

CHAPTER 10

MUSCULAR SYSTEM: Histology and Physiology

CHAPTER OVERVIEW: This chapter introduces the muscular system. The structures and mechanisms that allow contraction of individual fibers are described in detail. The structural and functional connections between motor neurons and skeletal muscles are described. The properties of whole muscle contraction are described and the relation to the activity of motor units is explained. Differences in cellular structure and contractile properties among muscle types are explained.

OUTLINE (two or three fifty-min. lectures):
Seeley, A&P, 5/e

Chapt. Object.	Topic Outline, Chapter 10	Figures & Tables	Transparency Acetates
1	I. General Functional Characteristics of Muscle	p. 276 Table 10.1, p.276	
	a. Contractility		
	b. Excitability		
	c. Extensibility		
	d. Elasticity		
2	II. Skeletal Muscle: Structure	Fig. 10.1, p.277	
	A. Connective Tissue	Fig. 10.2, p.277	TA-179
	1. External Lamina - Just Beyond Sarcolemma		
	2. Endomysium		
	3. Perimysium - Forms Fasciculi		
	4. Epimysium		
	5. Fascia		
3	B. Muscle Fibers	Fig. 10.3, p.279	TA-180
	a. Develop from Myoblasts		
	b. Sarcoplasm with Myofibrils		
	1) Actin Myofilaments		
	2) Myosin Myofilaments		
	1. Sarcomeres	Fig. 10.4, p.280	TA-181
	1) Z Disk	Fig. 10.5, p.280	TA-181
	2) I Bands (Isotropic)		
	3) A Bands (Anisotropic)		
	4) H Zones		
	5) M Lines		
	2. Actin and Myosin Myofilaments		
	a. Tropomyosin and Troponin	Fig. 10.6a, p.281	TA-182
	b. Globular Actin (G protein)	Fig. 10.6b, p.281	TA-182
	c. Heavy Myosin Molecules	Fig. 10.7, p.281	TA-182
	d. Crossbridges		
	3. T-Tubules and Sarcoplasmic Reticulum	Fig. 10.7, p. 281	TA-183
	a. Terminal Cisternae & Triads		
	III. Sliding Filament Model , p. 280	Predict Quest. 1:	TA-184

		Fig. 10.8, p.282	
	IV. Physiology of Skeletal Muscle Fibers , p. 282		
4	A. Neuromuscular Junction	Fig. 10.9, p.283	TA-185
		Predict Quest. 2	
	a. Synapse	Fig. 10.10, p.284	TA-186
	b. Presynaptic Terminal		
	c. Synaptic Cleft	Fig. 10.10a, p.284	TA-186
	d. Postsynaptic Membrane/Motor End Plate		
	e. Acetylcholine as the Neurotransmitter	Fig. 10.11a, p.285	TA-187 TA-187
	f. Acetylcholinesterase	Fig. 10.11b, p.285	
5	B. Excitation-Contraction Coupling	Fig. 10.12, p.286;	TA-188
		Clinical Note, p.284; Predict Question 3	
	1. Action Potential in Sarcolemma		
	2. Action Potential Along T-Tubule System		
	3. Release of Calcium from Sarcoplasmic Reticulum		
	4. Binding of Calcium to Troponin		
	5. Shift in Troponin-Tropomyosin Complex		
	6. Uncovering of Actin Active Sites		
	7. Myosin Binding to Actin		
	8. Cycles of Cross-Bridge Formation	Fig. 10.12, p.286	TA-188
		Fig. 10.13, p.287	TA-189
	C. Energy Requirements for Muscle Contraction	Fig. 10.13, p.287	TA-189
	1. Power Strokes		
	2. Recovery Strokes		
	3. Cycles Require Ongoing Presence of ATP & Ca ²⁺		
5, 6	D. Muscle Relaxation	Predict Quest. 4	
	1. Breaking of Cross-Bridges		
	2. Active Transport of Ca ²⁺ into Sarcoplasmic Reticulum		
	V. Physiology of Skeletal Muscle, p. 288		
	A. Muscle Twitch	Table 10.2, p.289	
		Fig. 10.14, p.288	TA-190
	1. Lag (Latent) Phase		
	2. Contraction Phase		
	3. Relaxation Phase		
	B. Stimulus Strength and Muscle Contraction		
	1. All-or None Law of Skeletal Muscle Fiber Contraction		
	a. Subthreshold Stimulus Produces		

	no Contraction	
	b. Stimuli of Threshold or Higher Strength Produce Similar Contraction	
	2. Motor Units	
	a. Structure	Fig. 10.15, p.290 TA-191
	b. All-or-None Fashion	Fig. 10.16, p.291
	c. Multiple Motor Unit Summation	Predict Quest. 5
	1) Graded Response to Stimulus Strength	
	2) Submaximal Stimulus Intensity Possible	
	3) Recruitment of Motor Units	
6	C. Stimulus Frequency and Muscle Contraction	
	1. Multiple Wave Summation (Little or no Relaxation Between Contractions)	Fig. 10.17, p.281
	a. Incomplete Tetanus	
	b. Complete Tetanus	
	2. Relaxation Between Contractions and Treppe	Fig. 10.18, p.292
	3. Intracellular Events Responsible for These Phenomena	
	D. Types of Whole Muscle Contractions	Table 10.3, p.292
	1. Isometric Contractions	
	2. Isotonic Contractions	
6	3. Muscle Tone	Predict Quest. 6
	4. Concentric Contractions	
	5. Eccentric Contractions	
7	E. Length versus Tension	Fig. 10.19, p.294 TA-192
	1. Active Tension and Active Tension Curve	
	2. Passive Tension	
	3. Total Tension	
	4. Relation of Active Tension to Sarcomere Length	
8	F. Fatigue	Clinical Note, p.295
	1. Psychological	
	2. Muscular	
	3. Synaptic	
9	G. Physiological Contracture and Rigor Mortis	
	1. Role of Ca^{2+}	
	2. Role of ATP Availability	
	H. Energy Sources	
	1. Creatine Phosphate	
	a. Most Rapid	
	b. Supply Quickly Exhausted (10-15 Sec.)	

- 2. Anaerobic Respiration
 - a. Occurs in Absence of O₂
 - b. Lactic Acid Waste Product
 - c. Faster, but Less Efficient than Aerobic Respiration
 - 3. Aerobic Respiration
 - a. Slower, but Many More ATP Produced
 - b. CO₂ waste Product
- 10 I. An Oxygen Debt Clinical Note,p.296
Predict Quest. 7
- 11 J. Slow and Fast Fibers
- 1. Slow-Twitch or High Oxidative Fibers
 - a. Contain Myoglobin
 - b. Many Mitochondria
 - c. Fibers are Resistant to Muscular Fatigue
 - d. Slow Speed of Contraction
 - 2. Fast-Twitch or Low Oxidative Fibers
 - a. Rapid Turn-Over of ATP
 - b. Contain Much Glycogen
 - c. Fibers Fatigue Quickly
 - 3. Distribution in the Body of Each Type
 - a. Most Muscles Contain Both Types of Cells
 - b. Proportion Established Developmentally
- 12 K. Effects of Exercise
- 1. Cannot Change the Type of a Cell
 - a. Can Improve Blood Supply
 - b. Can Train to Produce Fatigue-Resistant Fast-Twitch MusclesPredict Quest. 8
 - 2. Cell Hypertrophy in Response to Use Clinical Note, p.297
 - 3. Cell Atrophy in Response to Disuse
- 13 L. Heat Production
- 1. Increased During and Immediately After Exercise
 - 2. Shivering Increases Body Temperature
- VI. Smooth Muscle , p. 298
- A. Cell Structure Fig. 10.20, p.298 TA-193
 - 1. Myofilaments Not Arranged in Sarcomeres
 - a. Intermediate Filaments
 - b. Dense Bodies Fig. 10.21, p.299 TA-193
 - 2. Sarcoplasmic Reticulum Less Abundant
 - 3. Caveolae Rather than T-Tubules
 - 5. Different Mechanism for Cross-Bridge Formation

- a. Have Calmodulin as Ca^{2+} Binding Site
 - b. Myosin Kinase
 - c. Myosin Phosphatase
- Fig. 10.22, p.300 TA-194
- 14 B. Types of Smooth Muscle
- 1. Visceral or Unitary Smooth Muscle
 - a. Many Gap Junctions
 - b. Form Functional Syncytia
 - 2. Multiunit Smooth Muscle
 - a. Few Gap Junctions
 - b. Act as Independent Units
- 15 C. Electrical Properties of Smooth Muscle
- 1. Smaller Resting Membrane Potential
 - 2. Slow Waves of Depolarization and Repolarization
 - 3. Spontaneous Action Potentials Result
 - 4. Mechanical Response is not All-or-None
 - 5. Pacemaker Cells Have Fastest Rates of Spontaneous Depolarization
 - 6. Opening of Ligand-Gated Ca^{2+} Channels also Initiates Contraction Without an Action Potential
- Fig. 10.23a, p.301
Fig. 10.23b, p.2301
- Predict Quest. 9
- 16 D. Functional Properties of Smooth Muscle
- 1. Some Visceral Smooth Muscle has Autorhythmic Contractions
 - 2. Smooth Muscle Contracts in Response to Sudden Stretch but not Slow Increase in Length
 - 3. Smooth Muscle Tone Relatively Constant in Response to Gradual Increase in Length
 - 4. Amplitude of Contraction Constant, Although Muscle Length Varies
- E. Regulation of Smooth Muscle
- 1. Autonomic Nervous System Innervation = Involuntary Control
 - 2. Hormones Important
 - a. Epinephrine
 - b. Oxytocin
 - c. Local Factors - Histamine & Prostaglandins
- 17 VII. Cardiac Muscle, p. 301 (Detail in Chapter 20)
- A. Found Only in Heart
 - B. Specialized Cell-to-Cell Attachments, the Intercalated Disks
- VIII. Systems Pathology, p. 303
- Clinical Focus, p.302
Predict Quest. 10
Systemic Interactions,

IMPORTANT CONSIDERATIONS:: To separate this material into three segments, the logical breaks come after the discussion of the structure and explanation of excitation/contraction coupling, and then between summation and miscellaneous characteristics of muscles. Students may need to be lead through the sequential processes of contraction. The dimension of time and the involvement of multiple cellular components are important organizing concepts which students will have to sort out to achieve understanding of the physiology of muscle contraction.

SEE INSTRUCTOR'S MANUAL AND COURSE SOLUTIONS MANUAL FOR ADDITIONAL RESOURCES.