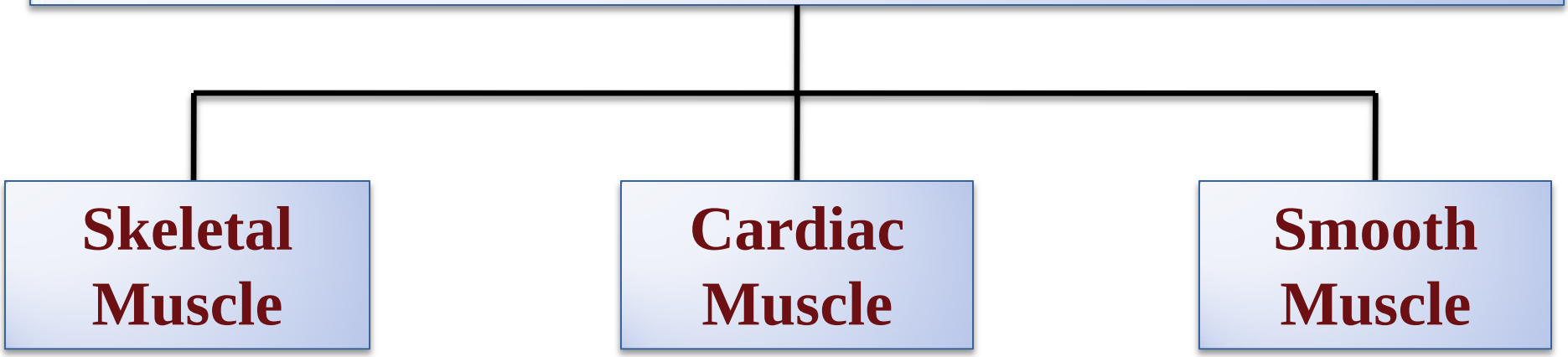
Classification & Comparison of Muscles

Dr.Viral I. Champaneri, MD
Assistant Professor
Department of Physiology

Classification of Muscles



Comparison Features

1. Structural features
2. Nerve supply and control
3. Electrical features
4. Excitation contraction coupling

Comparison Features

5. Contractility characteristics
6. Chemical composition
7. Blood supply
8. O_2 consumption and Muscle energetics

Structural Features

Striations

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Present	• Present	• Absent

Size of Fibers

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Length ▫ 1-40 mm	• Length ▫ 80 µm	• Length ▫ 50-500 µm
• Diameter ▫ 50-500 µm	• Diameter ▫ 15 µm	• Diameter ▫ 2-10 µm

Shape of the Muscle Fibers

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Cylindrical	• Cylindrical	• Spindle shaped

Branching of Fibers

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Absent	• Present	• Absent

Connection between fibers

Skeletal Muscles	Cardiac Muscles	Smooth Muscles

• Absent	• Functional connections
	• Forming Functional Syncytium
		• Single Unit
		  ▫ Functional connection Present
		• Multiunit
		  ▫ No connections

Nucleus

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Single /	• Central	• Single
• Multiple	with many	
• At periphery	nuclei	

Sarcoplasmic reticulum (SR)

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Very well developed	• Well developed • Not as Skeletal muscle	• Moderately developed

Sarcotubular system

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Present • Well developed	• Present	• Present • But not well developed

Sarcotubular system

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• 2 Triad	• 1 Triad	• Not well developed
• Per Sarcomere	• Per Sarcomere	

T - Tubule

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• At	• At	• Not well developed
• A-I junction	• Z line	

Thick & Thin filaments

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Arranged	• Arranged	• Not arranged
• regularly	• regularly	• regularly

Sarcomere

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Present	• Present	• Absent

Regulating protein

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Troponin	• Troponin	• Calmodulin

Ca^{2+} store & Ca^{2+} Pump in SR

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• High	• Moderate	• Low

Na^+ channels in the membrane

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Fast Voltage gated Na^+ channels	• Fast voltage gated Na^+ channels • Slow voltage gated Na^+-Ca^+ channels	• Mainly slow Voltage gated Na^+-Ca^+ channels • Few Fast voltage gated Na+ channels

Mitochondria

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Few	• Many	• Few

Nerve supply & Control

Nerve supply

Skeletal Muscles	Cardiac Muscles	Smooth Muscles

• Somatic nerves	• Autonomic nerves
	• Sympathetic
	  ▫ Excitatory
	• Parasympathetic
	  ▫ Inhibitory
		• Autonomic nerves
		• Sympathetic
		  ▫ Inhibitory
		• Parasympathetic
		  ▫ Excitatory

Control

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Voluntary	• Involuntary	▫ Involuntary

Electrical features

Resting Membrane Potential (RMP)

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• -80 to -90 mV	• -80 to -85 mV	• -50 to -60 mV

Action potential Shape

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Spike potential	▫ Plateau potential	• Single Unit ▫ Plateau & Spike • Multiunit ▫ Spike

Action potential duration

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• 1 to 5 milliseconds	• 100 - 300 milliseconds	• Single Unit • Plateau for 100-1000 msec • Spike for 10-50 mSec

Stimulated by

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Somatic nerves	• Autonomic nerves	• Autonomic nerves • Hormones • Local tissue factors

Excitability

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• High	• Moderate	• Low

Conductivity

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Fast	• Slow	• Slow

Absolute refractory Period

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• 1 to 3 msec	• 180 – 200 msec	• Not defined

Autorhythmicity

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Not present	• Present	• Present in • Single unit muscle

Excitation - Contraction Coupling

Speed of Phenomenon

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Rapid	• Very rapid	• Very Slow

Site of Ca^{2+} attachment

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Troponin	• Troponin	• Myosin

Mechanism of Ca^{2+} Mobilization

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• T-tubule depolarized	• Ca^{2+} induced Ca^{2+} released	• Inositol triphosphate (IP_3) • Increases release of Ca^{2+}

Dependence on ECF [Ca^{2+}]

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Not dependent	• Partly dependent	• Almost • Totally dependent

Contractility characteristics

Rate of contraction

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Fast	• Fast	• Slow

Rate of relaxation

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Fast	• Fast	• Slow

Duration of Muscle Twitch

Skeletal Muscles	Cardiac Muscles	Smooth Muscles

• Fast fibers
  ▫ 7.5 msec
• Slow fibers
  ▫ 100 msec
	• $1^{1/2}$ times of total duration of Action potential
	• [100 to 300 mSec]
		• About 1000 msec

All or None law

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Obeyed by	• Obeyed by	• Single Unit
• Single muscle fiber	• Whole Muscle	• Whole muscle
		• Multiunit
		• Single muscle fiber

Multiple (Quantal) summation

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Possible	• Not possible • Work as • Functional syncytium	• Not possible

Tetanus (Wave) summation

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Possible	• Not possible • Due to long refractory period (ARP) • (180 – 200mSec)	• Not possible • Process of contraction is long

Fatigue

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Possible	• Not possible • Due to long refractory period • More blood supply	• Possible • Difficult to demonstrate

Length-Tension Relationship

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Maximum tension • Developed at • Optimal length	• Maximum tension • Developed at • Optimal length	• Shows property of Plasticity

Chemical composition

Protein

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Maximum	• Less	• Less

Glycogen

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Less	• More	• Less

ATP & Phosphogen

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Present	• Present	• Present

Fat

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Mainly natural fats	• More Phospholipids • Cholesterol	• Mainly natural fats

Blood supply

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• 840 ml/min	• 250 ml /min	• 350 ml /min
• 3 to 4 ml/100gm/min	• 80 ml/100gm/min	• 1.4 ml/100gm/min

Oxygen consumption

Skeletal Muscles	Cardiac Muscles	Smooth Muscles
• Moderate	• High	• Low

Neuromuscular Junction

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Neuromuscular Junction

- Skeletal muscle fibers
- Innervated by Large myelinated nerve fibers
- Originate in large motoneurons of the anterior horns of spinal cord

Neuromuscular Junction

- Each nerve fiber
- After entering the muscle belly
- Branches and stimulates
- Three to several hundred skeletal muscle fibers

Neuromuscular Junction

- Each nerve ending makes a junction
- Called Neuromuscular Junction
- With the muscle fiber
- Near its midpoint

Neuromuscular Junction

- **Synapse between**
- ***Nerve fiber***
- **And**
- **The *muscle fiber***

Neuromuscular Junction

- Resulting action potential in the muscle fiber
- Travels in both directions
- Towards
- The muscle fiber ends

Neuromuscular Junction

- **Exception : 2% of the muscle fibers**
- **Only one (1) neuromuscular junction**
- **Per muscle fiber**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- Neuromuscular junction formed
- By ➔ Large myelinated nerve fiber
- To ➔ A skeletal muscle fiber

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- Nerve fiber ➔ Branches at its end
- To form complex of *branching nerve terminals*
- Invaginate muscle fiber
- But lies outside
- The muscle fiber plasma membrane

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **The entire structure**
- **Branching nerve terminal**
- **Invagination of muscle fiber is called**
- ***Motor end plate***

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Motor end plate:**
- **Thickened portion of**
- **Muscle membrane at the junction**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Motor end plate:**
- **Specialized portion of**
- **The sarcolemma of the muscle fiber**
- **Surrounding the terminal end of the axon**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- The nerve endings fit into ➔ Junctional folds
- Junctional folds ➔
- Depression in the motor end plate

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- *Motor end plate*
- Covered by one or more Schwann cells
- That insulate motor end plate
- From surrounding fluids

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- Invaginated membrane is called
- Synaptic gutter
- Or
- Synaptic trough

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- The space between
- The terminal nerve ending and
- Thickened muscle fiber membrane
- Synaptic space or Synaptic cleft

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- Synaptic space or Synaptic cleft
- 20 to 30 nanometers (nm) wide
- Comparable to synaptic cleft at
- Neuron-to-neuron synapses

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Subneural clefts:**
- **At the bottom of synaptic gutter**
- **Numerous smaller folds of muscle membrane**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Subneural clefts:**
- **Increase surface area**
- **At which synaptic transmitter**
- **Can act**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Axon terminal:**
- **Many Mitochondria**
- **Supply Adenoosine Triphosphate (ATP)**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- ATP ➔ Energy source
- Used mainly for
- Synthesis of excitatory transmitter ➔ Acetylcholine (Ach)

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- Acetylcholine (Ach):
- Excites muscle fiber membrane
- Synthesized : In cytoplasm of nerve terminal
- Absorbed rapidly
- In to many small synaptic vesicles

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Synaptic vesicles:**
- **3,00,000**
- **Terminal of single end plate**

Physiological Anatomy of Neuromuscular Junction : Motor End Plate

- **Acetylcholineesterase:**
- **Synaptic space**
- **Capable to destroying acetylcholine (Ach)**