Objectives

- Describe the embryonic origin of skeletal muscle
- Describe the origins of the innervation of the segmental musculature.
- Describe the origins of the musculature of the tongue, eye, and pharyngeal arch
- Describe the embryonic origin of cardiac muscles
- Describe the embryonic origin of smooth muscles

Skeletal muscle is derived from paraxial mesoderm, which forms somites from the occipital to the sacral regions and somitomeres in the head. Somitomeres are seven in number. They are partially segmented whorls of mesenchymal cells derived from paraxial mesoderm.

Somites initially form as somitomeres, extend from the occipital region to the tail bud. Immediately after segmentation, these somitomeres undergo a process of epithelization and form a “ball” of epithelial cells with a small cavity in the center. The ventral region of each somite then becomes mesenchymal again and forms the sclerotome, the bone-forming cells for the vertebrae and ribs.

Cells in the upper region of the somite form the dermatome and two muscle-forming areas at the ventrolateral (VLL) and dorsomedial (DML) lips (or edges), respectively. Cells from these two areas migrate and proliferate to form progenitor muscle cells ventral to the dermatome, thereby forming the dermomyotome. Some cells from the ventrolateral region also migrate into the adjacent parietal layer of the lateral plate mesoderm.

LATERAL SOMITIC FRONTIER

Initially, there is a well-defined border between each somite and the parietal layer of lateral plate mesoderm called the lateral somitic frontier. This frontier separates two mesodermal domains in the embryo:

- **the primaxial domain** that comprises the region around the neural tube and contains only somite-derived (paraxial mesoderm) cells and
the abaxial domain that consists of the parietal layer of lateral plate mesoderm together with somite cells that have migrated across the lateral somitic frontier.

The lateral somitic frontier also
defines the border of dermis derived from dermatomes in the back and dermis derived from lateral plate mesoderm in the body wall.
defines a border for rib development with the bony components of each rib derived from primaxial sclerotome cells and the cartilaginous parts of those ribs derived from sclerotome cells that migrate across the lateral somitic frontier (abaxial cells).

Muscle cells that cross this frontier (those from the ventrolateral edge of the myotome) and enter the lateral plate mesoderm comprise the abaxial muscle cell precursors and receive many of their signals for differentiation from lateral plate mesoderm; those that remain in the paraxial mesoderm and do not cross the frontier comprise the primaxial muscle cell precursors and receive many of their developmental signals from the neural tube and notochord.

Regardless of their domain, each myotome receives its innervation from spinal nerves derived from the same segment as the muscle cells.

The new description of muscle development characterized by primaxial and abaxial domains (based on the actual embryological origin) differs from the old concept of epimeres (back muscles) and hypomeres (limb and body wall muscles), which was based on a functional definition of innervation:

Epimeric (epiaxial) muscles were innervated by dorsal primary rami;

hypomeric (hypaxial) muscles by ventral primary rami.

**MYOGENESIS (MUSCLE FORMATION)**

The first indication of myogenesis (muscle formation) is the elongation of the nuclei and cell bodies of mesenchymal cells as they differentiate into myoblasts. Soon these primordial muscle cells fuse to form elongated, multinucleated, cylindrical structures—myotubes.
During or after fusion of the myoblasts, myofilaments develop in the cytoplasm of the myotubes. Other organelles characteristic of striated muscle cells, such as myofibrils, also form. By the end of the third month, cross-striations, typical of skeletal muscle, appear.

As the myotubes develop, they become invested with external laminae, which segregate them from the surrounding connective tissue. Fibroblasts produce the perimysium and epimysium layers of the fibrous sheath of the muscle; the endomysium is formed by the external lamina, and reticular fibers.

Somitomeres remain loosely organized structures and never segregate into sclerotome and dermomyotome segments.

Tendons for the attachment of muscles to bones are derived from sclerotome cells lying adjacent to myotomes at the anterior and posterior borders of somites.

**PATTERning OF MUSCLES**

are controlled by connective tissue into which myoblasts migrate.

- In the head region, these connective tissues are derived from neural crest cells;
- in cervical and occipital regions, they differentiate from somitic mesoderm; and
- in the body wall and limbs, they originate from the parietal layer of lateral plate mesoderm.

**Head Musculature**

All voluntary muscles of the head region are derived from paraxial mesoderm (somitomeres and somites), including musculature of the

- tongue,
- eye (except that of the iris, which is derived from optic cup ectoderm), and
- that associated with the pharyngeal (visceral) arches
Table showing the origin of craniofacial muscles

<table>
<thead>
<tr>
<th>Mesodermal Origin Muscles</th>
<th>Innervation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somitomeres 1 and 2</td>
<td>Superior, medial, ventral recti</td>
</tr>
<tr>
<td>Somitomere 3</td>
<td>Superior oblique</td>
</tr>
<tr>
<td>Somitomere 4</td>
<td>Jaw closing</td>
</tr>
<tr>
<td>Somitomere 5</td>
<td>Lateral rectus</td>
</tr>
<tr>
<td>Somitomere 6</td>
<td>Jaw opening, other second arch</td>
</tr>
<tr>
<td>Somitomere 7</td>
<td>Stylopharyngeus</td>
</tr>
<tr>
<td>Somites 1 and 2</td>
<td>Intrinsic laryngeals</td>
</tr>
<tr>
<td>Somites 2 to 5</td>
<td>Tongue</td>
</tr>
</tbody>
</table>

* Somites 2 to 5 constitute the occipital group (somite 1 degenerates for the most part).

**Limb Musculature**

The first indication of limb musculature is observed in the seventh week of development as a condensation of mesenchyme near the base of the limb buds. The mesenchyme is derived from dorsolateral cells of the somites that migrate into the limb bud to form the muscles.

With elongation of the limb buds, the muscle tissue splits into flexor and extensor components.

Although muscles of the limbs are segmental initially, with time, they fuse and are then composed of tissue derived from several segments.

- The upper limb buds lie opposite the lower five cervical and upper two thoracic segments, and
- the lower limb buds lie opposite the lower four lumbar and upper two sacral segments.
Table showing Origins of Muscles From Abaxial and Primaxial Precursors

<table>
<thead>
<tr>
<th>Origins of Muscles From Abaxial and Primaxial Precursors</th>
<th>Primaxial</th>
<th>Abaxial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical region</td>
<td>Scalenes</td>
<td>Infrahoid</td>
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<tr>
<td></td>
<td>Geniohyoid</td>
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<tr>
<td></td>
<td>Prevertebral</td>
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<tr>
<td>Thoracoabdominal region</td>
<td>Intercostals</td>
<td>Pectoralis major and minor</td>
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<tr>
<td></td>
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<td>External oblique</td>
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<td></td>
<td></td>
<td>Internal oblique</td>
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<tr>
<td></td>
<td></td>
<td>Transversus abdominus</td>
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<tr>
<td></td>
<td></td>
<td>Sternalis</td>
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<tr>
<td></td>
<td></td>
<td>Rectus abdominus</td>
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<tr>
<td></td>
<td></td>
<td>Pelvic diaphragm</td>
</tr>
<tr>
<td>Upper limb</td>
<td>Rhomboids</td>
<td>Distal limb muscles</td>
</tr>
<tr>
<td></td>
<td>Levator scapulae</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latissimus dorsi</td>
<td></td>
</tr>
<tr>
<td>Lower limb</td>
<td></td>
<td>All lower limb muscles</td>
</tr>
</tbody>
</table>

* The precise origin of muscles in the pelvic region and lower limb has not been determined, but most if not all are abaxial in origin.

**CARDIAC MUSCLE**

Cardiac muscle develops from splanchnic mesoderm surrounding the endothelial heart tube.

The myoblasts adhere to each other as in developing skeletal muscle, but the intervening cell membranes do not disintegrate; these areas of adhesion give rise to intercalated discs. Myofibrils develop as in skeletal muscle, but myoblasts do not fuse.

Late in the embryonic period, special bundles of muscle cells develop with relatively few myofibrils and relatively larger diameters than typical cardiac muscle fibers. These atypical cardiac muscle cells—Purkinje fibers—form the conducting system of the heart.

**SMOOTH MUSCLE**
Smooth muscle for the dorsal aorta and large arteries is derived from lateral plate mesoderm and neural crest cells. In the coronary arteries, smooth muscle originates from proepicardial cells and neural crest cells. Smooth muscle in the wall of the gut and gut derivatives is derived from the splanchnic layer of lateral plate mesoderm that surrounds these structures. Only the sphincter and dilator muscles of the pupil and muscle tissue in the mammary and sweat glands are derived from ectoderm.

Clinical Correlates

Partial or complete absence of a muscle is common. Examples include partial or complete absence of the palmaris longus, serratus anterior, or quadratus femoris muscles. A more serious defect is called Poland sequence which is characterized by absence of the pectoralis minor and partial loss of the pectoralis major (usually the sternal head) muscles. The nipple and areola are absent or displaced, and there are often digital defects (syndactyly [fused digits] and brachydactyly [short digits]) on the affected side.

Prune belly syndrome
Is partial or complete absence of abdominal musculature. Usually, the abdominal wall is so thin that organs are visible and easily palpated. This defect is associated with malformations of the urinary tract and bladder, including urethral obstruction. These defects cause an accumulation of fluid that distends the abdomen, resulting in atrophy of the abdominal muscles.

Muscular dystrophy
is the term for a group of inherited muscle diseases that cause progressive muscular wasting and weakness. There are a large number of these types of diseases of which Duchenne's muscular dystrophy (DMD) is the most common. The disease is inherited as X-linked recessive such that males are much more often affected than females.
Some cases of torticollis (wryneck) result from tearing of fibers of the sternocleidomastoid muscle during childbirth. Bleeding into the muscle occurs in a localized area, forming a hematoma (a small collection of blood). Later a solid mass develops because of necrosis (death) of muscle fibers and fibrosis (formation of fibrous tissue). Shortening of the muscle usually follows, which causes lateral bending of the head to the affected side and a slight turning away of the head from the side of the short muscle.

Although birth trauma is commonly considered as a cause of congenital torticollis, the fact that the condition has been observed in infants delivered by cesarean section suggests that there are other causes as well.

**Summary**

With the exception of some smooth muscle tissue, the muscular system develops from the mesodermal germ layer

- Skeletal muscle is derived from paraxial mesoderm, which forms somites from the occipital to the sacral regions and somitomeres in the head
- Smooth muscle differentiates from
  - somatic mesoderm which provides smooth muscle in the walls of many blood and lymphatic vessels.
  - *visceral splanchnic mesoderm* surrounding the gut and its derivatives
  - ectoderm (the muscles of the iris (sphincter and dilator pupillae) and the myoepithelial cells in mammary and sweat glands are thought to be derived from mesenchymal cells that originate from ectoderm).
- Cardiac muscle is derived from visceral splanchnic mesoderm surrounding the heart tube.

Thank you