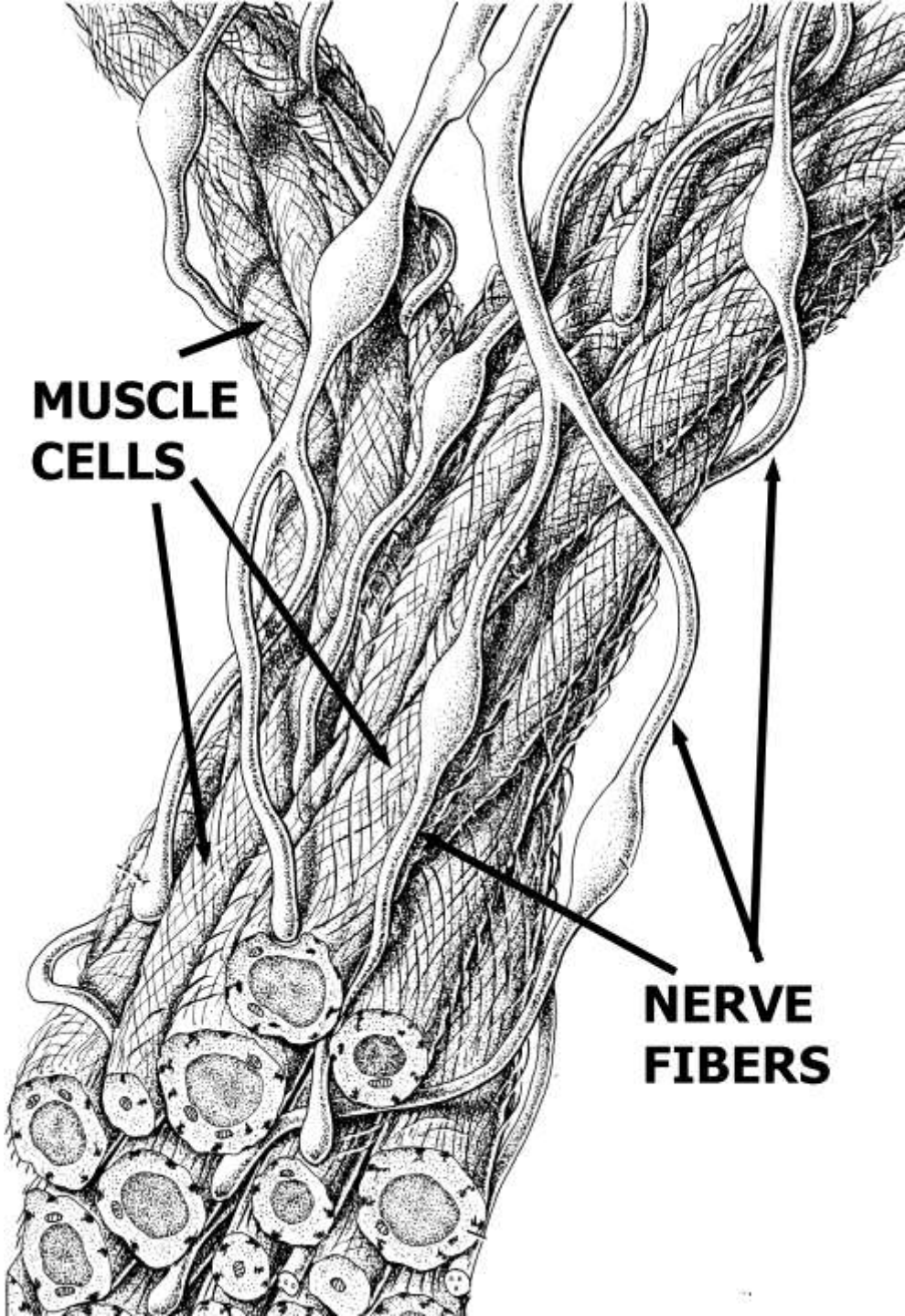
MOTOR UNIT



- **ONE axon controls several myofibers**
- **The axon and its fibers comprise a single MOTOR UNIT**
- **Switching motor units on and off regulates & sustains force**
- **Feedback loops control mechanism**

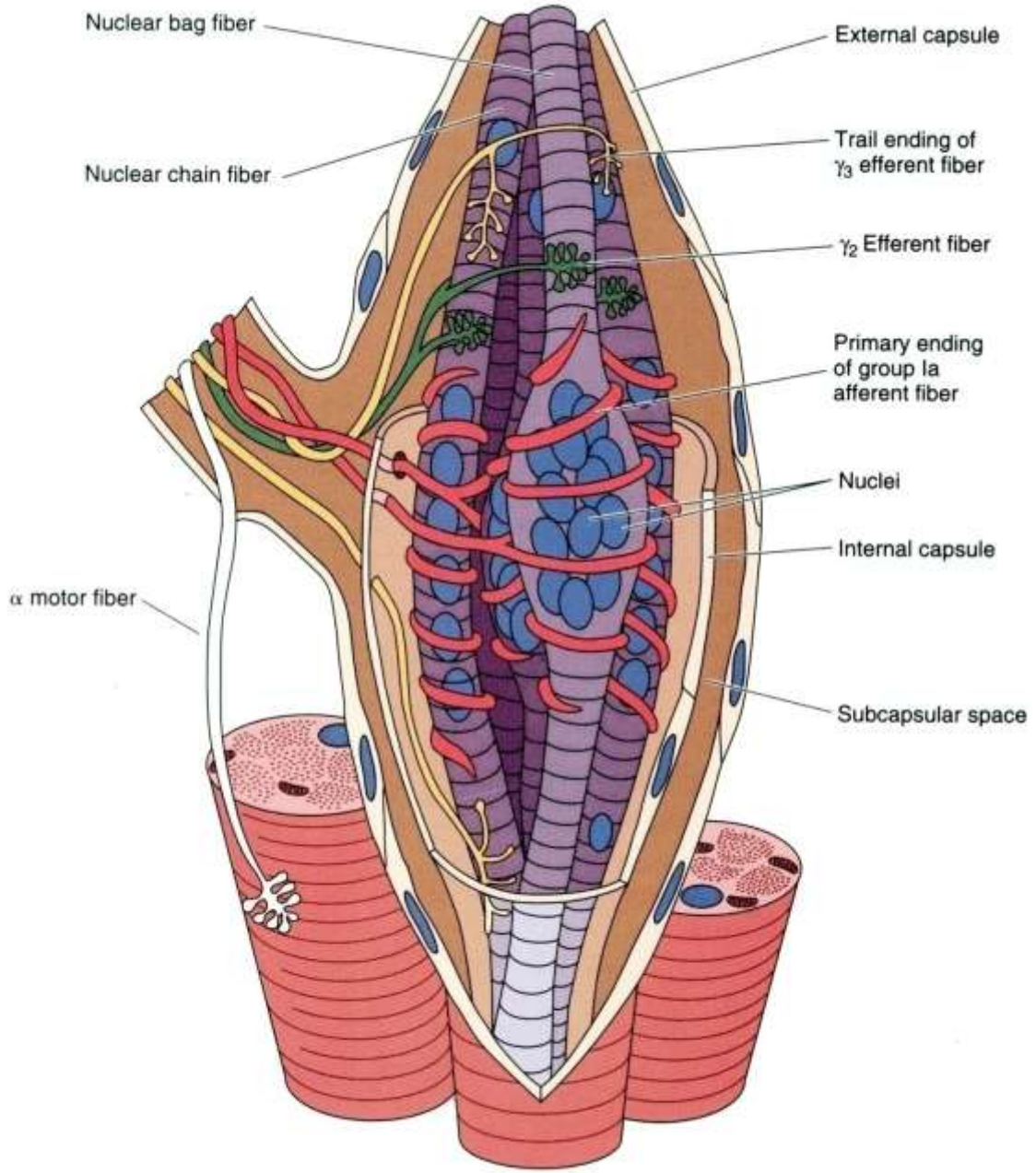
NEURAL RELATIONSHIPS IN SMOOTH MUSCLE

- NO elaborate NMJ
- Nerve fibers end on cells
- Neurotrans-mitter uptake by pinocytosis and/or diffusion



MUSCLE SPINDLE

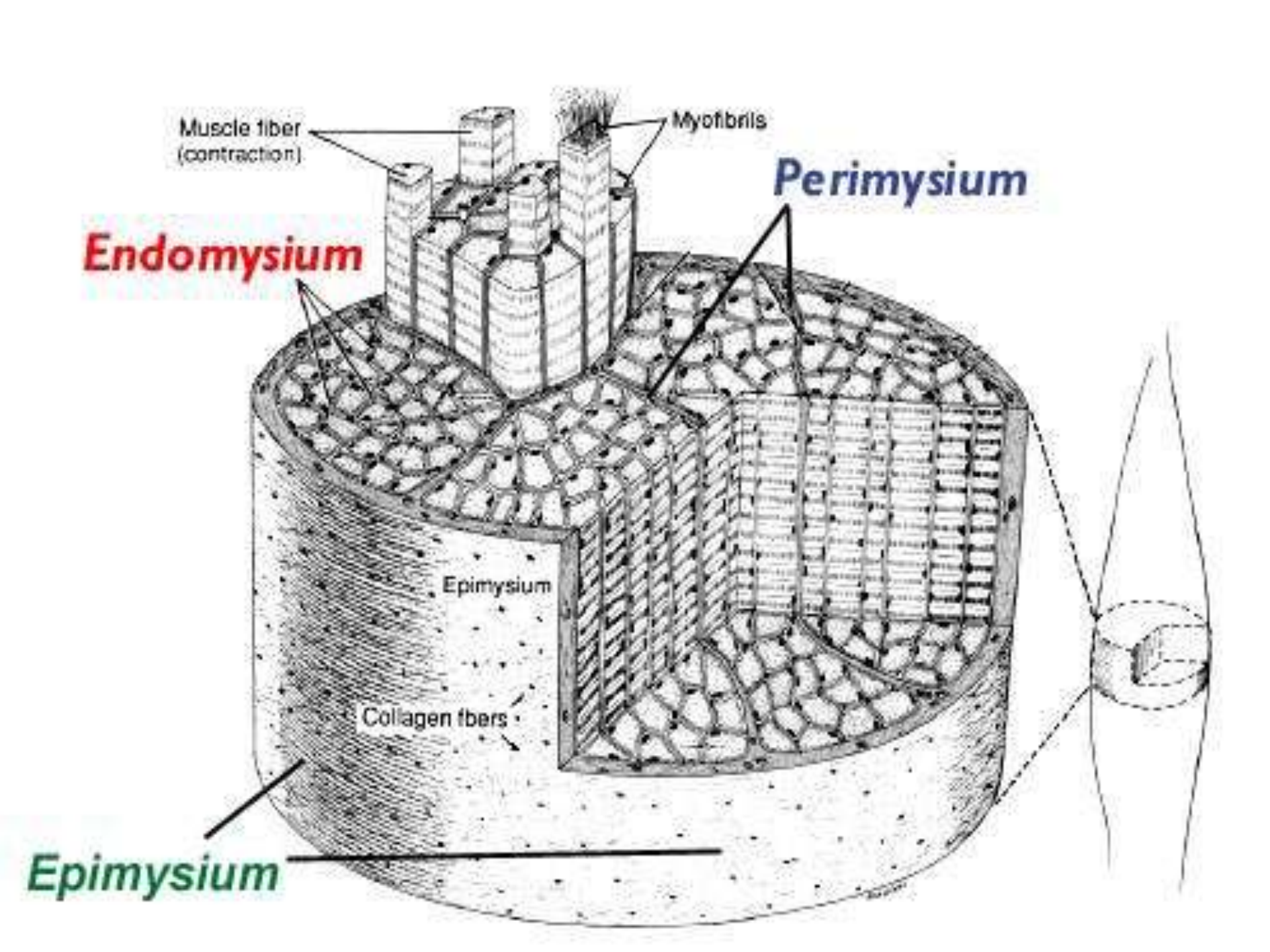
- A control device for skeletal muscle
- Works like a thermostat
  - Sensory & neural fibers
  - Modified skeletal muscle fibers
  - "Set point" can be modified as needed
- More numerous where fine control is needed



- **SPINDLE LIES AMONG FIBERS**
  - Detects tension changes & reports
  - Brain re-sets as needed

INTERCELLULAR COLLAGEN NETWORK

- All muscle cells are invested by CT
- CT forms a basketwork around cells and connects to higher levels
- Force is transmitted through CT
- No CT, no work!


Muscle fiber
(contraction)
Myofibrils
Perimysium
Endomysium
Epimysium
Collagen fibers
Epimysium

REGENERATION AND REPAIR

- Muscle cells can't divide
  - Injury usually causes some loss of material, part or all of a myofiber
- Scarring "fills in" the space with collagen
  - Collagen is non-contractile
- A scanty reserve of myoblasts exists in skeletal muscle
  - Not in smooth or cardiac
  - MAY be some LIMITED regeneration from these, but not much!
  - Never in cardiac muscle