

04-00

# Muscular Tissue

# 04 Muscular Tissue

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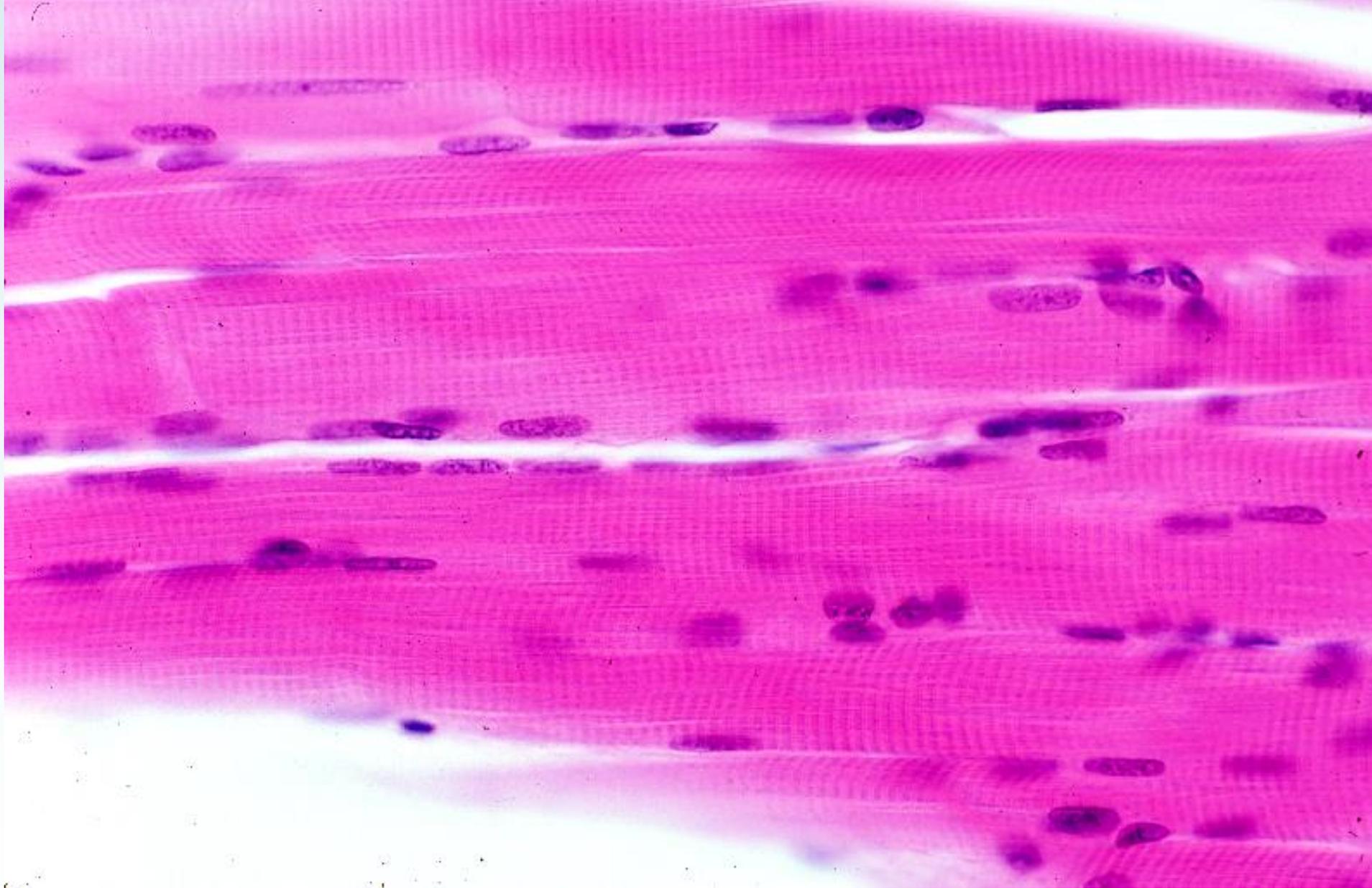
[04-32.](#) Smooth muscle fibers, transverse section. Human, H-E stain. X 160.

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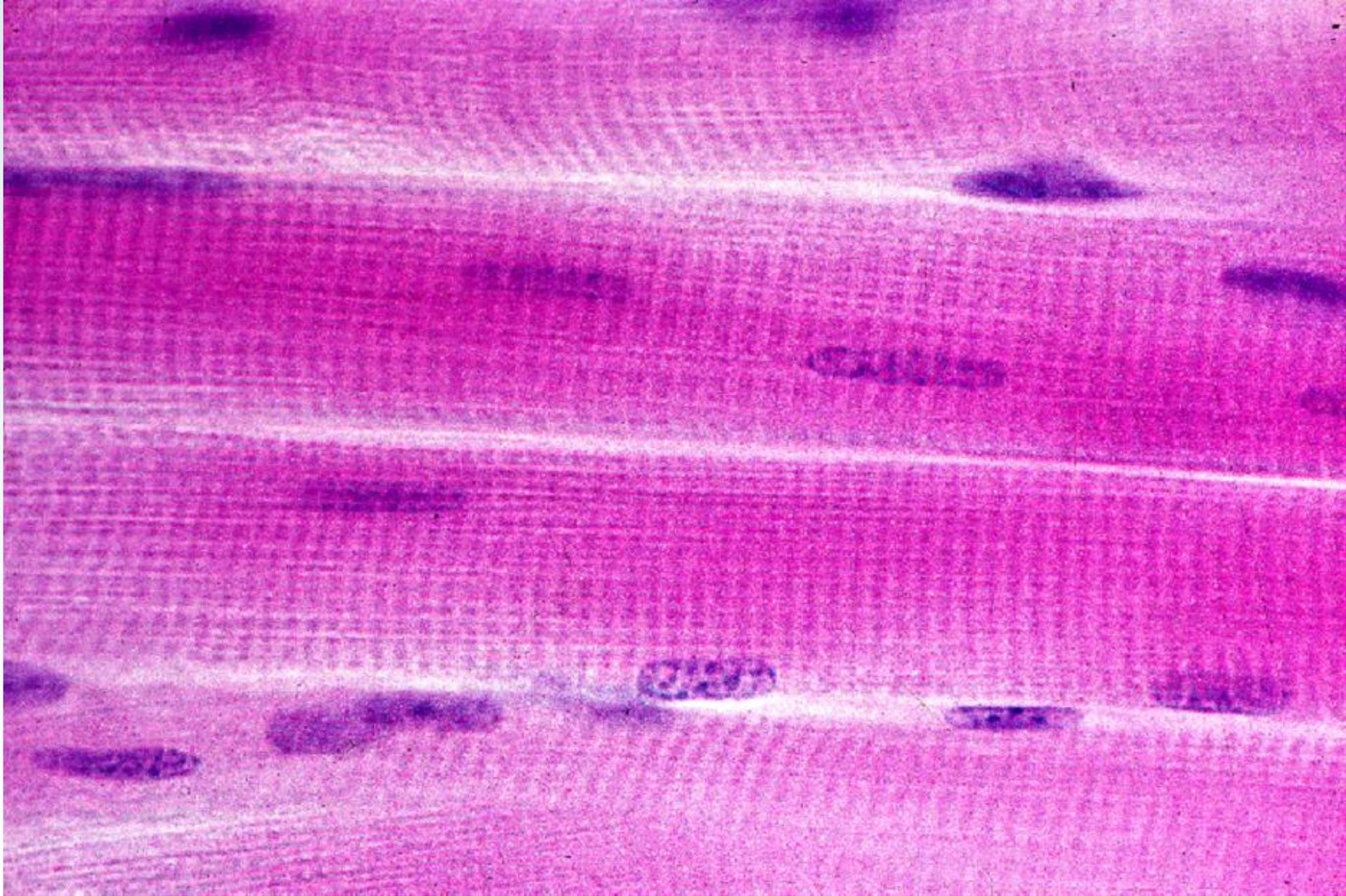
[04-34.](#) Smooth muscle fibers, transverse section. Human, silver impregnation and Kernechtrot stain. X 250.

# 04-001

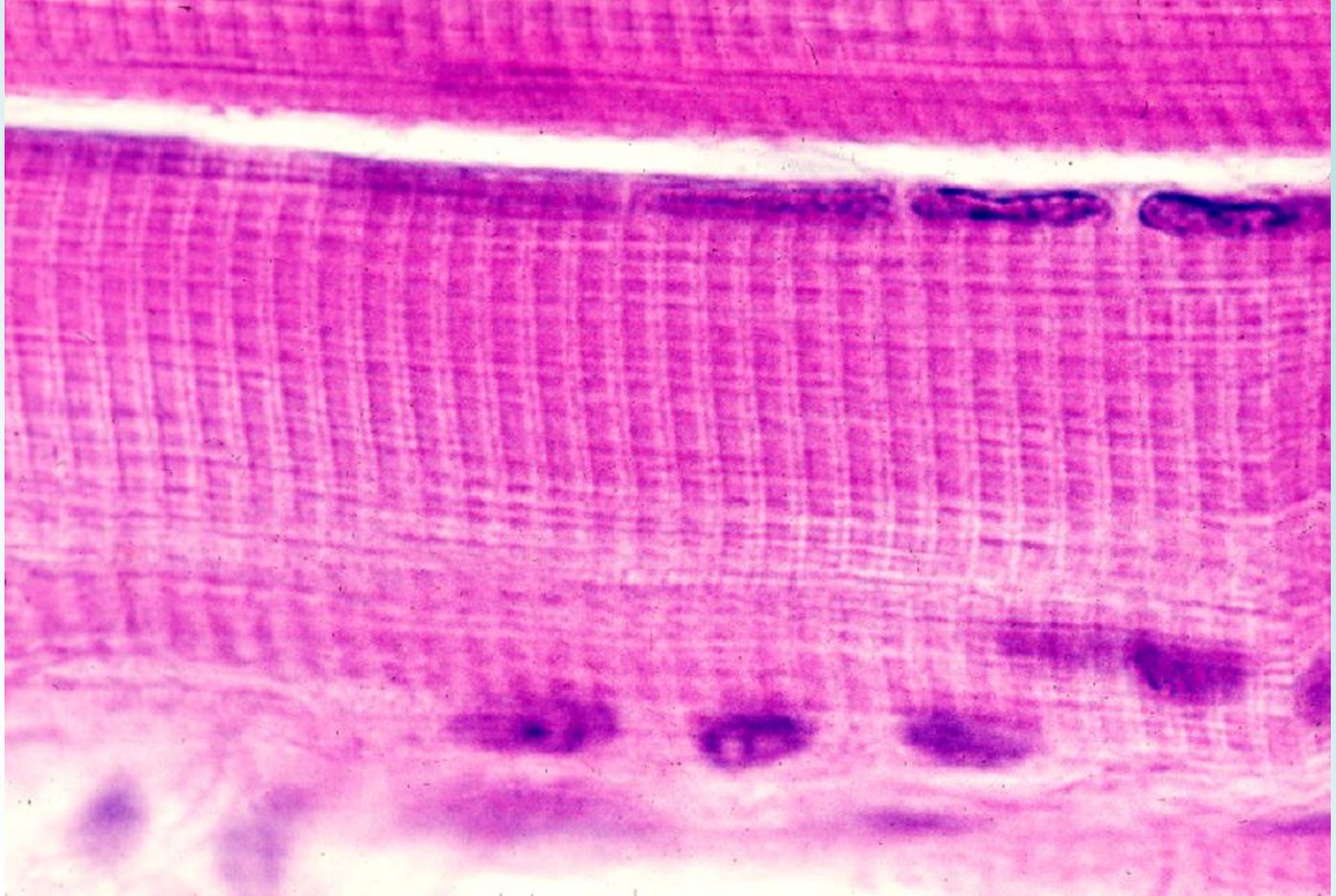
# Skeletal Muscle



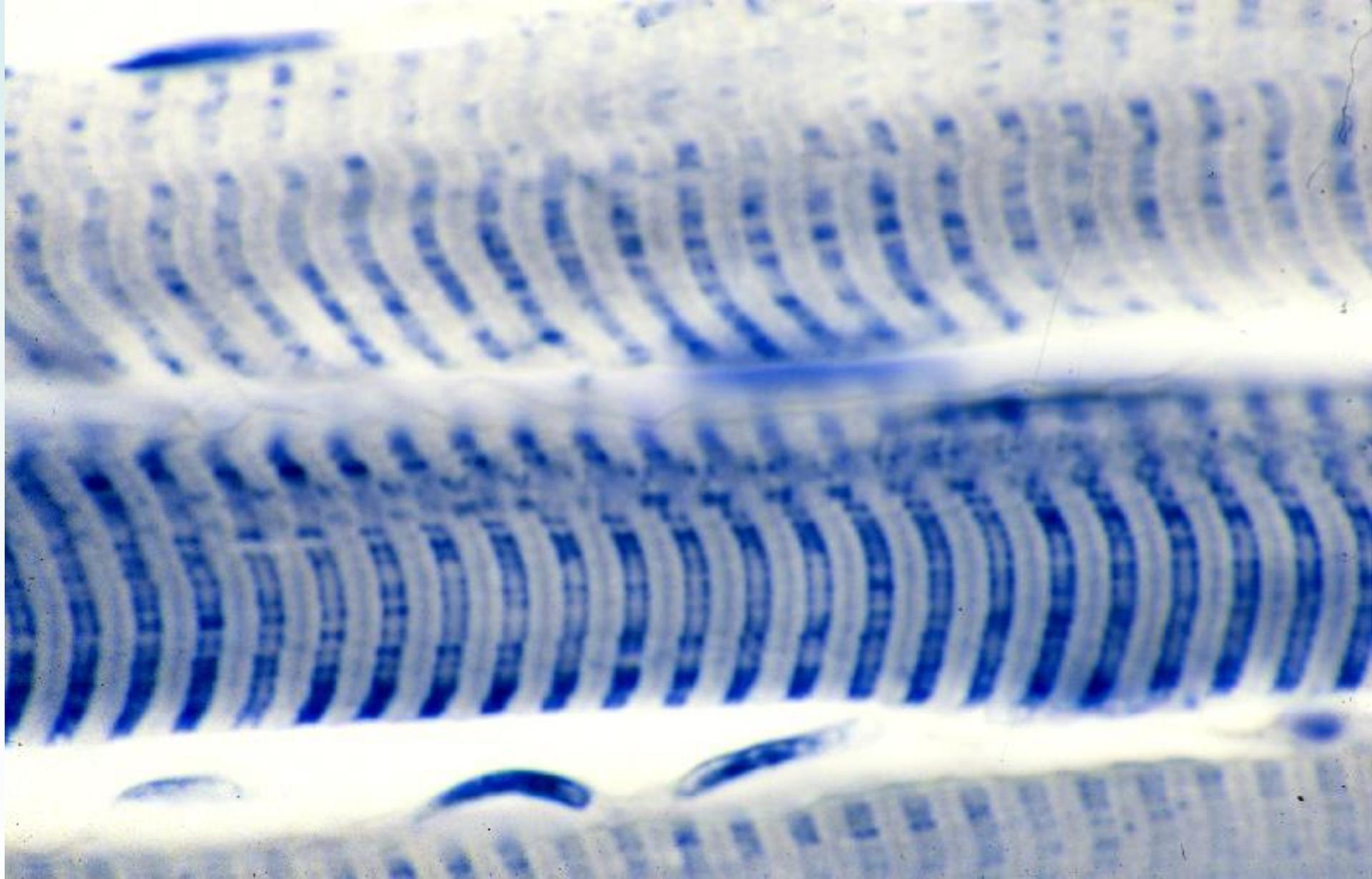
04-01 Skeletal muscles, longitudinal section 1. Human tongue, H-E stain, x 160.



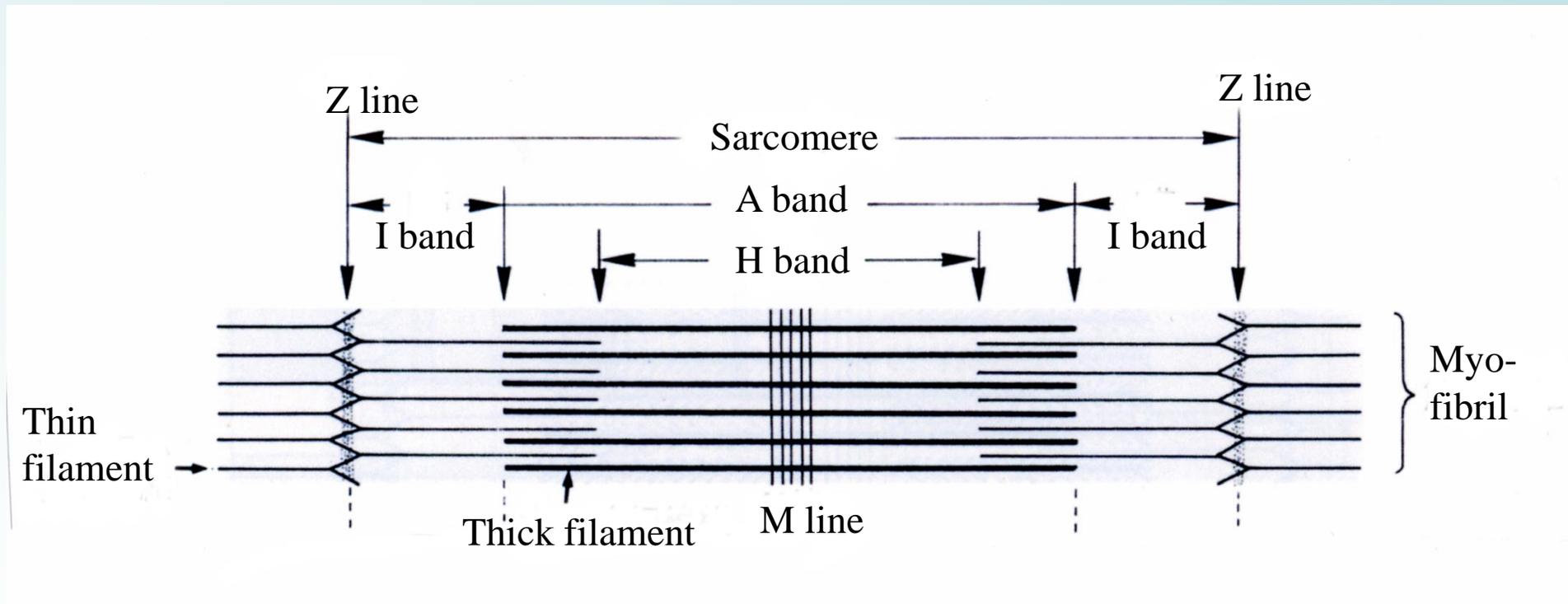
04-02 Skeletal muscles, longitudinal section 2. Monkey, H-E stain, x 250.



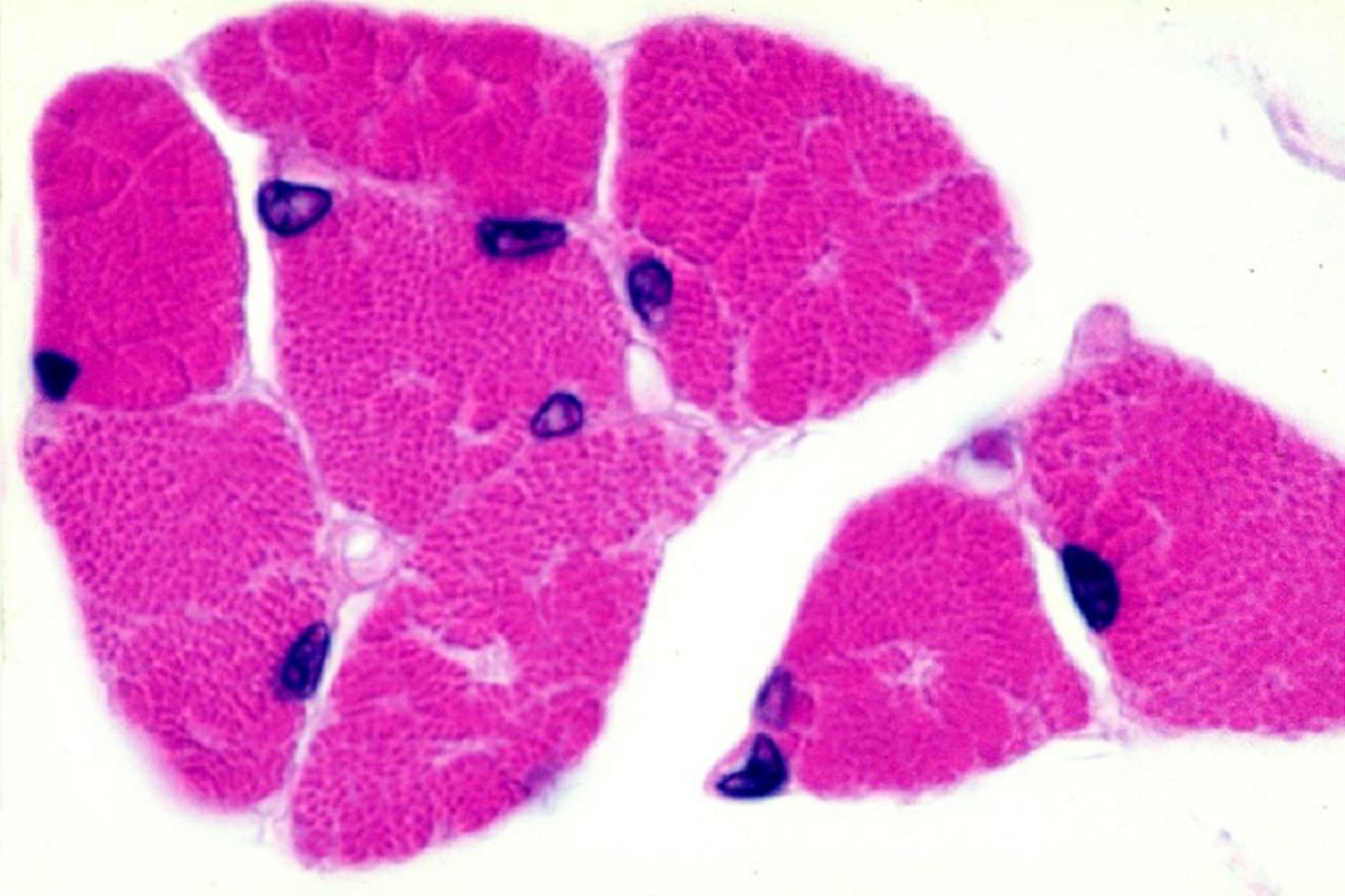
04-03 Skeletal muscles, longitudinal section 3. Human tongue, H-E stain, x 400.



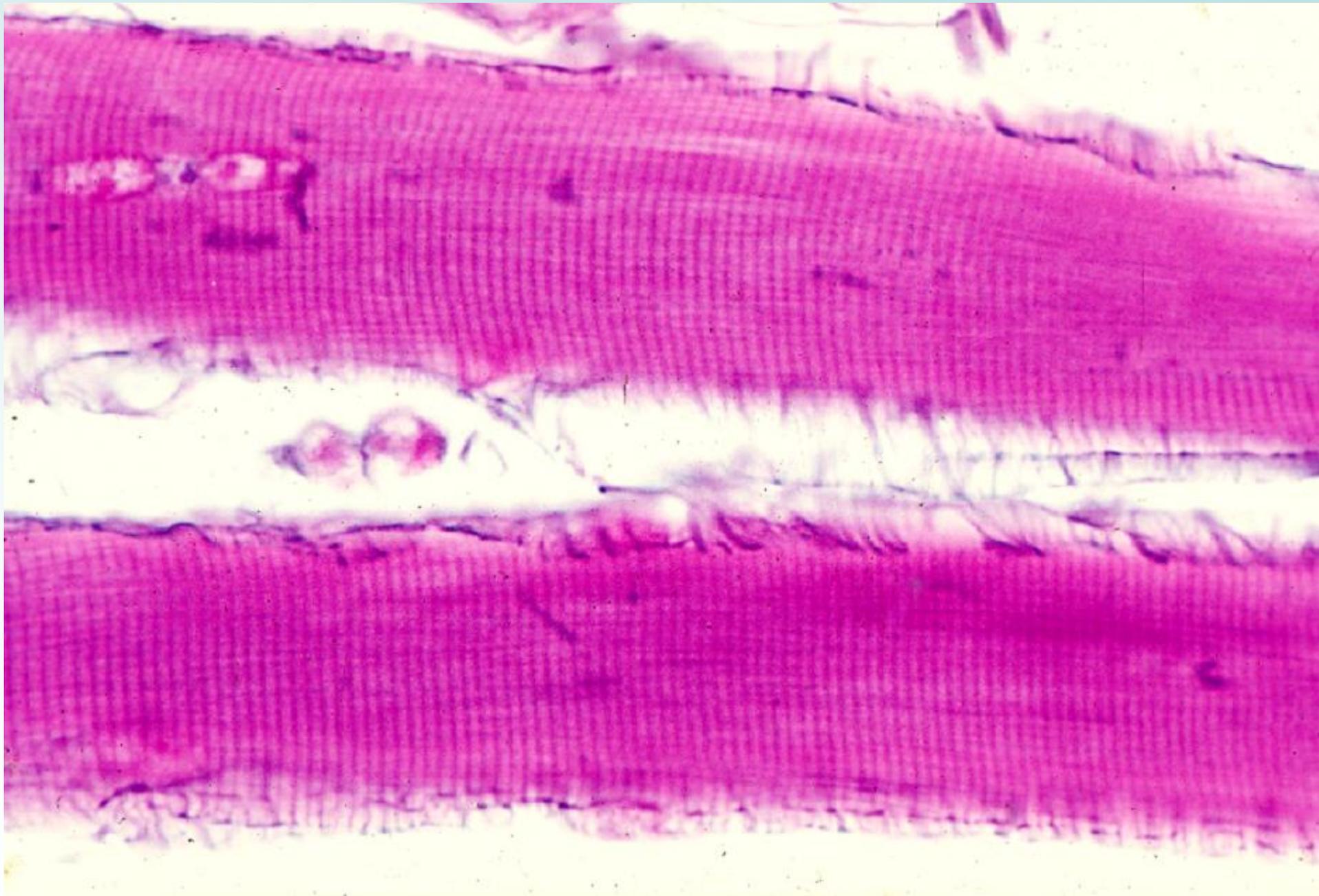
04-04 Skeletal muscles, longitudinal section 4. Rat, Heidenhain's iron-hematoxylin stain, x 500.



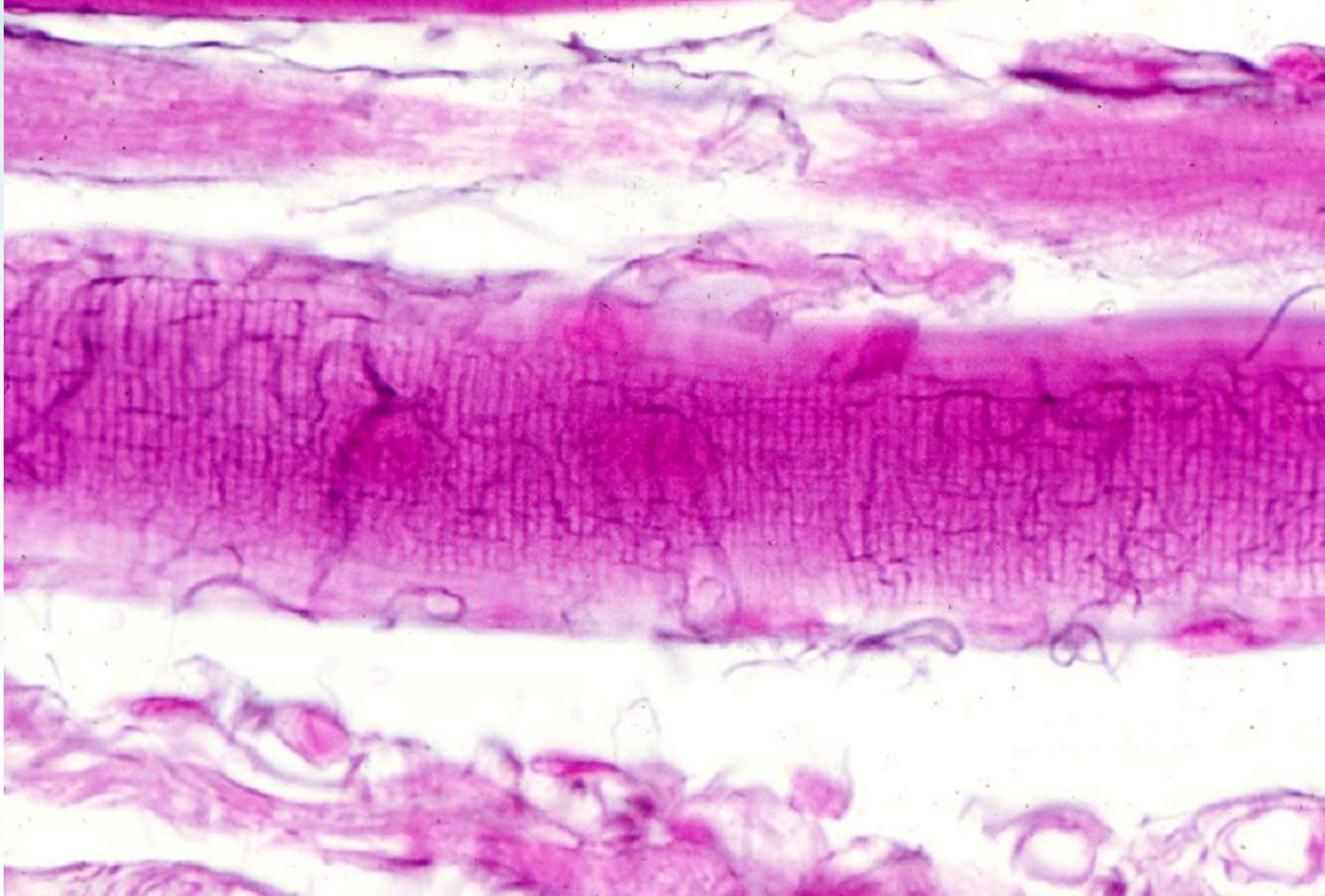
04-05 Scheme showing ultrastructure of a myofilament.



04-06 Skeletal muscle fibers, transverse section 1. Human, H-E stain, x 500.

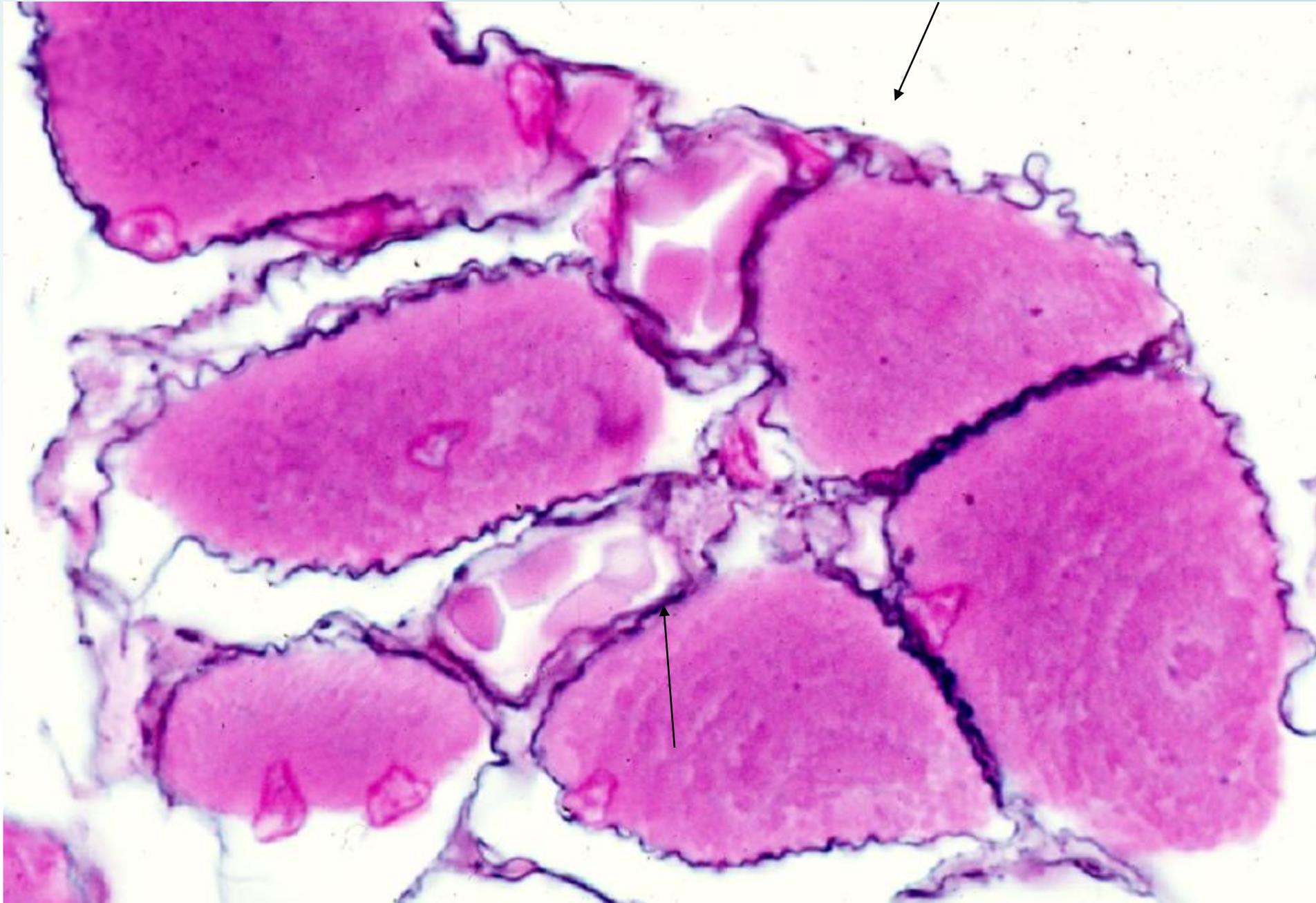


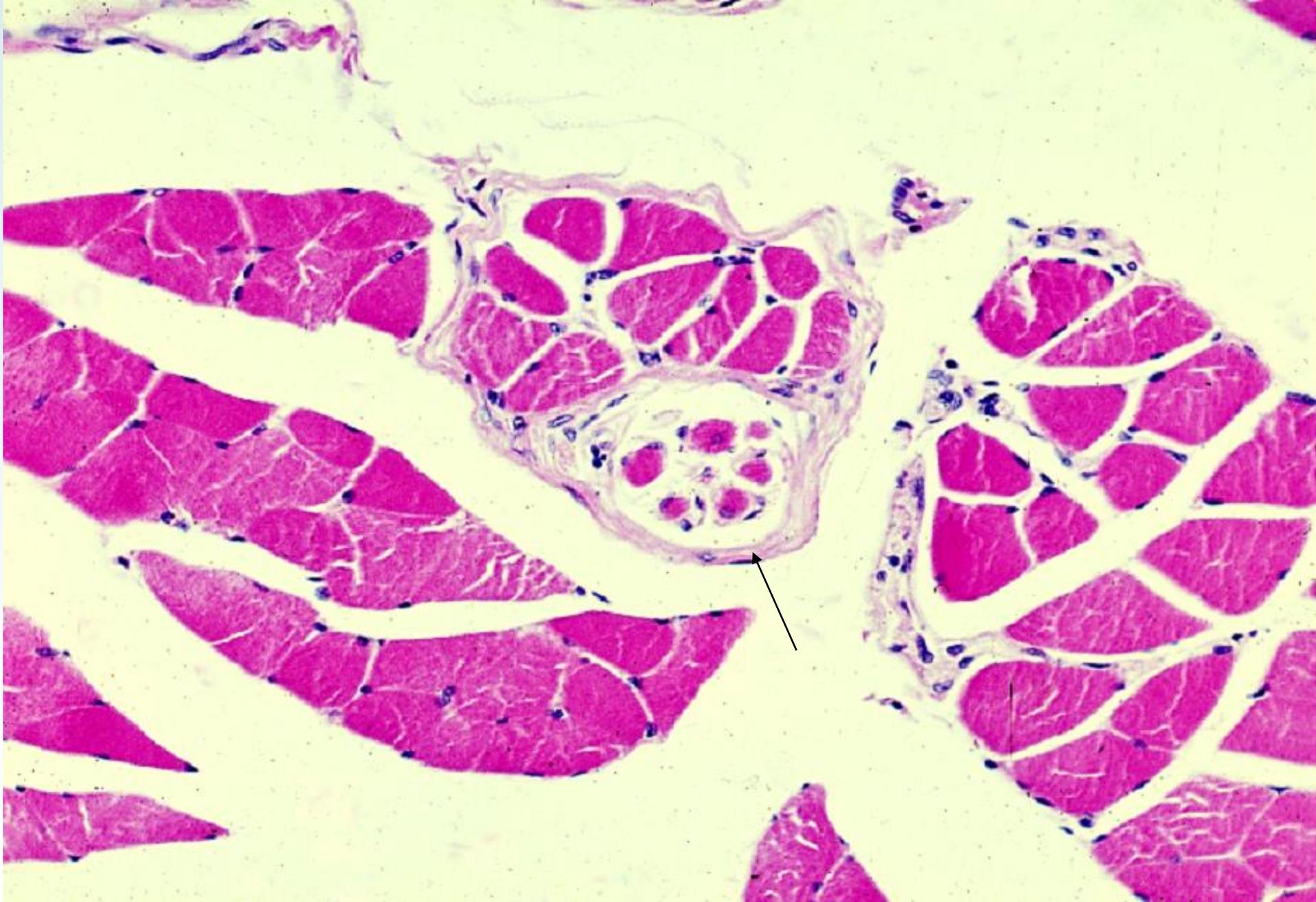
04-07 Skeletal muscle fibers, longitudinal section. Endomysium 1. Human, Silver impregnation and Kernechtrot stain, x 250.



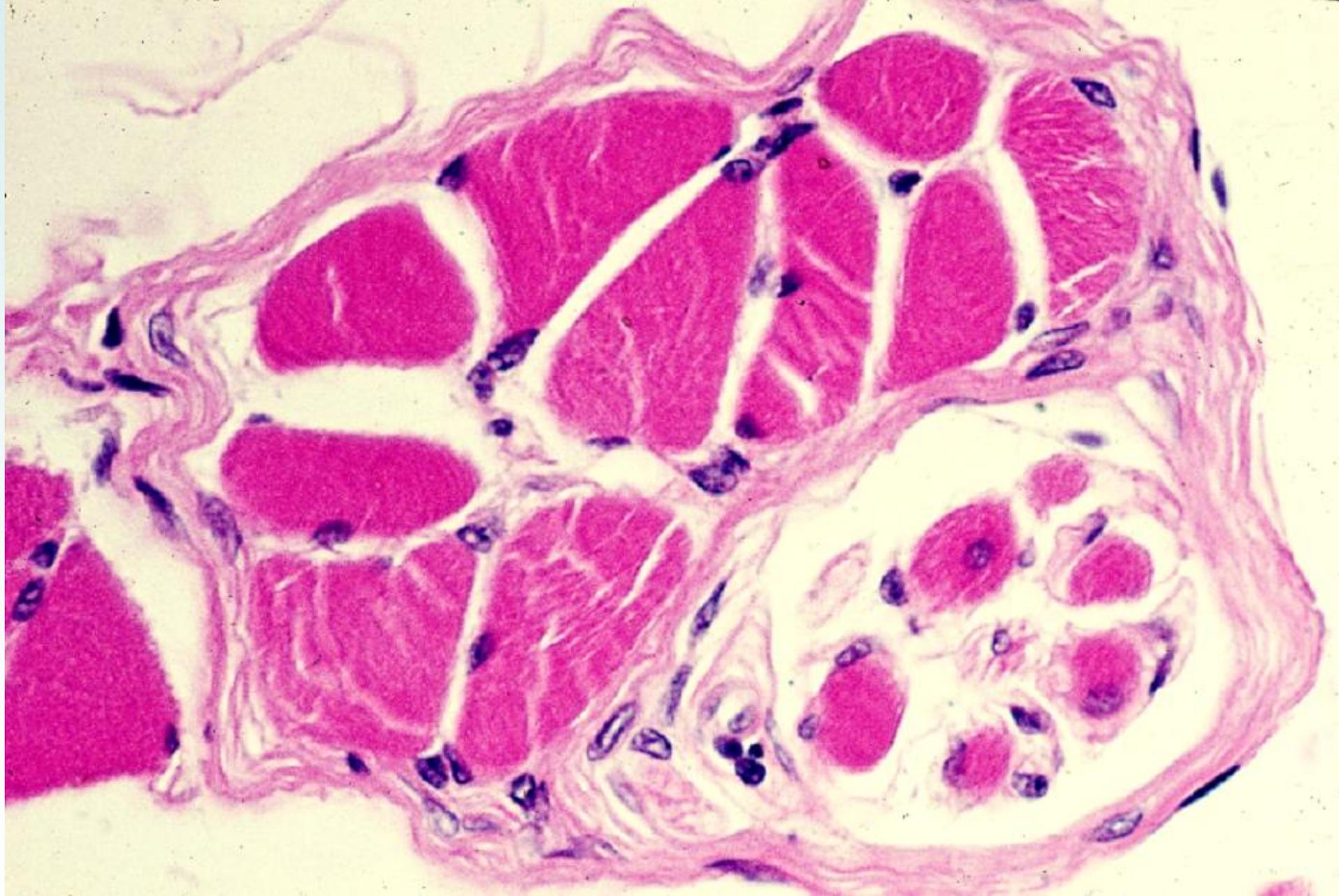
04-08 Skeletal muscle fibers, longitudinal section. Endomysium 2. Human, Silver impregnation and Kernechtrot stain, x 250.

04-09 Skeletal muscle fibers, transverse section 2. Human, Silver impregnation and Kernechtrot stain, x 400.

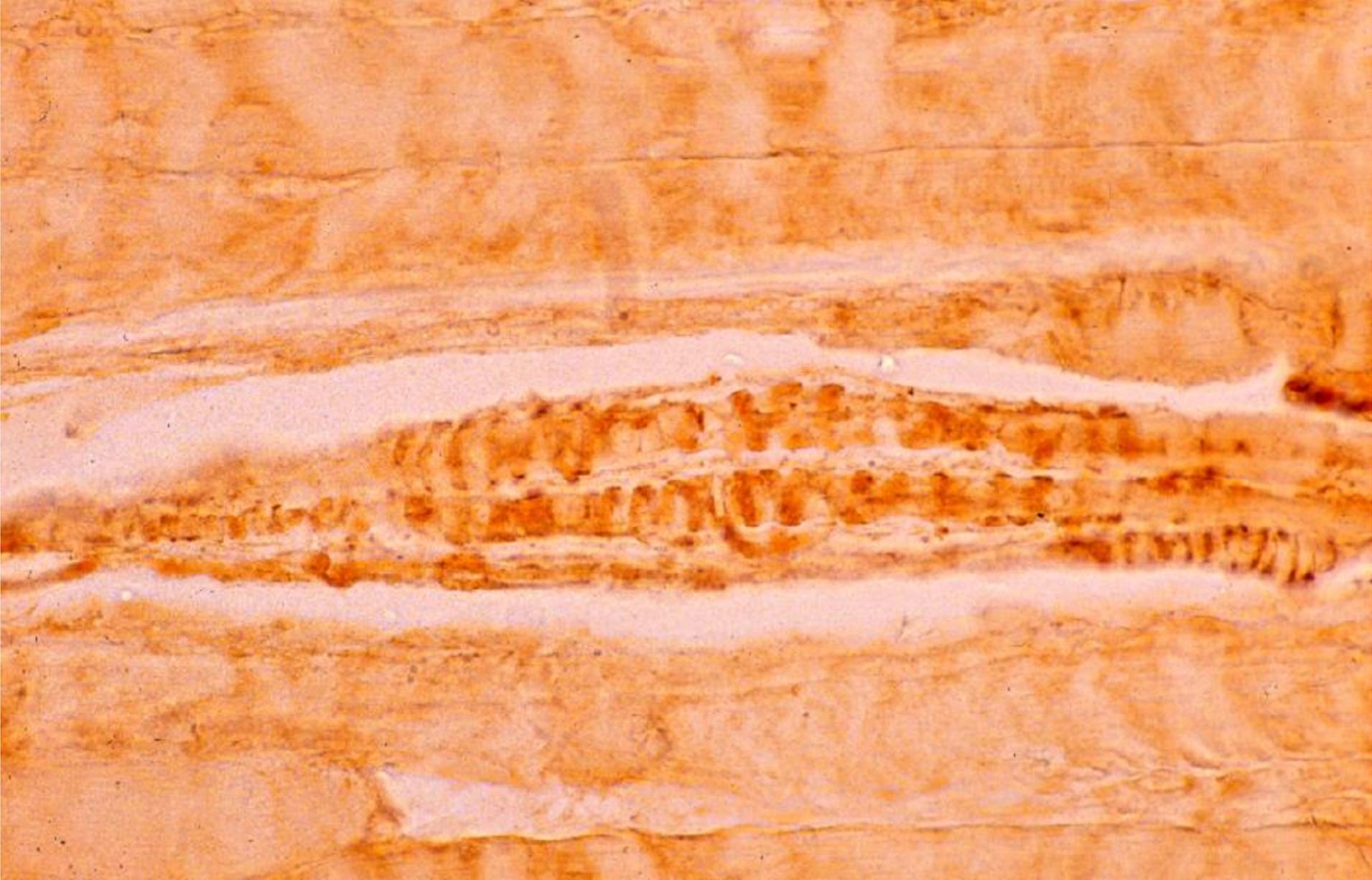




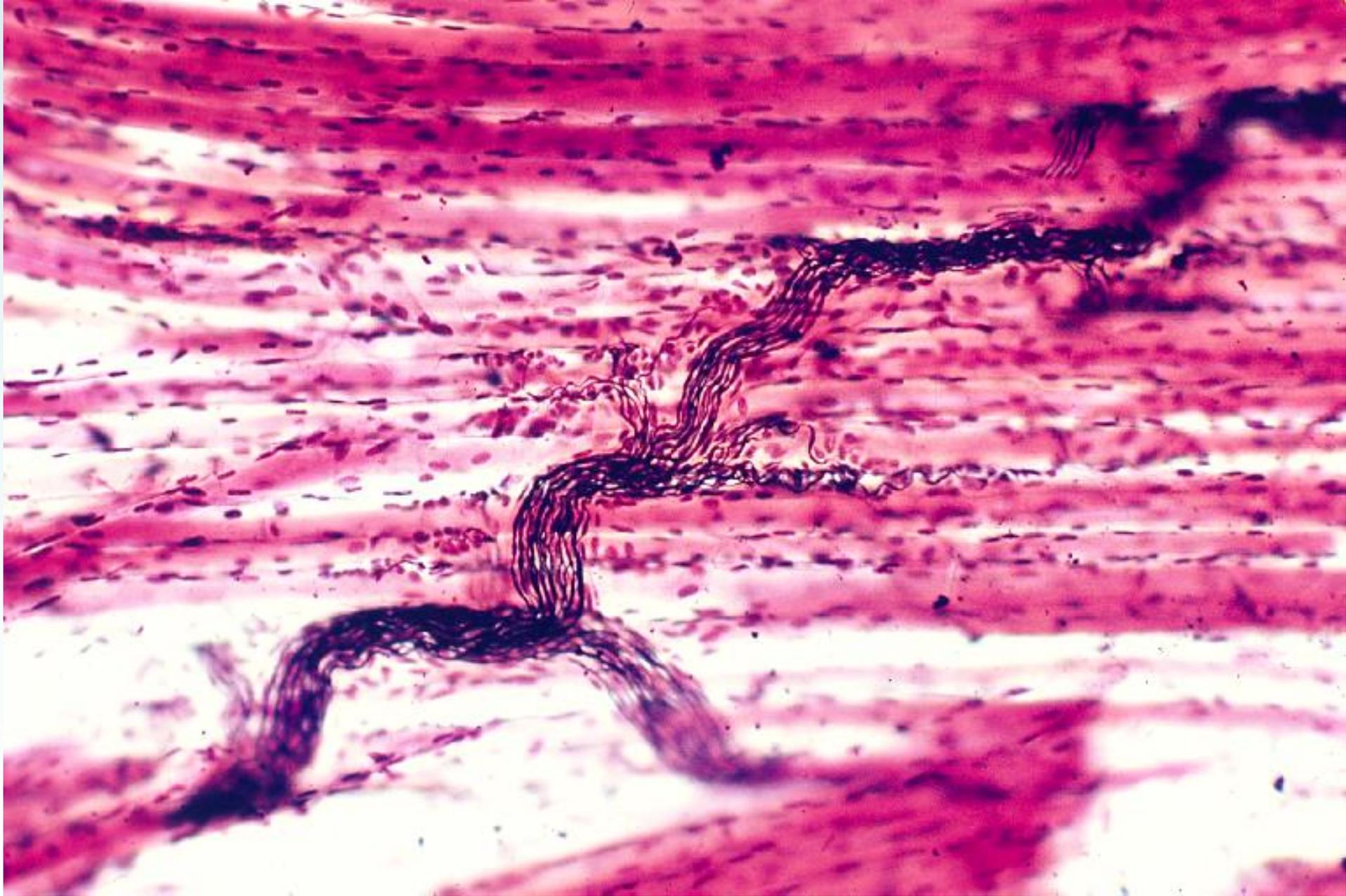
04-10 Muscle spindle 1. Human, H-E stain, x 64.



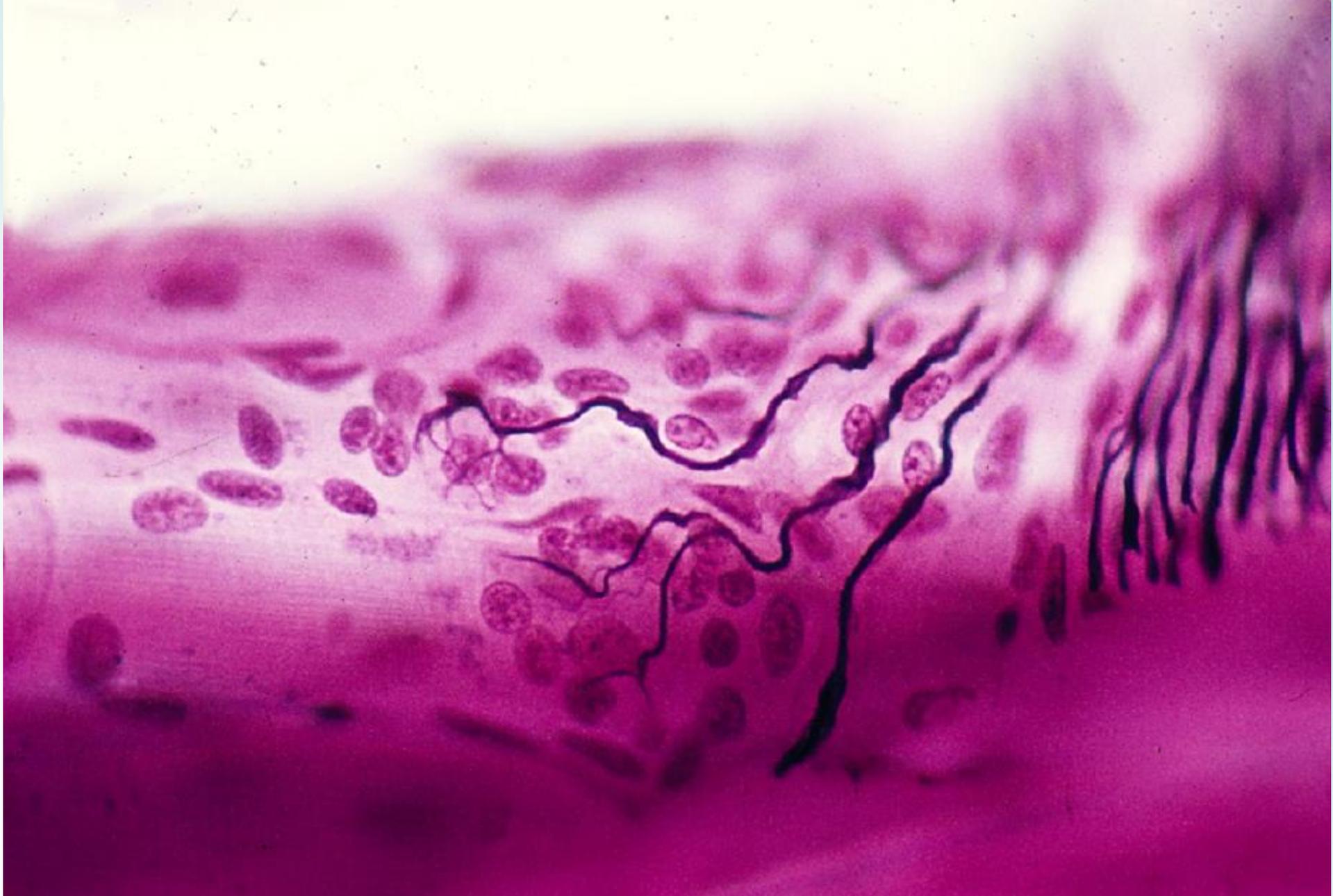
04-11 Muscle spindle 2. Human, H-E stain, x 160.



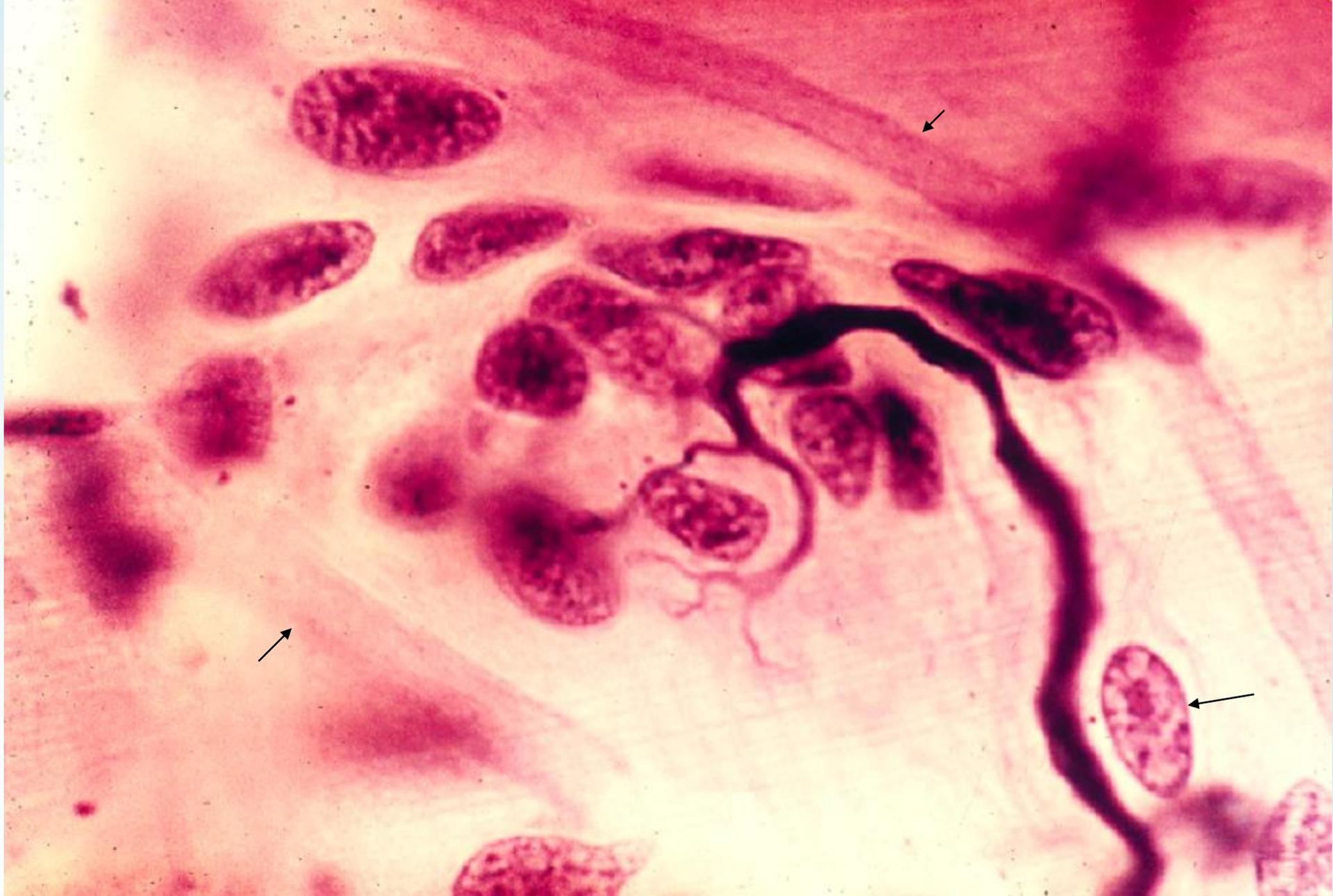
**04-12 Muscle spindle 3. Rat, monoclonal antibody reaction using synaptophysin, x 130.**



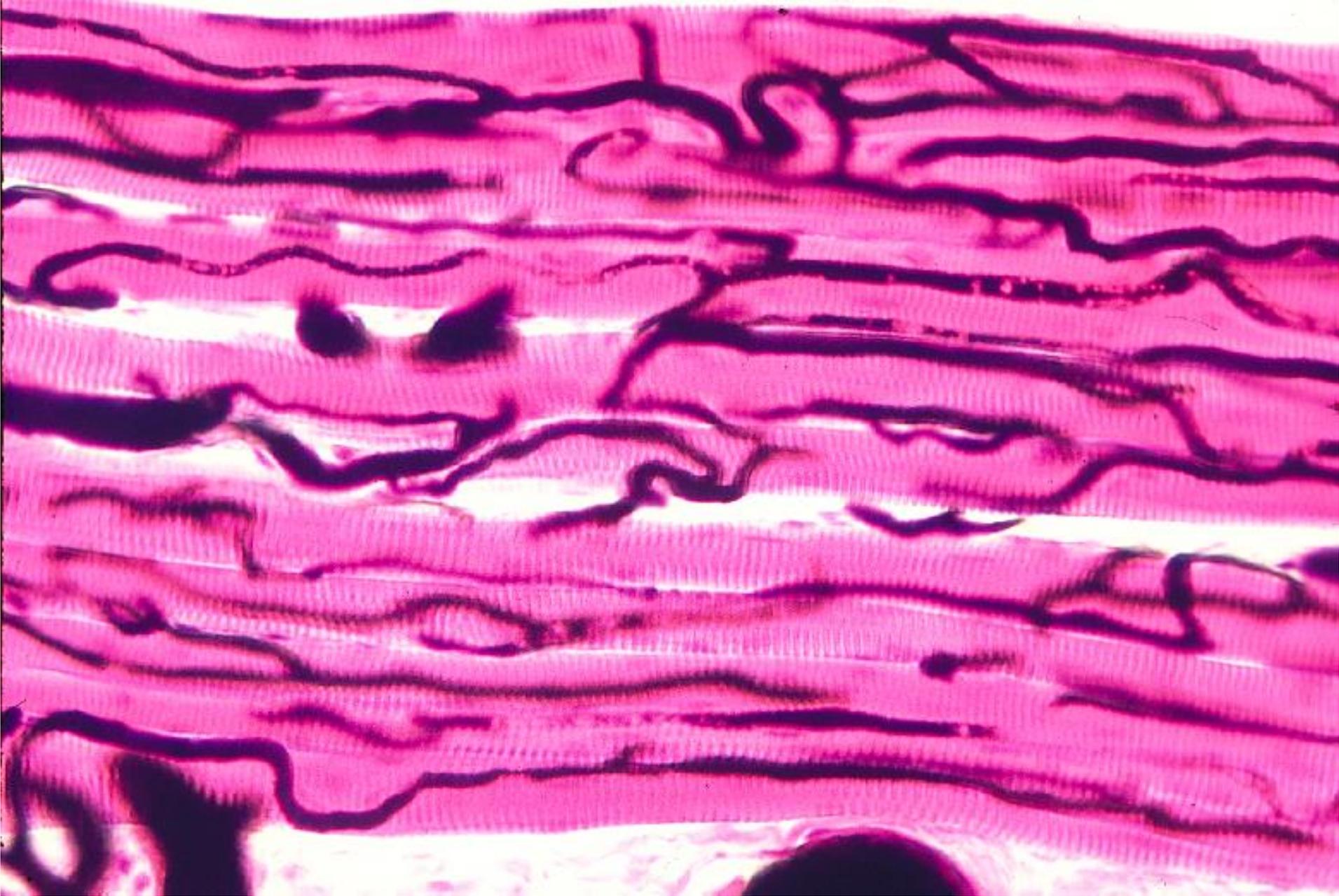
04-13 Motor nerve endings 1. Monkey tongue, silver impregnation, x 64.



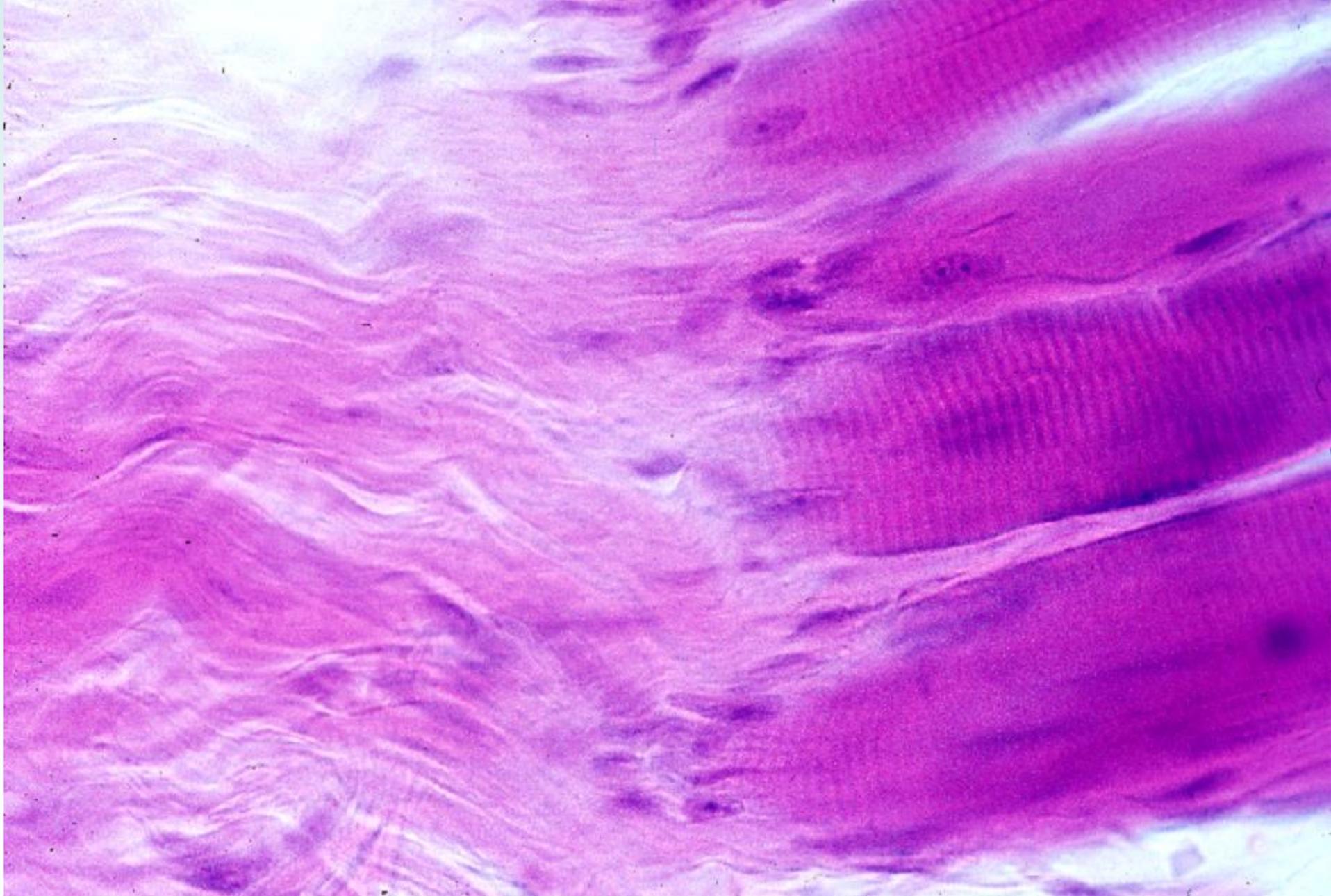
04-14 Motor nerve endings 2. Monkey tongue, silver impregnation, x160.



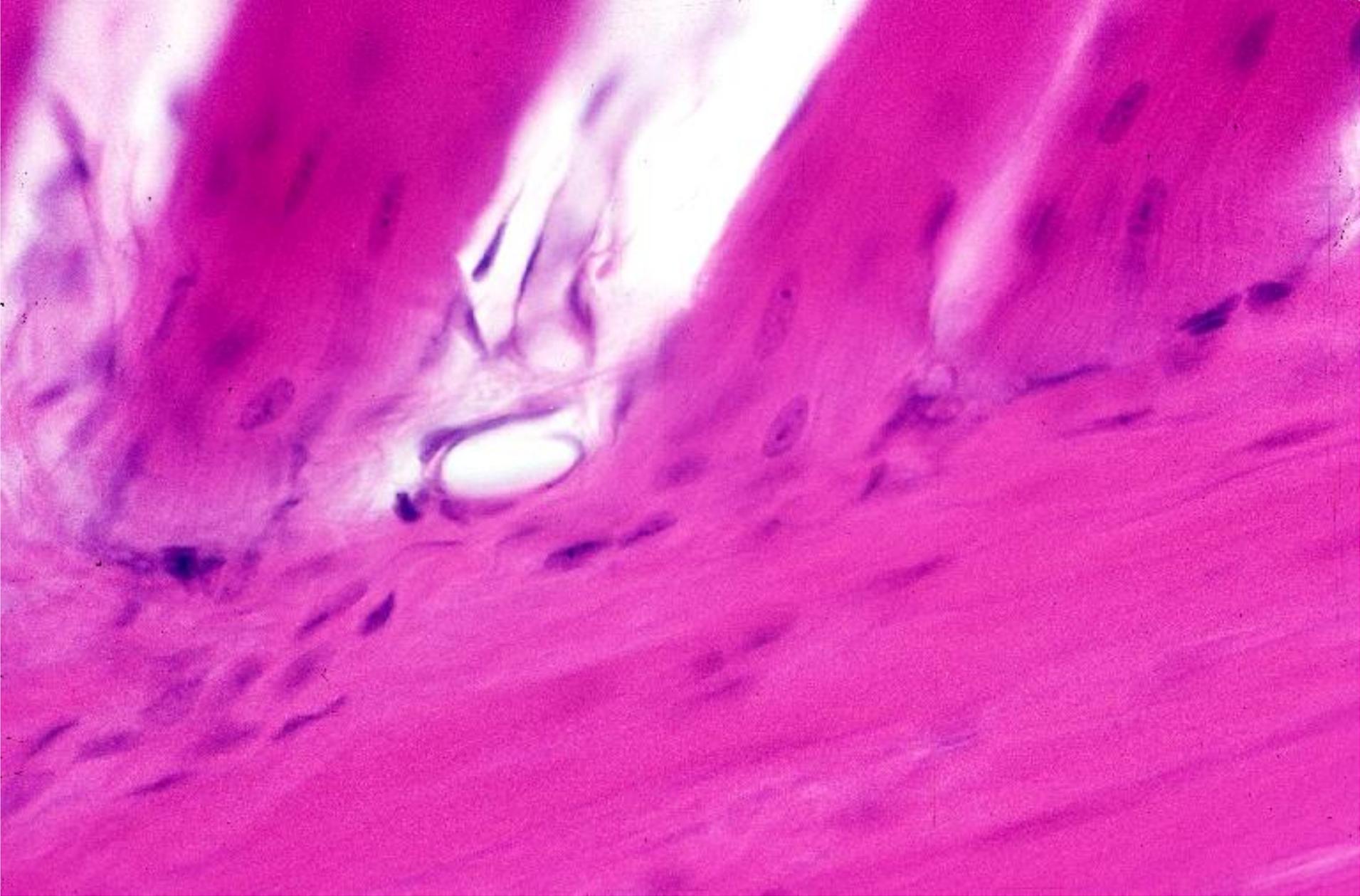
04-15 Motor nerve endings 3. Monkey tongue, silver impregnation, x400.



04-16 Capillaries in the skeletal muscle fibers. Cat, infusion of India ink, x 100.



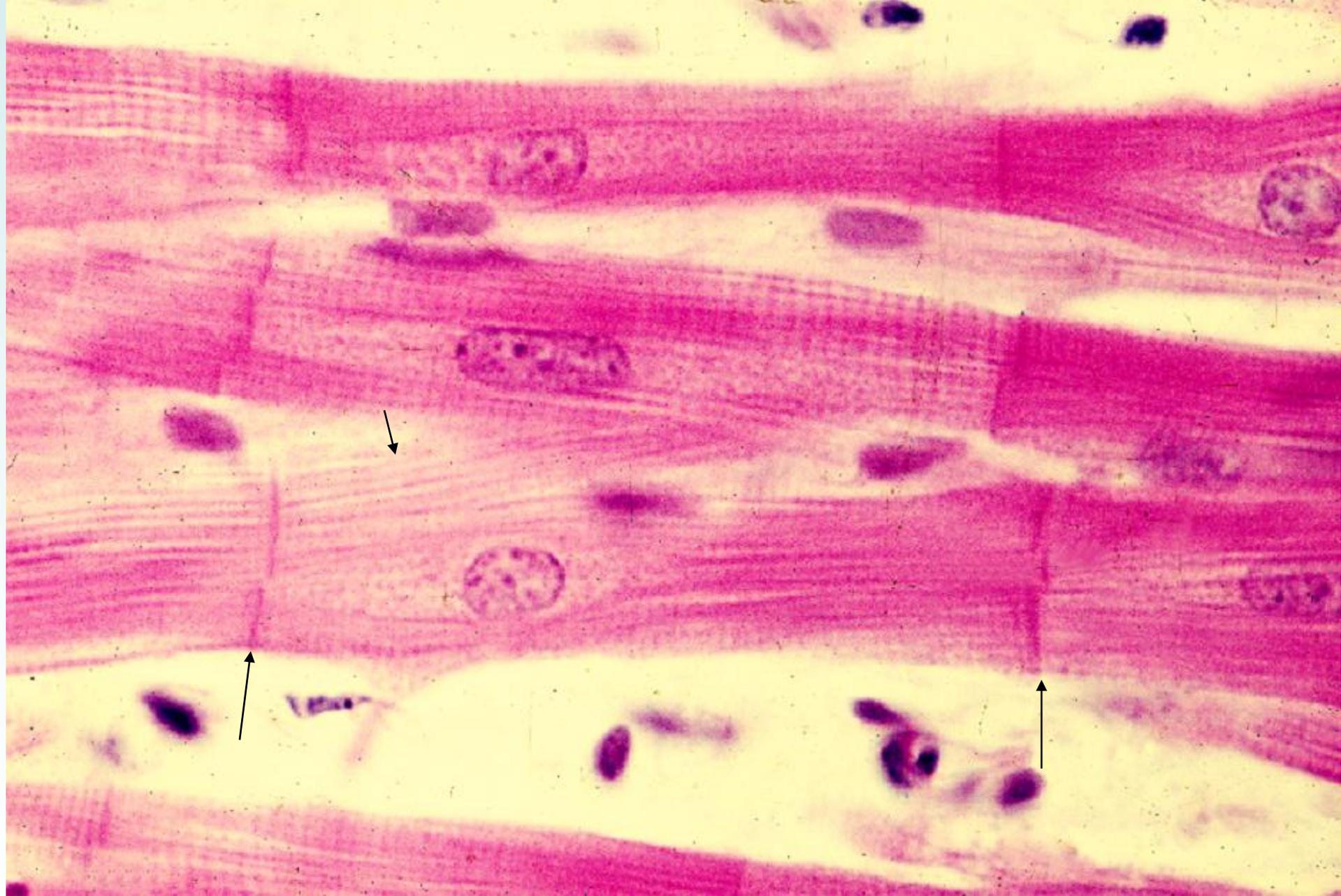
04-17 Muscle-tendon junction 1. Monkey, H-E stain, x 160.



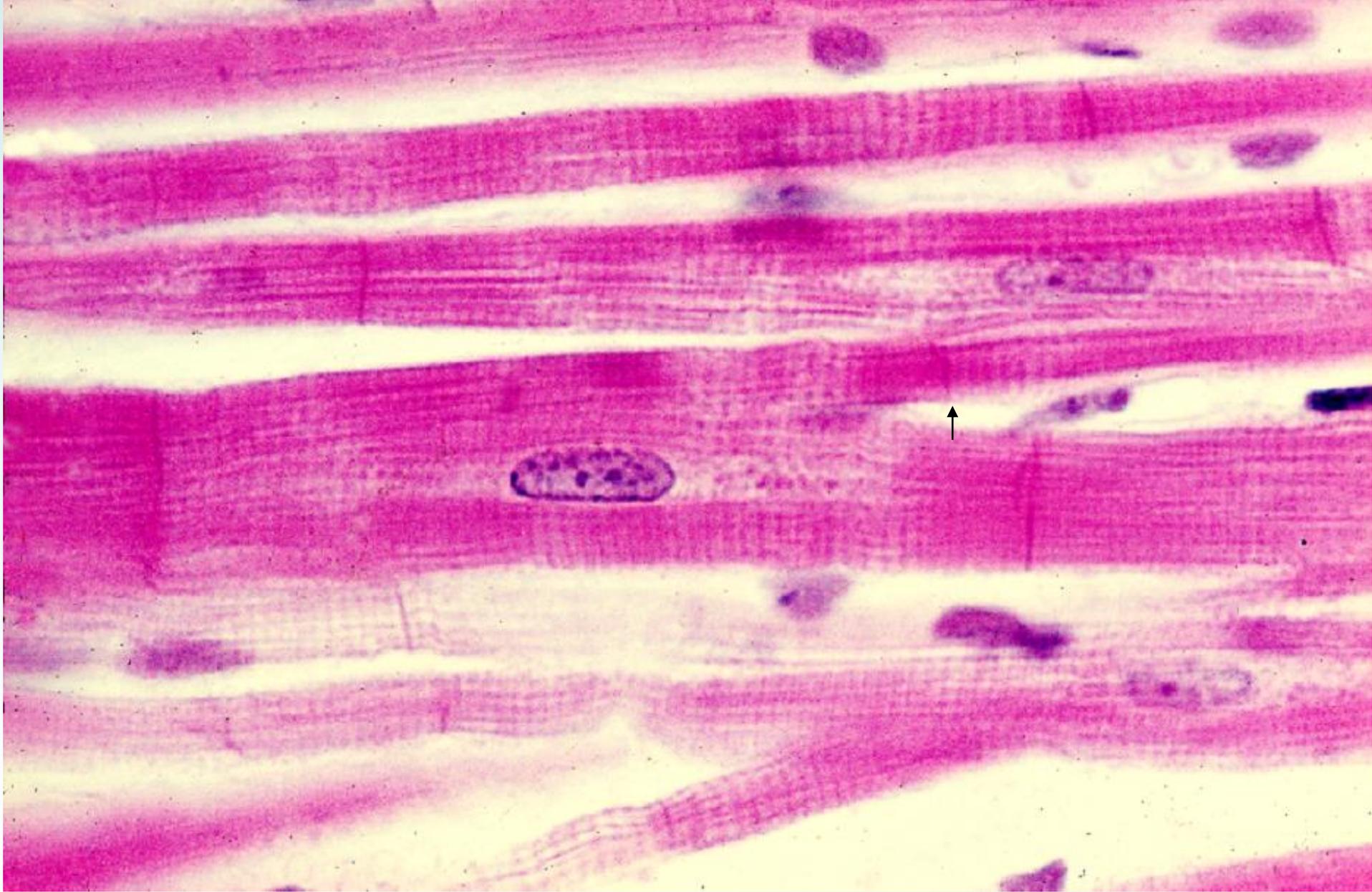
04-18 Muscle-tendon junction 2. Monkey, H-E stain, x 160.

04-002

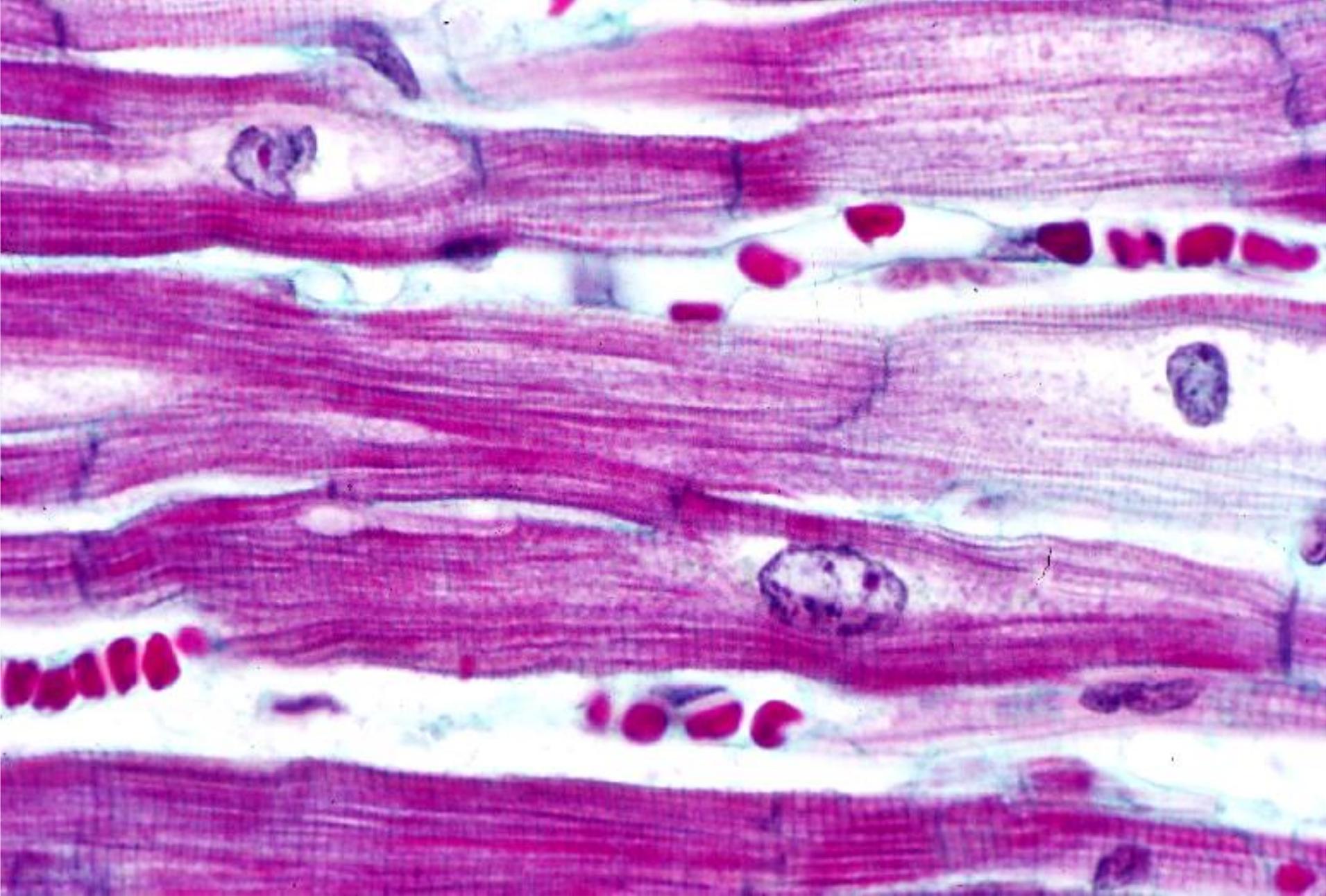
# Cardiac Muscle



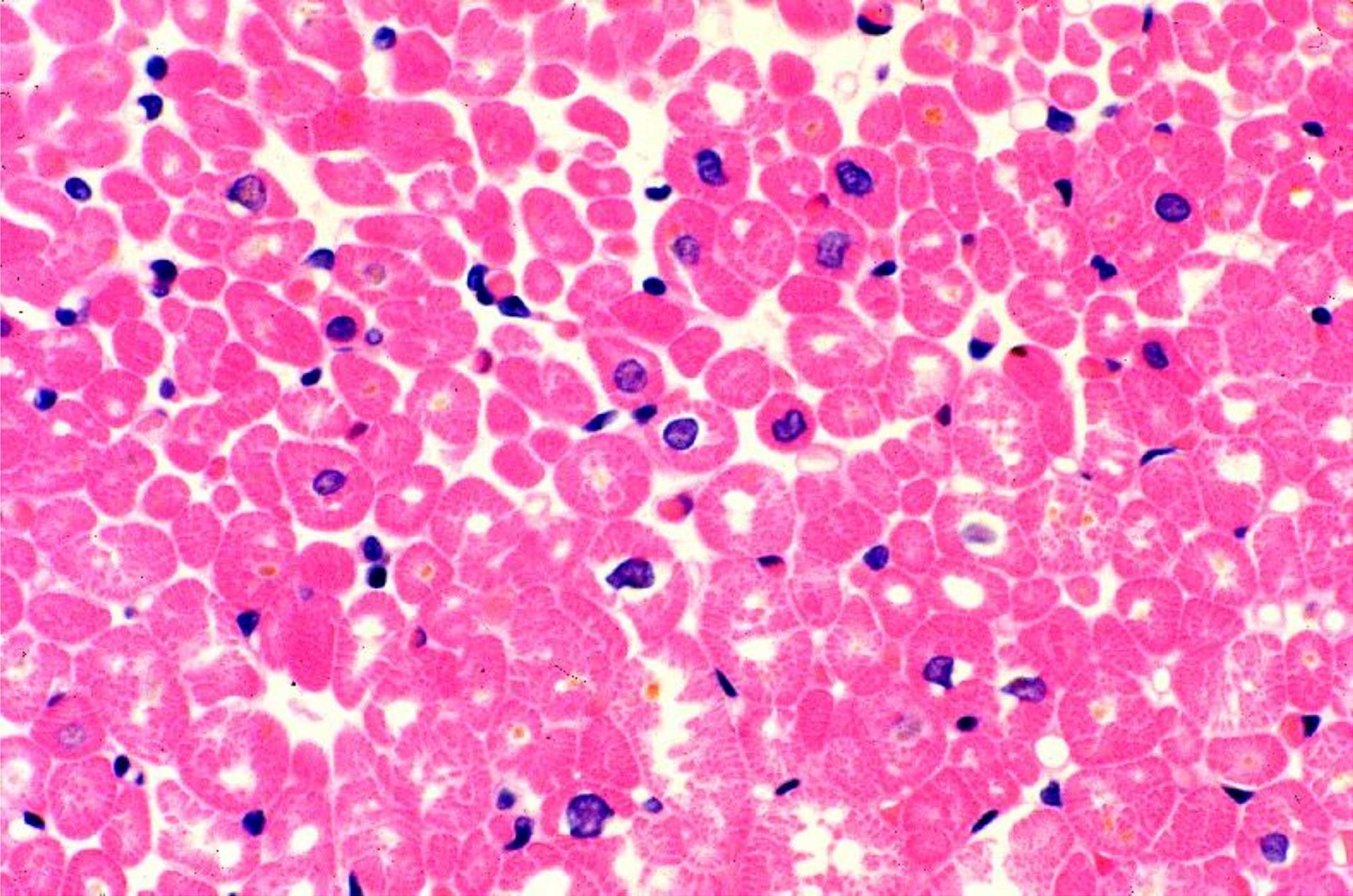
04-19 Cardiac muscles, longitudinal section 1. Human, H-E stain, x 250.



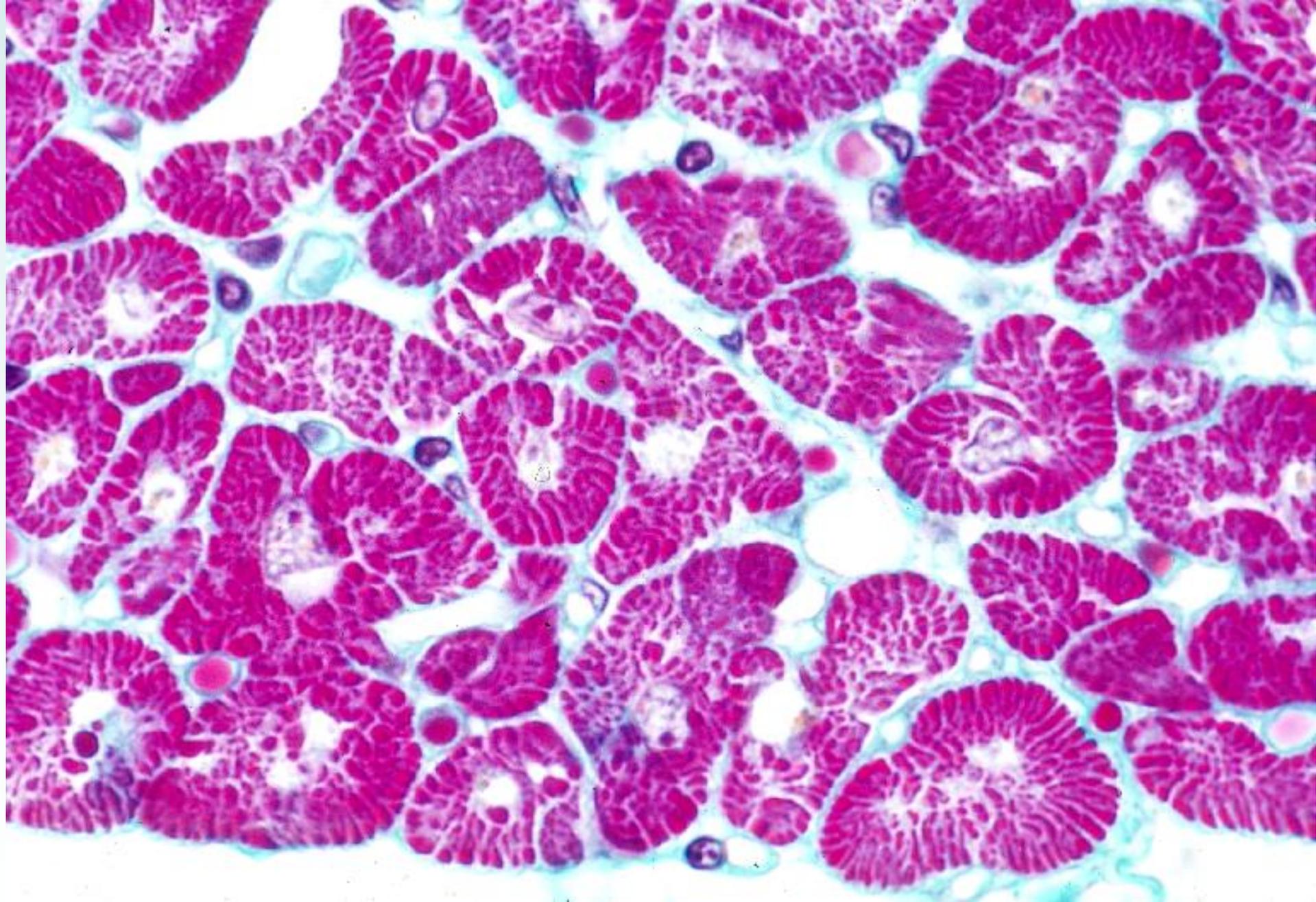
04-20 Cardiac muscles, longitudinal section 2. Human, H-E stain, x 250.



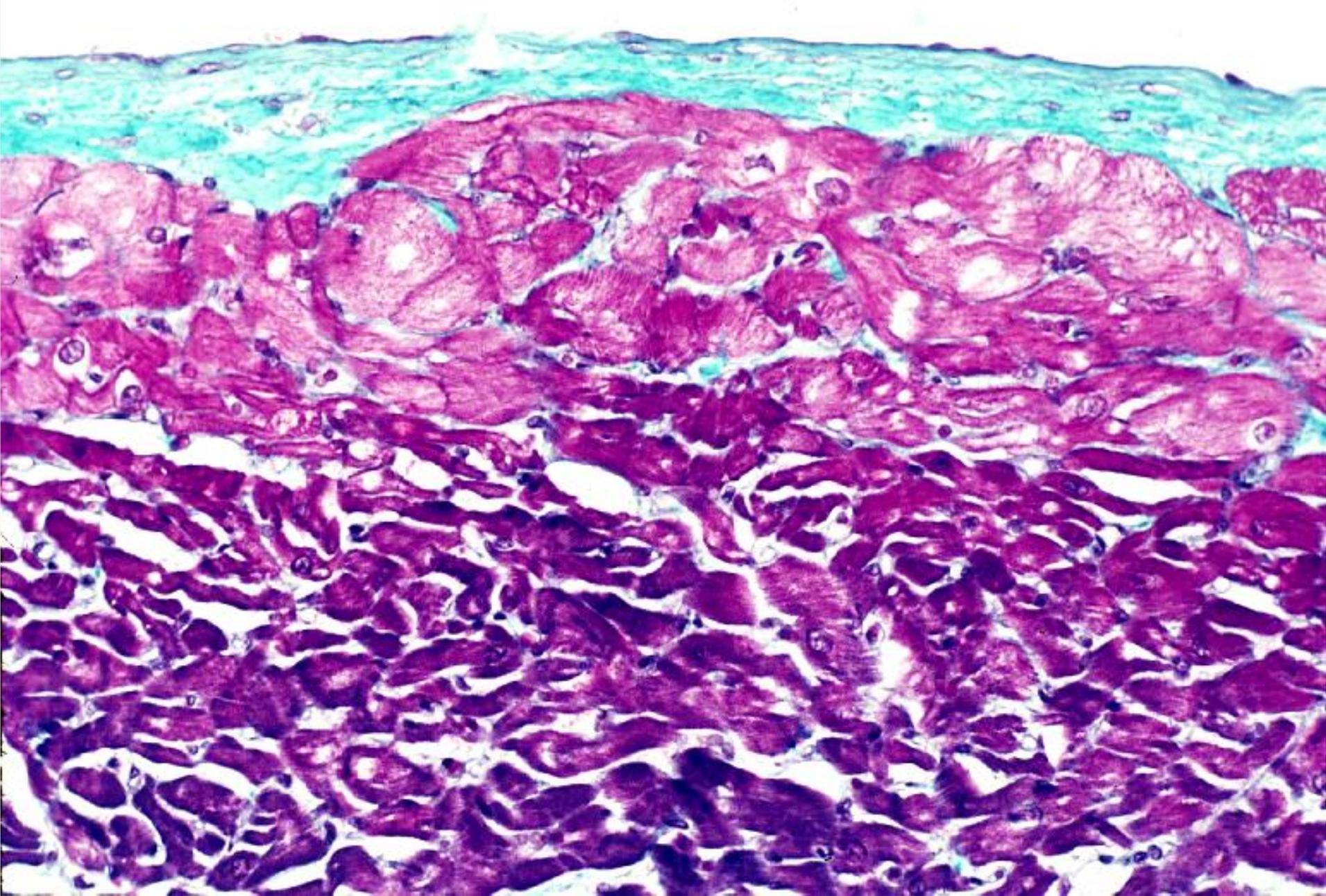
04-21 Cardiac muscles, longitudinal section 3. Human, M-G stain, x 250.



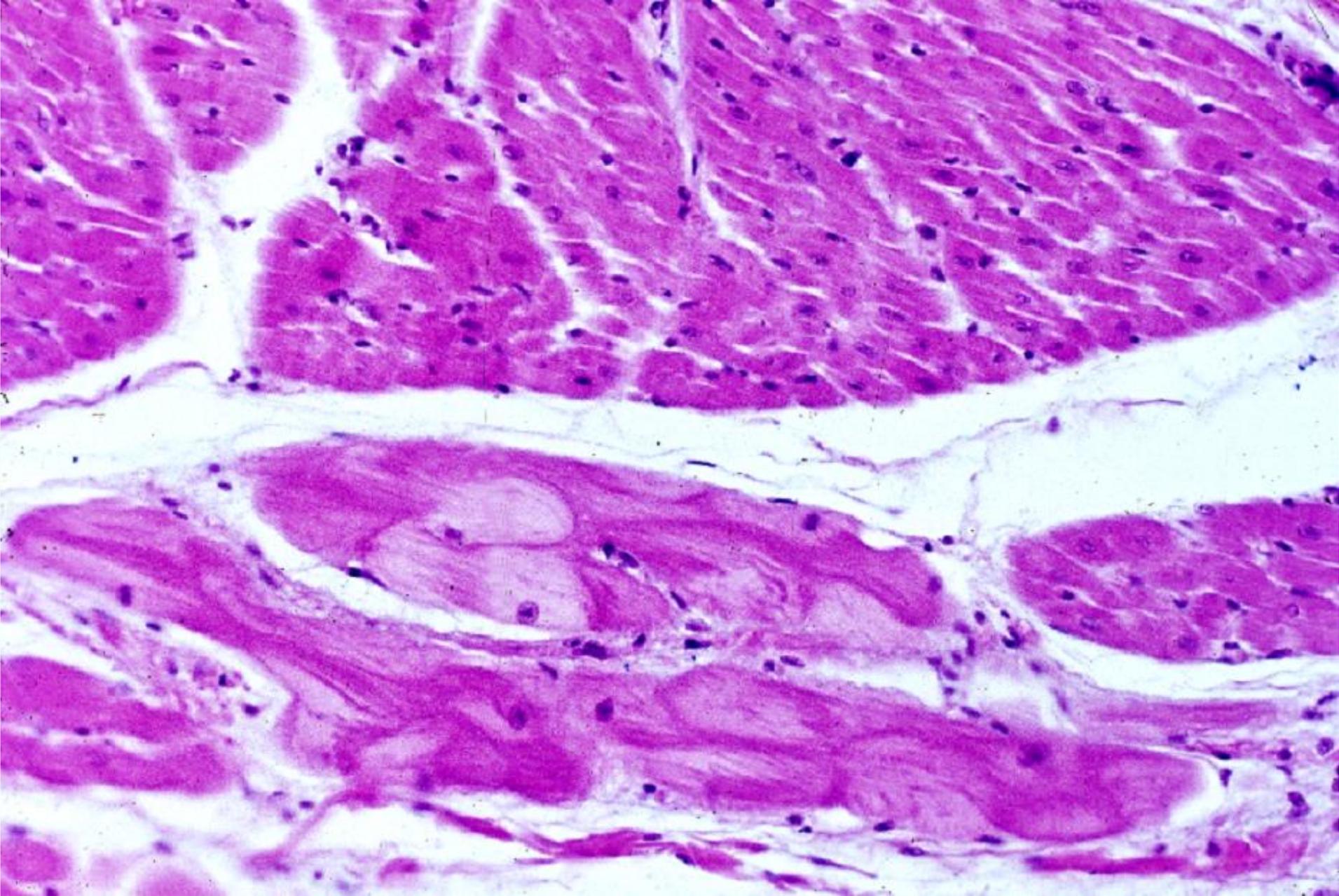
04-22 Cardiac muscles, transverse section 1. Human, H-E stain, x 160.



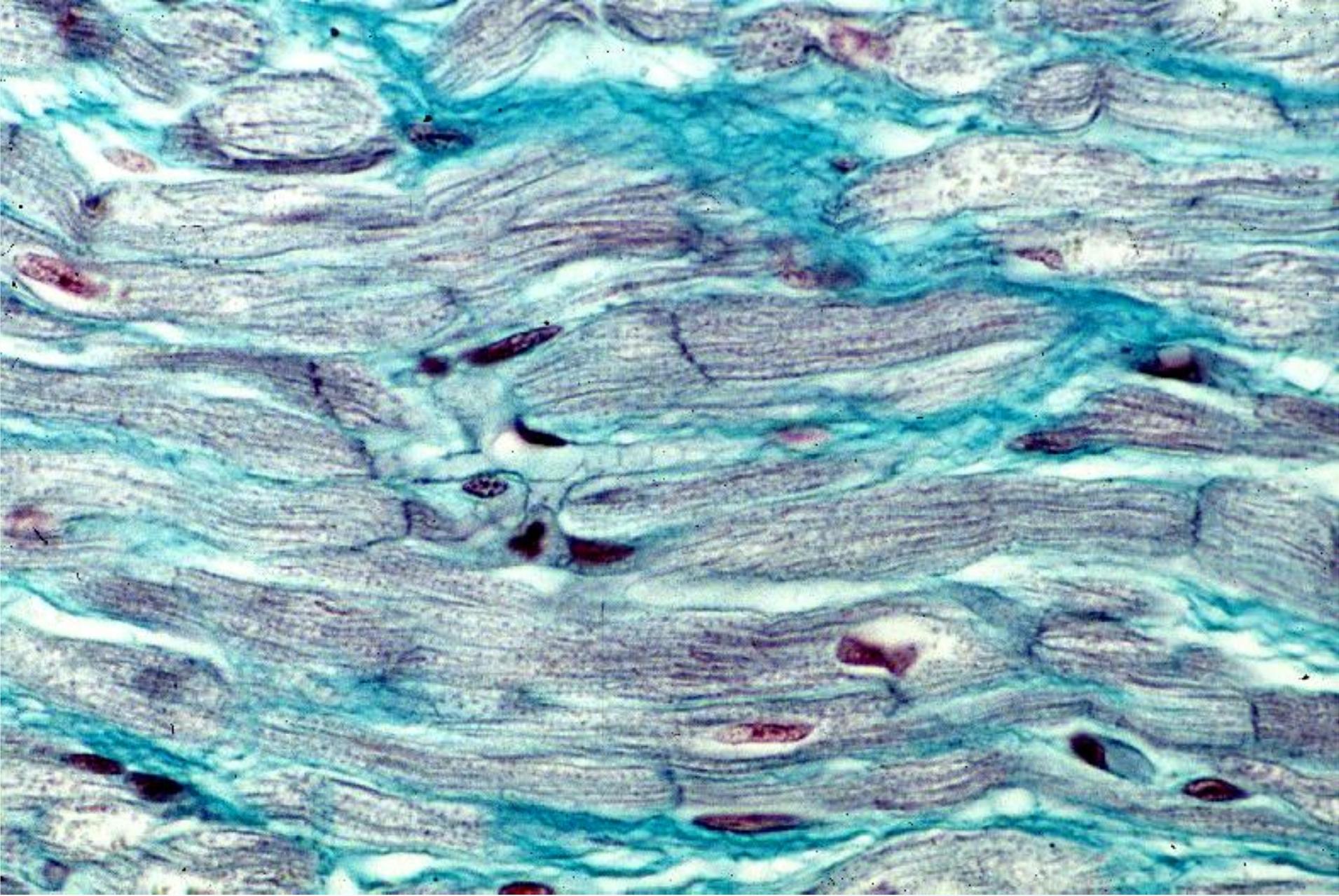
04-23 Cardiac muscles, transverse section 2. Human, M-G stain, x 250.



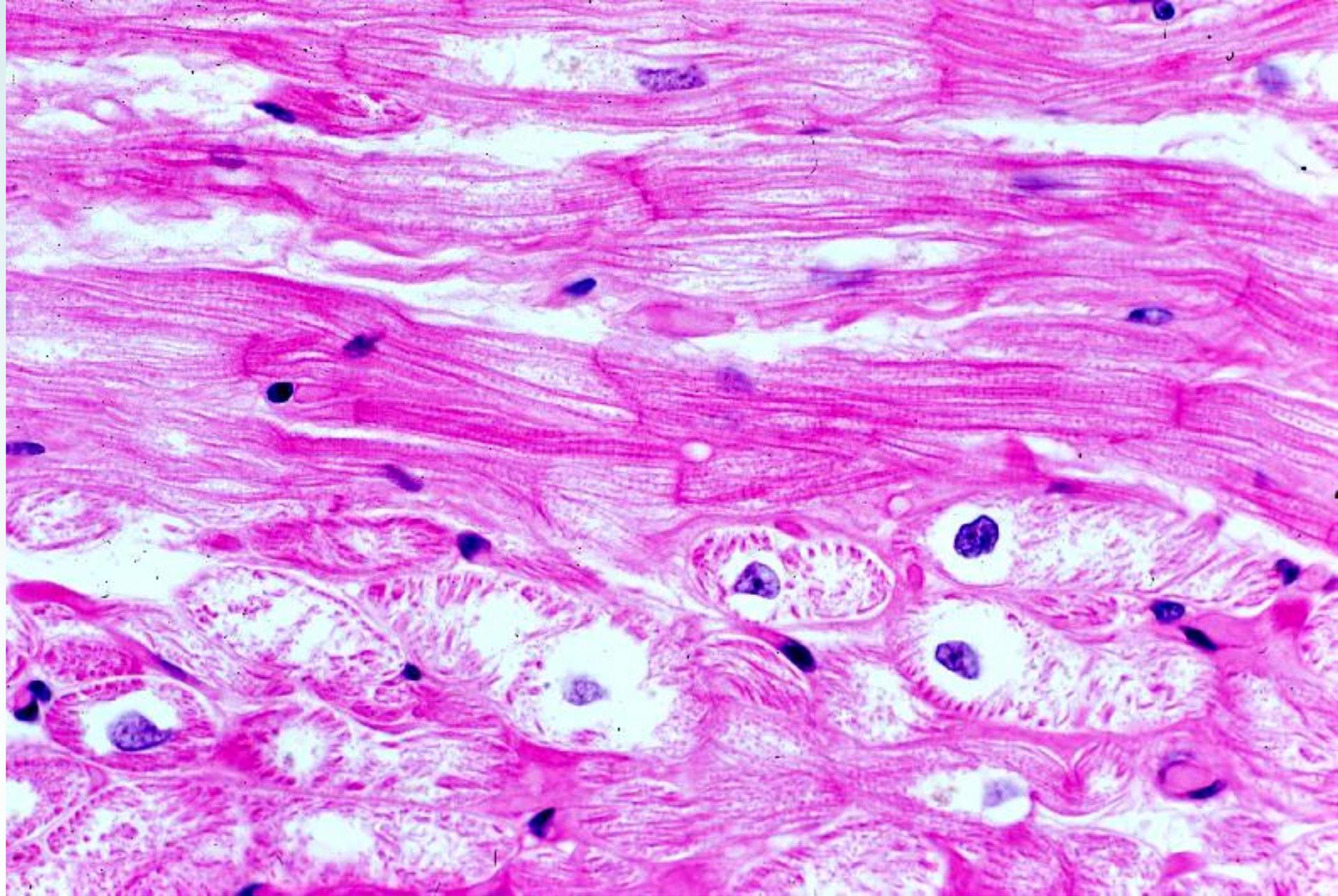
04-24 Cardiac muscles, specialized conducting fibers 1. Human, M-G stain, x 64.



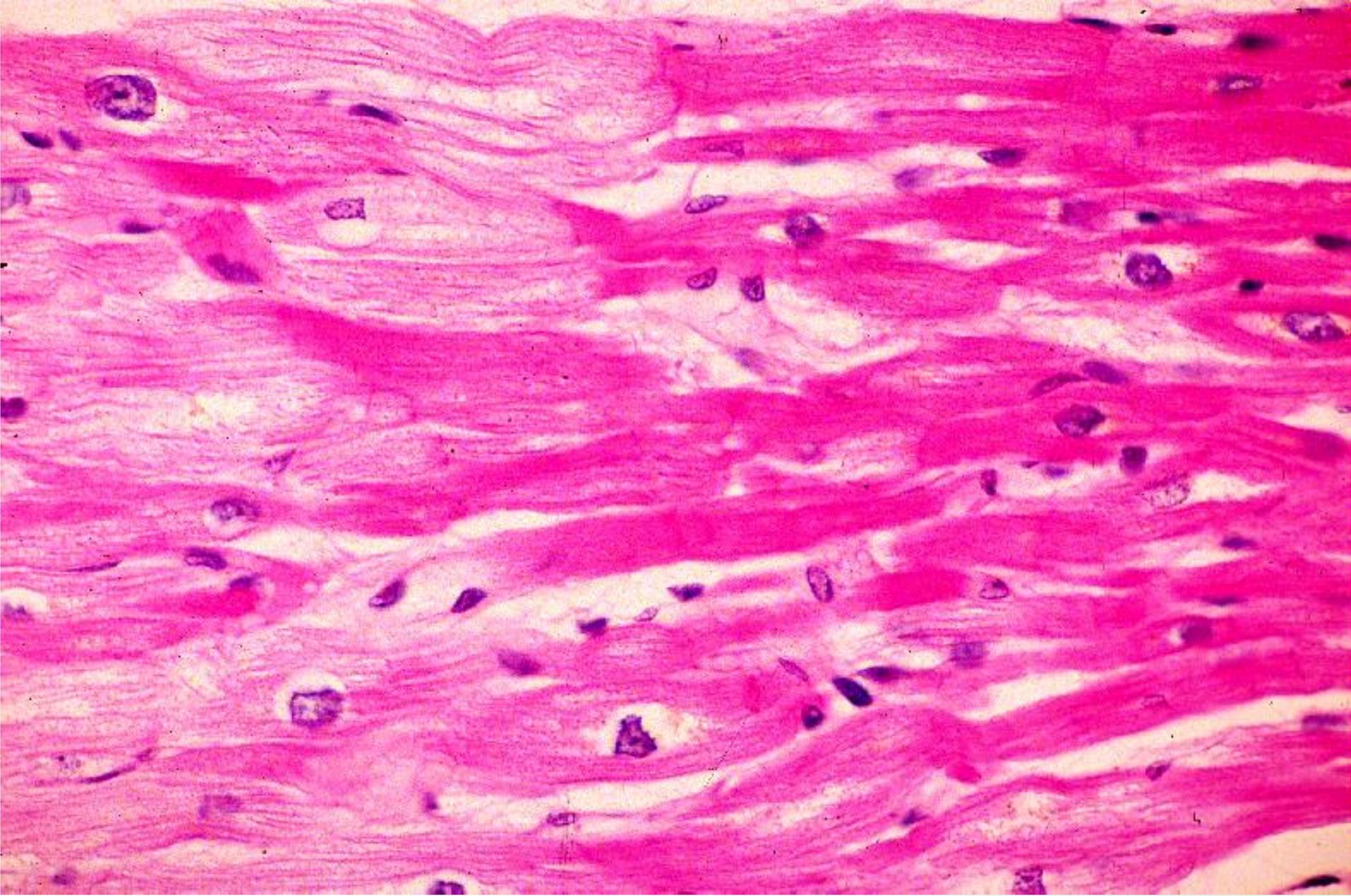
04-25 Purkinje fibers. Bovine, H-E stain, x 64.



04-26 Cardiac muscle fibers, specialized conducting fibers. Human, M-G stain, x 160.



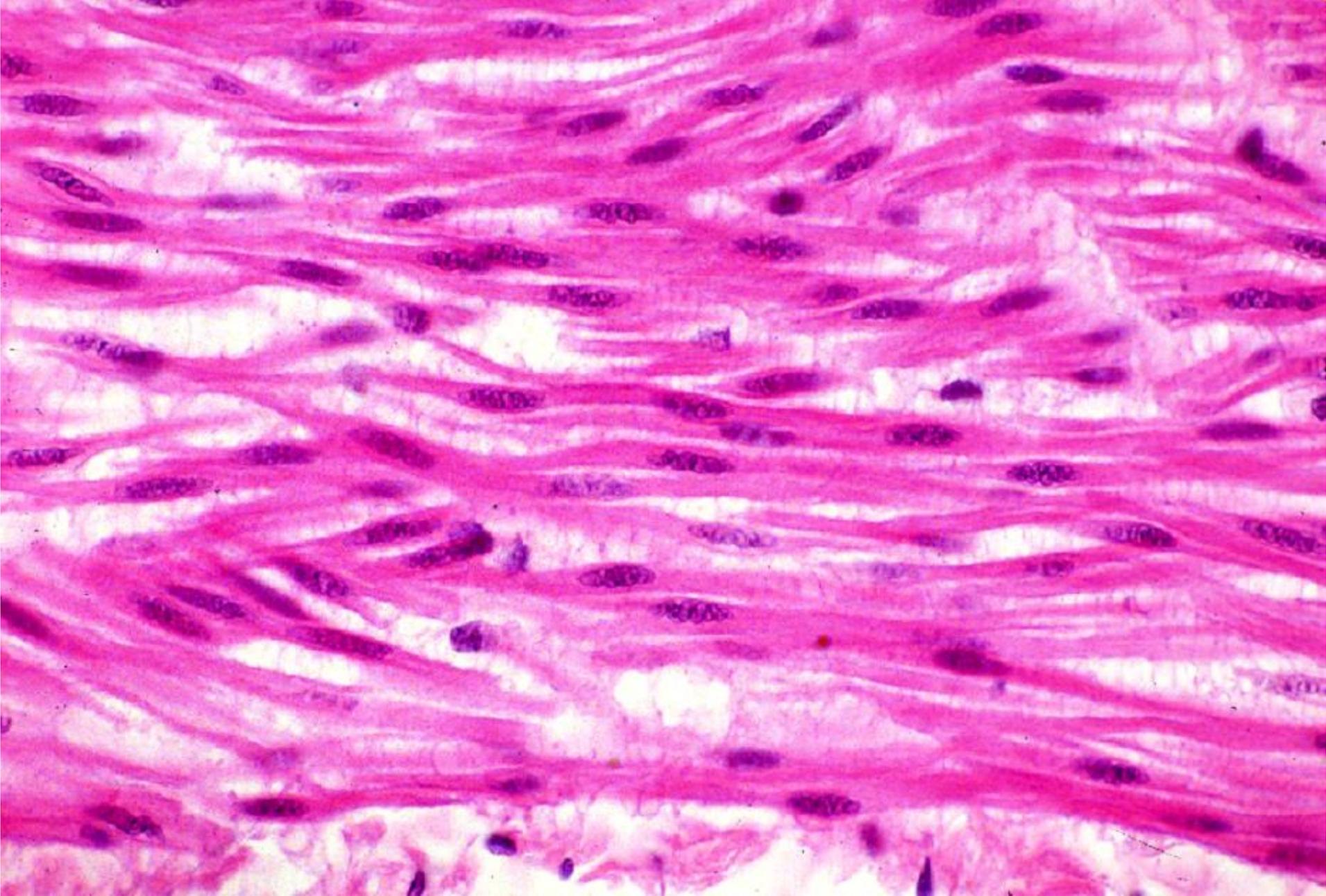
04-27 Cardiac muscle fibers, specialized conducting fibers. Human, H-E stain, x 250.



04-28 Junction between specialized conducting fibers and normal cardiac fibers. Human, H-E stain. X 160.

# 04-003

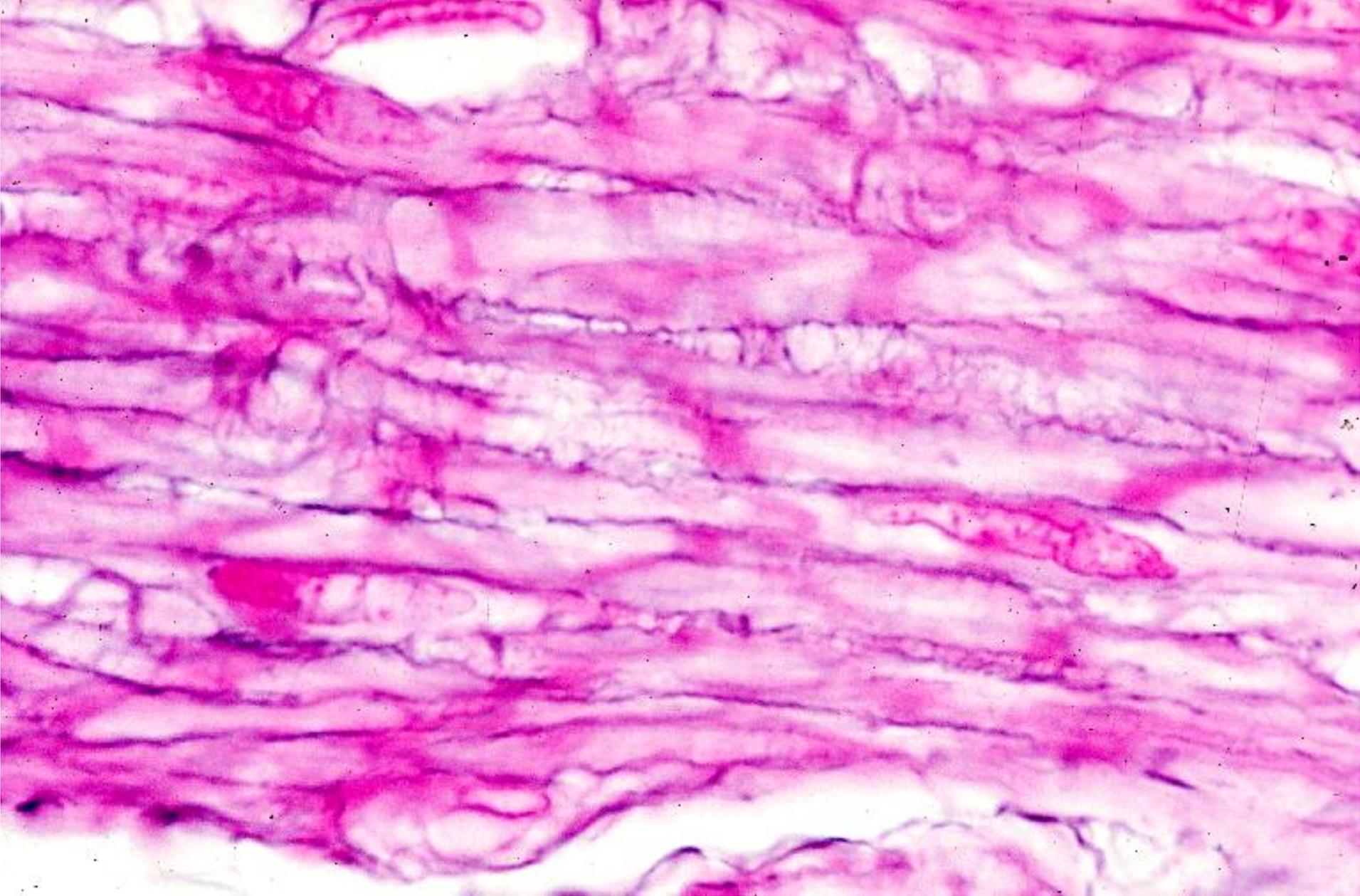
# Smooth Muscle



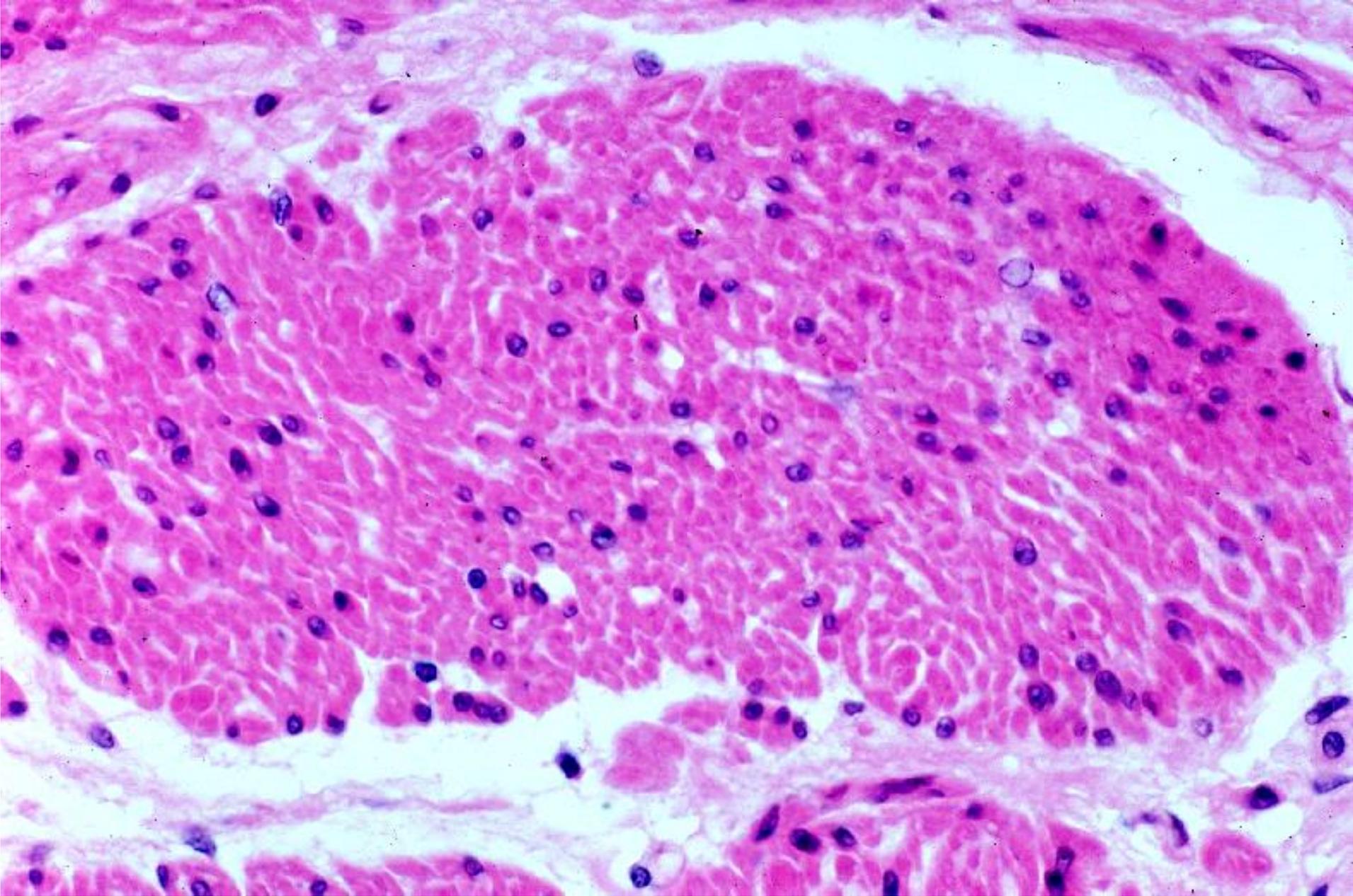
04-29 Smooth muscle fibers, longitudinal section. Human, H-E stain. X 160.



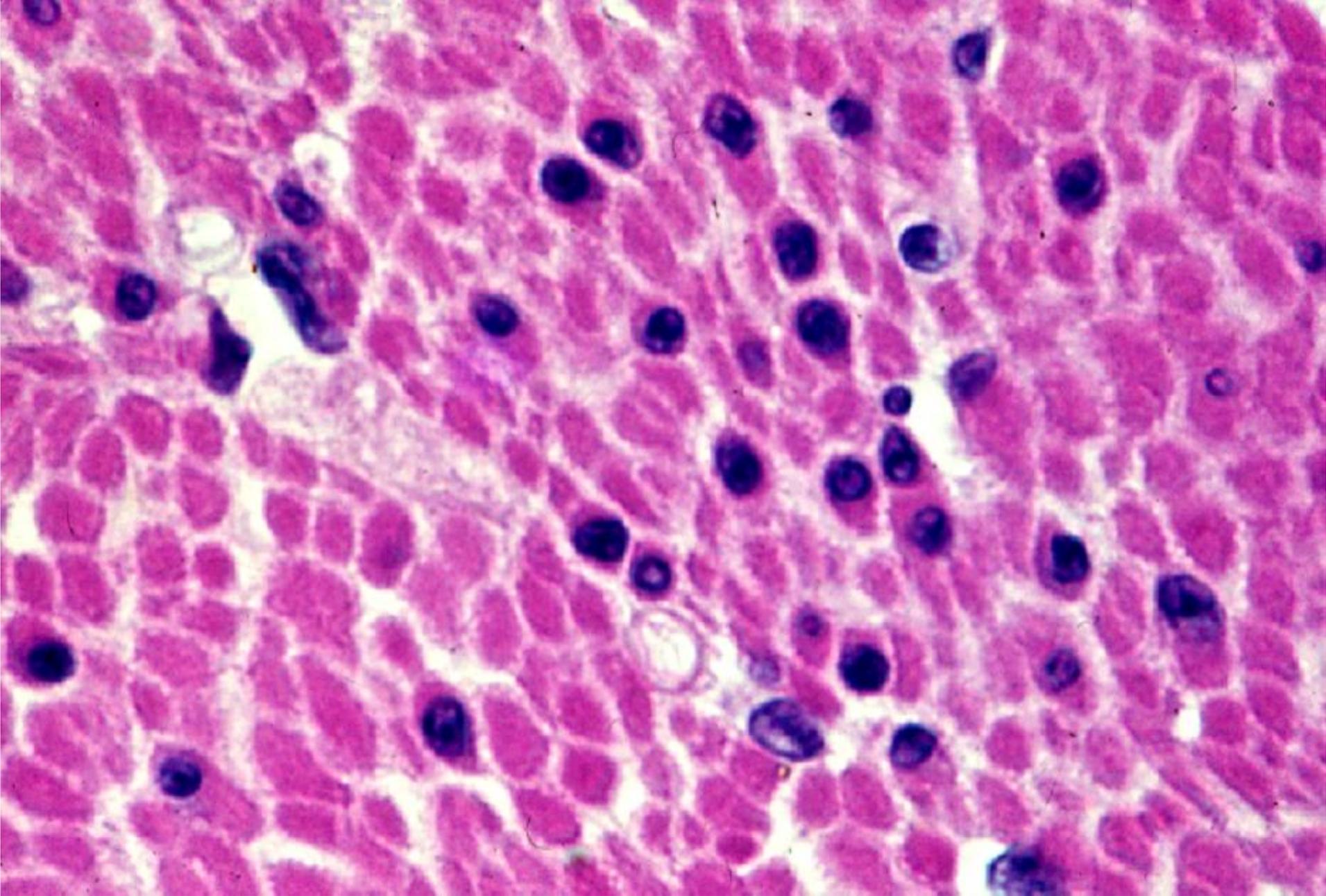
**04-30 Smooth muscle fibers, longitudinal section. Monkey, H-E stain. X 250.**



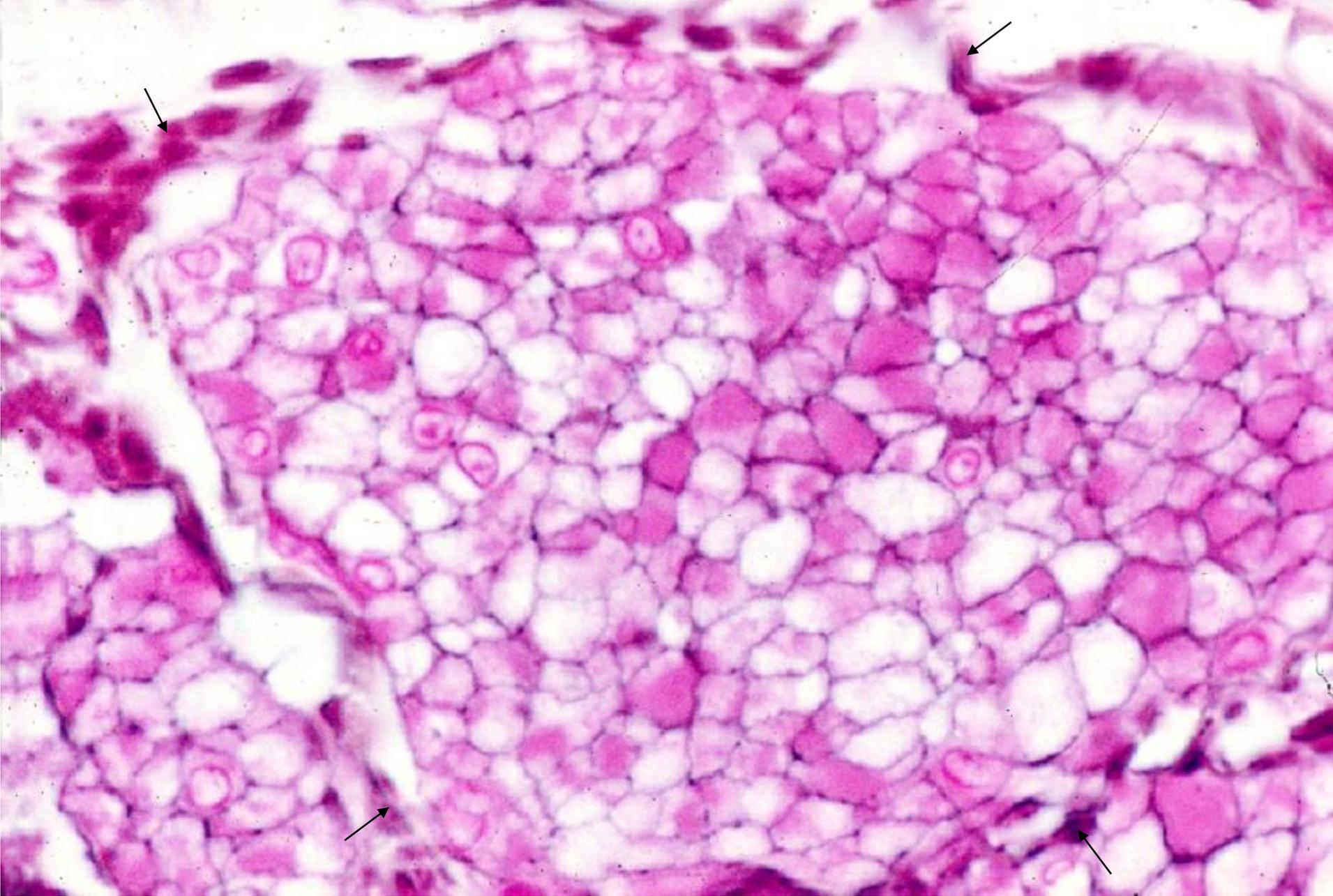
**04-31 Smooth muscle fibers, longitudinal section. Human, silver impregnation and Kernechtrot stain. X 250.**



04-32 Smooth muscle fibers, transverse section. Human, H-E stain. X 160.



04-33 Smooth muscle fibers, transverse section. Human, H-E stain. X 400.



04-34 Smooth muscle fibers, transverse section. Human, silver impregnation and Kernechtrot stain. X 250.

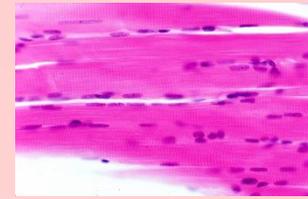
## 04-00 Muscular tissue

- The cells, whose protoplasmic property of contractility is highly developed, are called muscle cells, and the tissue consisting of muscle cells is the muscular tissue. As the muscle cells are elongated in the direction of contraction, they are usually called muscle fibers. Each muscle fiber is enclosed by reticular ( argylophilic ) fibers, connected with these fibers and constitutes the muscular tissue.
- Two categories of muscle are recognized according to the presence or absence of regular transverse bands along the length of the fibers: striated and smooth. Striated muscle is subdivided into two distinct types, skeletal and cardiac. The fibers of skeletal muscle are syncytial. The fibers of cardiac muscle are made up, on the contrary to the skeletal muscle, of separate cellular units.

## 04-001 Skeletal muscle

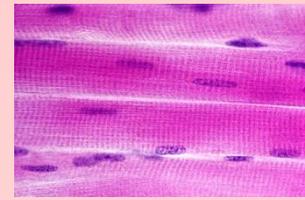
- The skeletal muscle fiber is a long cylindrical multinucleate cell, visible with the light microscope. Large number of parallel muscle fibers are grouped into fascicles, visible to the naked eye. The muscle fibers, the fascicles, and the whole muscle are each invested by connective tissue that forms a continuous stroma. The muscle as a whole is enclosed by a connective tissue layer called epimysium. Thin collagenous septa that extend inward, surrounding all of the fascicles, collectively comprise the perimysium, and the exceedingly delicate reticulum that invests the individual muscle fibers constitutes the endomysium.
- The blood vessels supplying skeletal muscle course in the connective tissue septa and ramify into a rich capillary bed around the individual muscle fibers. The capillaries are sufficiently tortuous to permit their accommodation to changes in length of the fibers, by straightening during elongation and contorting during contraction.

## 04-01 Skeletal muscles, longitudinal section 1. Human tongue, H-E stain, x 160.



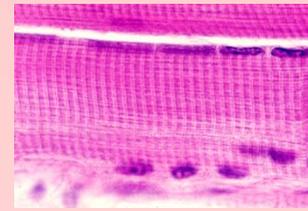
- These are human tongue muscle fibers. Skeletal muscle fibers are long cylindrical multinucleated cells ranging from 10 to 30 cm in length and from 100 to 500  $\mu$  m in diameter. They stain with acid dyes very deeply and show a closely spaced transverse striation. A fine longitudinal striation is also detectable; this is due to fine contractile fibrils, myofibrils, of about 1  $\mu$  m in diameter. The cross striation of the muscle fiber is due to the fact that corresponding segments of the closely packed myofibrils are in register across the entire width of the fiber. The nuclei locate in the periphery of the cell, i.e. namely, directly beneath the cell membrane, sarcolemma.

**04-02 Skeletal muscles, longitudinal section 2. Monkey,  
H-E stain, x 250.**



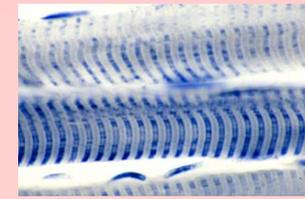
- In this figure the cross striation is distinct; a dark stained band alters with pale stained band regularly.

### 04-03 Skeletal muscles, longitudinal section 3. Human tongue, H-E stain, x 400.



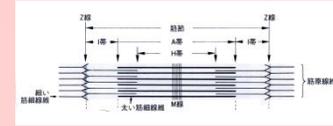
- The cross striation consisting of the dark stained band and the pale stained bands is very distinct. The dark bands are anisotropic ( birefringent ) and called A-bands and the pale bands are isotropic and called I-bands. The relative length of the bands depends on the state of contraction: The length of the I-bands becomes very short during contraction, longer during relaxation, and that of the A-bands remains constant in all phases. In the middle of the I-bands a thin transverse line crosses across the whole width of the muscle fiber, that is the Z-line or Z-disc. The segments of myofibrils between successive Z-lines are called sarcomeres and all of the morphological changes during the contractile cycle are described with reference to this structural unit.
- The peripheral location of the nuclei, just beneath cell surface is very distinct.

**04-04 Skeletal muscles, longitudinal section 4. Rat,  
Heidenhain's iron-hematoxylin stain, x 500.**



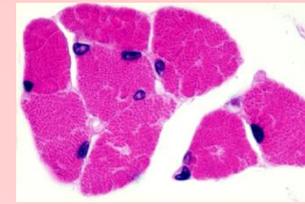
- This is the rat soleus muscle, stretched out and fixed. Heidenhain's iron-hematoxylin stains A-band especially deep. The I-bands are longer than usual and the Z-lines are conspicuously noted. In the middle of the deeply stained A-bands, a thin pale band, crossing the whole muscle fiber, is perceived, that is named H-band..

## 04-05 Scheme showing ultrastructure of a myofibril.



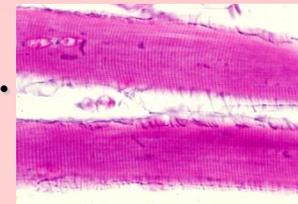
- The myofibrils are the smallest units of the contractile material of muscle, that are visible with the light microscope, but in electron micrographs, these are found to be composed of even smaller units, the myofilaments. These are of two kinds, thin actin filaments and thicker myosin filaments. The cross-banded pattern of striated muscle is due to a highly ordered arrangement of interdigitating sets of these filaments.
- Myosin filaments,  $1.5 \mu\text{m}$  in length and  $15 \text{ nm}$  in diameter, are oriented longitudinally in parallel array and spaced about  $45 \text{ nm}$  apart. They are the principal constituent of the A-bands of the sarcomeres. Each is slightly thicker in the middle and tapers toward its end. This thicker central portions cause a thin linear density called M-line that bisects paler H-band at the middle of each A-band.
- Actin filaments,  $1.0 \mu\text{m}$  in length and  $5$  to  $7 \text{ nm}$  in diameter, are the dominant component of the I-bands, but at their ends, they interdigitate with myosin filaments in the neighboring A-bands to varying degrees depending on the state of muscle contraction. At their another ends the actin filaments attach to the Z-band.
- This figure shows the relaxed state of the myofibril; the I-band is composed of actin filaments alone, the A-band, of both interdigitating actin and myosin filaments, causing the birefringency, and the H-band consists of myosin alone. At contraction, interdigitating actin filaments slide into the myosin area deeply from both sides, causing the shortening of the entire length of the muscle fiber. In this state the I-band becomes very short and H-band disappears.

**04-06 Skeletal muscle fibers, transverse section 1.  
Human, H-E stain, x 500.**



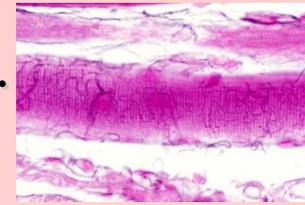
- This is a skeletal muscle fiber bundle, fascicle, consisting of several muscle fibers.. The individual fibers are enclosed by endomysium. In transverse sections, most of the interior of the individual fiber is occupied by myofibrils, 1 to 2  $\mu$  m in diameter. They are resolved as fine dots either uniformly distributed or grouped in polygonal areas called the fields of Cohnheim. The peripheral location of nuclei is clear.

**04-07 Skeletal muscle fibers, longitudinal section. Endomysium 1.  
Human, Silver impregnation and Kernechtrot stain, x 250.**



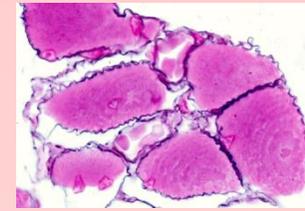
- Each skeletal muscle fiber is directly surrounded by reticular fibers; this coat is called endomysium. In this figure two longitudinally sectioned skeletal muscle fibers are shown, whose surface is wrapped by the argylophilic fibers, that's endomysium.

**04-08 Skeletal muscle fibers, longitudinal section. Endomysium 2.  
Human, Silver impregnation and Kernechtrot stain, x 250.**



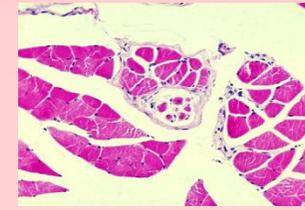
- This is a surface view of a skeletal muscle fiber. The endomysium wrapping the muscle fiber appears as relatively dense network on the surface of the muscle fiber.

**04-09 Skeletal muscle fibers, transverse section 2.  
Human, Silver impregnation and Kernechtrot stain, x 400.**



- This is to show the endomysium consisting of reticular fibers, directly wraps the individual fiber. Arrows indicate blood vessels containing erythrocytes.

## 04-10 Muscle spindle 1. Human, H-E stain, x 64.



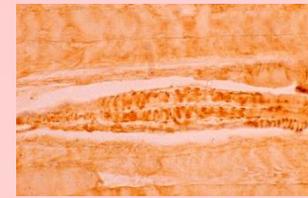
- This is a muscle spindle ( arrow ) found in the human thyrohyoideus muscle.
- For muscles to be used in a coordinated manner for locomotion and other voluntary movement, the central nervous system continuously needs information about the position of the limbs and the state of contraction of the various muscles. Such sensory inputs are collectively called proprioception. To meet this need muscles contain complex sensors called neuromuscular spindles ( muscle spindles ).
- The muscle spindle consists of several modified thin striated muscle fibers enclosed in a fusiform capsule. They are 5 to 10 mm long and therefore much shorter than the surrounding muscle fibers.
- The specialized muscle fibers in the interior of the spindle are referred to as intra- fusal fibers to distinguish them from the unspecialized extrafusal fibers. The intrafusal fibers, from 6 to 12. in number, are kept in the central portion of the fusiform cavity filled with a gelatinous substance.

## 04-11 Muscle spindle 2. Human, H-E stain, x 160.



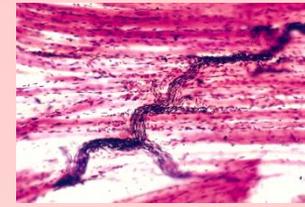
- Higher magnification of 04-10. The morphological differences between the intrafusal and extrafusal muscle fibers are conspicuous. The capsule of the muscle spindle is incorporated in the perimysium enclosing the extrafusal muscle fibers.

### 04-12 Muscle spindle 3. Rat, monoclonal antibody reaction using synaptophysin, x 130.



- The nerve endings on the intrafusal muscle fibers are visualized by a monoclonal antibody reaction using synaptophysin. The afferent nerve fibers end on the intrafusal muscle fibers making spirals around them.
- This preparation was made by Prof. Dr. A. Mizoguchi.

## 04-13 Motor nerve endings 1. Monkey tongue, silver impregnation, x 64.



- The skeletal muscle is innervated by craniospinal motor nerves. Nerve fibers, coming into the muscle fiber bundles, ramify and lose the myelin sheath, then attach to the muscle fibers, forming the motor nerve endings.
- This figure shows a part of tongue muscle of monkey, silver impregnated. One nerve fiber bundle runs from bottom left to top right. In the center this sends 3 branches to the muscle fiber bundles.

## 04-14 Motor nerve endings 2. Monkey tongue, silver impregnation, x160.



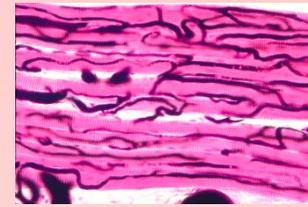
- This is a surface view of 4 nerve fibers, attaching to one muscle fiber forming the terminal branches, axon endings. Groups of round or oval nuclei around the terminal branches are of Schwann cells which constitute the covering, cell of Doyere.

### 04-15 Motor nerve endings 3. Monkey tongue, silver impregnation, x400.



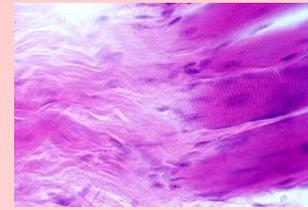
- This is also a surface view of one nerve fiber, terminating on one muscle fiber. One myelinated nerve fiber comes from bottom right upwards, turns to left and ramifies to form the end plates on the surface of a muscle fiber. In the center, the terminal branchings and their covering are conspicuous. The long arrow indicates myelin sheath and Schwann cell nucleus and the short ones capillaries.

**04-16 Capillaries in the skeletal muscle fibers. Cat,  
infusion of India ink, x 100.**



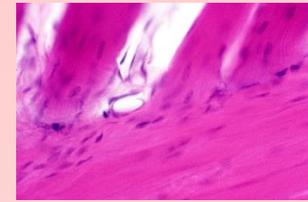
- The skeletal muscle is very rich in the blood supply. This is a part of the skeletal muscle fibers infused with India ink to visualize the capillaries. The specimen is counter stained with carmine. Most of capillaries run longitudinally between the muscle fibers.

## 04-17 Muscle-tendon junction 1. Monkey, H-E stain, x 160.



- The force generated by contraction of a muscle is transmitted to its insertion through a tendon. The specialized region of attachment at the interface between muscle cells and the bundles of collagen fibrils comprising the tendon is called the myotendinous junction. At the end of muscle fibers there are very large number of anastomosing folds and cylindrical processes that interdigitate with the collagen fiber bundles of tendon. These folds and processes are enclosed by the reticular fiber network very tightly and they interdigitate with collagen fibrils of tendon, also tightly enveloped by the reticular fiber network. The reticular fibers of both sides connect with each other so tightly that the myotendinous junction is very firm.
- This figure shows the part where 4 skeletal muscle fibers pass into the tendon fibers. The end of the skeletal muscle fibers with cross striation gradually loses the striation and passes into the tendon fibrils.

**04-18 Muscle-tendon junction 2. Monkey, H-E stain,  
x 160.**

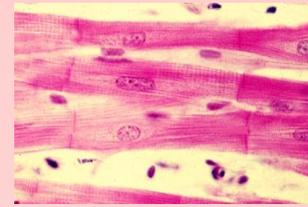


- In this figure 3 skeletal muscle fibers attach obliquely to the periosteum, occupying bottom right one third of this field. The lower end of the skeletal muscle fibers spread out, pass into collagen fibrils and attach to the periosteum.

## 04-002 Cardiac muscle

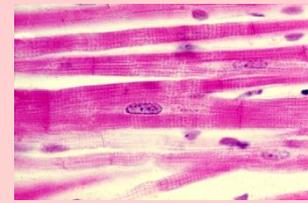
- The heart consists exclusively of specialized striated muscle, the cardiac muscle. The cardiac muscles exist only in the heart, and differ in several aspects from skeletal muscle fibers:
  - ①. Cardiac muscle consists of separate cellular units 10 to 20  $\mu$  m in diameter and 50 to 150  $\mu$  m in length. They are joined end to end by special surface specializations, intercalated discs, that run transversely across the muscle cells.
  - ②. The cardiac muscle cells form strands so predominantly parallel, but the individual cells branch and form oblique interconnections with neighboring strands resulting in a complex three dimensional organization ( network ).
  - ③. The elongated nuclei of the cellular units are usually situated deep in the axial portion of the cells, instead of immediately beneath the sarcolemma.
  - ④. The cardiac muscle beats spontaneously and its rhythmical contraction is not subject to voluntary control.

**04-19 Cardiac muscles, longitudinal section 1. Human,  
H-E stain, x 250.**



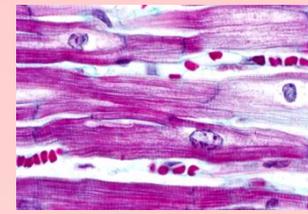
- This is a longitudinal section of cardiac muscles. The cardiac muscle cells are cylindrical in shape, and have an elongate nucleus in the middle of each cell. The myofibrils with cross striations are less numerous than in the skeletal muscle fibers and the granular cytoplasm, sarcoplasm, is distinctly recognized juxtannuclear region. The cells connect end to end with special surface specialization, the intercalated discs ( long arrows ) and form long parallel strands. At the center of this figure an oblique interconnection between the neighboring cells ( short arrow ) is seen. The meshes of the network of the cardiac muscle cells are filled by very loose connective tissue containing numerous capillaries.

04-20 Cardiac muscles, longitudinal section 2. Human,  
H-E stain, x 250.



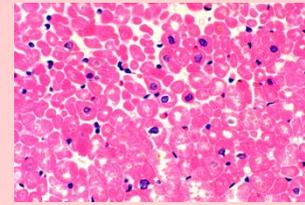
- In this figure a collateral branch of cardiac muscle cell and its connection with the neighboring cell are conspicuous. Arrow indicates the intercalated disc on this connection.

**04-21 Cardiac muscles, longitudinal section 3. Human,  
M-G stain, x 250.**



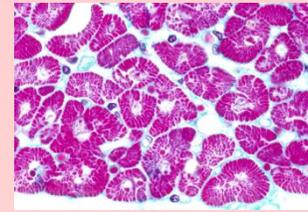
- In this specimen reticular fibers wrapping the individual muscle cell are stained blue and intercalated discs dark blue distinctly. In the loose meshes made by the cardiac muscle cells capillaries containing erythrocytes are conspicuous.

**04-22 Cardiac muscles, transverse section 1. Human,  
H-E stain, x 160.**



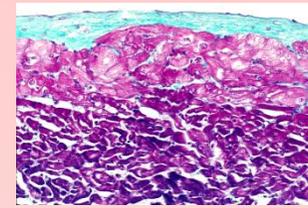
- This is a transverse section of cardiac muscle cells. The contour of the individual cells is round or polygonal and the central position of their nuclei is evident.

**04-23 Cardiac muscles, transverse section 2. Human,  
M-G stain, x 250.**



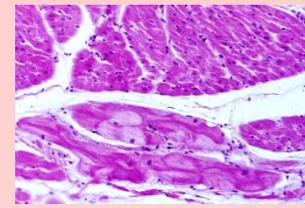
- The interior of cardiac muscle cell is filled with myofibrils and in the middle of it locates a nucleus. The surface of the individual cells is enveloped by reticular fibers stained green. Among the muscle cells there are numerous capillaries.

## 04-24 Cardiac muscles, specialized conducting fibers 1. Human, M-G stain, x 64.



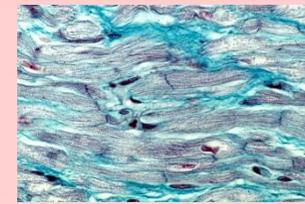
- The beats of heart start from the specialized region, sinoatrial node. To function effectively as a pump, the contraction of the atria must be completed slightly before the onset of ventricular contraction. The precise timing and coordination of events in the cardiac cycle depends on myocytes that are specialized for initiation of excitation and its conduction to different regions of the myocardium at a rate that will ensure their activation in the correct sequence.
- These specialized cardiac muscle cells establish a special conducting system consisting of sinoatrial node, atrioventricular node, internodular tracts, and atrioventricular bundle, dividing into right and left bundle branches that ramify beneath the endocardium of the right and left ventricles, establishing communicating junctions with the unspecialized working cardiac muscles.
- This figure shows a part of the conducting system beneath the endocardium of the atrium. The connective tissue underlying the endocardium stains green; directly beneath it, there are two kinds of cardiac muscle bundles, the upper consisting thick muscle cells are the conducting system and the lower the working cardiac cells. As the cardiac cells of the conducting system contain less numerous myofibrils they stain lightly red whereas the unspecialized working ones contains much myofibrils and stain dark red. At lower surface of the conductive system the communicating junctions are recognized.

## 04-25 Purkinje fibers. Bovine, H-E stain, x 64.



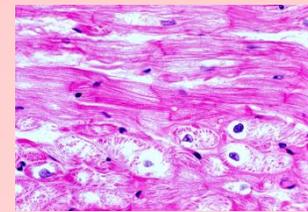
- In the bovine heart the conducting system consists of thick fibers, called Purkinje fibers. The lower half of this figure is occupied by the Purkinje fibers; they are very thick containing small nuclei. The muscle cells of the upper half of this figure are unspecialized working cardiac muscle cells.

**04-26 Cardiac muscle fibers, specialized conducting fibers. Human, M-G stain, x 160.**



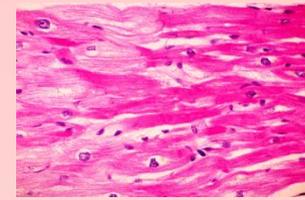
- The muscle cells of the conducting system contain less numerous myofibrils, as are seen here. The surface of the cells is enveloped by the reticular fibers. In this figure the intercalated discs are conspicuous.

**04-27 Cardiac muscle fibers, specialized conducting fibers. Human, H-E stain, x 250.**



- The longitudinal sections ( top ) and transverse sections ( bottom ) of the specialized conducting cardiac muscle cells are shown.

**04-28 Junction between specialized conducting fibers and normal cardiac fibers. Human, H-E stain. X 160.**

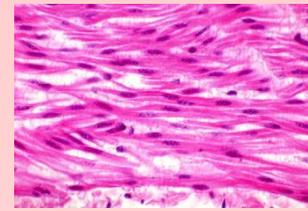


- The specialized conducting cells ( left half ) are making the communicating junctions with the unspecialized working cardiac muscle fibers ( right half ).

## 04- Smooth Muscles

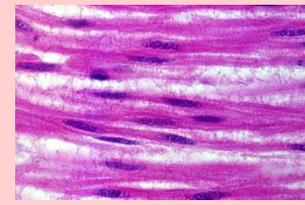
- The smooth muscle fibers are long fusiform or spindle-shaped with their elongated nucleus situated in their wider central position. They vary greatly in their length in different organs. In gravid human uterus smooth muscle fibers may reach a length of 0.5 mm, in the wall of the intestine their average length is about 0.2 mm, and in the wall of blood vessels, the smallest smooth muscle fibers may be only  $20 \mu\text{m}$  long.
- Where smooth muscle fibers is organized in bundles or extensive layers, the individual fibers offset such the wide portion of the cells are adjacent the thin tapering ends of neighboring cells. So, in the transverse sections, smooth muscle appears as a mosaic of rounded or polygonal profiles varying from one to several microns in diameter, with nuclei found only in the larger profiles.
- The cytoplasm stains with acid dyes deep homogeneously and no cell organelles nor fibrils with cross striation are perceived. The individual smooth muscle fibers are wrapped densely by reticular fibers and connected together with neighboring fibers.

**04-29 Smooth muscle fibers, longitudinal section.  
Human, H-E stain. X 160.**



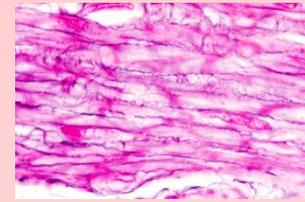
- These are smooth muscle fibers of the human duodenum. Individual fibers are long spindle-shaped and stain homogeneously deep red with eosin. Nuclei locate in their wide portion. Nappy fibers between the muscle fibers are reticular fibers.

**04-30 Smooth muscle fibers, longitudinal section.  
Monkey, H-E stain. X 250.**



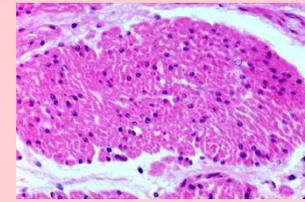
- These are also smooth muscle fibers of the intestine. They are somewhat contracted, so the nuclei shows uneven contour. The reticular fibers connecting the muscle fibers are very conspicuous as nappy fibers.

**04-31 Smooth muscle fibers, longitudinal section.  
Human, silver impregnation and Kernechtrot stain. X 250.**



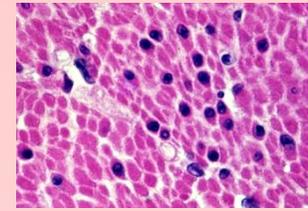
- These are smooth muscle fibers of human esophagus, silver impregnated. The reticular fibers wrapping the individual muscle fibers are blackened. The muscle fibers are connected with neighboring fibers by the blackened fibers. The specimen was counterstained with Kernechtrot.

**04-32 Smooth muscle fibers, transverse section. Human, H-E stain. X 160.**



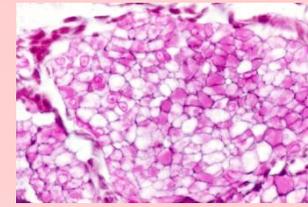
- This is transverse section of a smooth muscle bundle of the human stomach. It shows a mosaic pattern of polygonal profiles of thinner and thicker sections of muscle fibers. Only a few large profiles contain nuclei.

**04-33 Smooth muscle fibers, transverse section. Human, H-E stain. X 400.**



- Higher magnification of 04-32. The nappy fibers connecting the individual muscle fibers are conspicuous.

**04-34 Smooth muscle fibers, transverse section. Human, silver impregnation and Kernechtrot stain. X 250.**



- The individual muscle fibers are enclosed by reticular fiber, black line, so the mosaic pattern of polygonal profiles of thinner and thicker sections of muscle fibers is distinct. The arrows indicate the perimysium, consisting of collagen fibers, not blackened but colored deep brown.