# Essentials of Strength Training and Conditioning

FOURTH EDITION


**G. Gregory Haff, PhD, CSCS,*D, FNSCA**
Edith Cowan University, Western Australia

**N. Travis Triplett, PhD, CSCS,*D, FNSCA**
Appalachian State University, Boone, NC

**EDITORS**

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**Human Kinetics**
Website: www.HumanKinetics.com

*United States:* Human Kinetics
P.O. Box 5076
Champaign, IL 61825-5076
800-747-4457
e-mail: humank@hkusa.com

*Canada:* Human Kinetics
475 Devonshire Road Unit 100
Windsor, ON N8Y 2L5
800-465-7301 (in Canada only)
e-mail: info@hkcanada.com

*Europe:* Human Kinetics
107 Bradford Road
Stanningley
Leeds LS28 6AT, United Kingdom
+44 (0) 113 255 5665
e-mail: hk@hkeurope.com

*Australia:* Human Kinetics
57A Price Avenue
Lower Mitcham, South Australia 5062
08 8372 0999
e-mail: info@hkaustralia.com

*New Zealand:* Human Kinetics
P.O. Box 80
Mitcham Shopping Centre, South Australia 5062
0800 222 062
e-mail: info@hknewzealand.com

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# PREFACE

In 1994, the first edition of *Essentials of Strength Training and Conditioning* was published. After a second edition (in 2000) and sales of over 100,000 books, an expanded and updated third edition was published in 2008. This newest edition continues the tradition as the most comprehensive reference available for strength and conditioning professionals. In this text, 30 expert contributors further explore the scientific principles, concepts, and theories of strength training and conditioning and their applications to athletic performance.

The first edition grew out of an awareness that there was not a book about strength training and conditioning that captured the views of leading professionals in anatomy, biochemistry, biomechanics, endocrinology, nutrition, exercise physiology, psychology, and the other sciences and that related the principles from these disciplines to the design of safe and effective training programs. Also, the lack of relevant and well-conducted research studies had hindered earlier efforts to create an all-inclusive resource. Once it was finally developed, *Essentials of Strength Training and Conditioning* quickly became the definitive textbook on the subject.

The second edition, released six years later, was more than a simple freshening of the content; it was an overhaul of the scope and application of the first edition. Throughout the text and in the additional 100-plus pages, the chapter contributors used updated, relevant, and conclusive research and concepts to turn scientific information into information on performance. Many learning tools were added, such as chapter objectives, key points, application boxes, and sample resistance training programs for three different sports. These enhancements, plus the addition of a full-color interior and hundreds of color photographs, made the second edition truly exceptional.

The third edition, released eight years after the second edition, offered restructured chapters and expansions of other chapters complete with new photographs and updated terminology. In addition, the artwork was modernized and instructor and student resources were created to help keep this text the primary resource for the study and instruction of strength and conditioning.

## Updates to the Fourth Edition

This fourth edition expands on the earlier editions and applies the most current research and information in a logical format that reaffirms *Essentials of Strength Training and Conditioning* as the most prominent resource for students preparing for careers in strength and conditioning and for sport science professionals involved in training athletes. The primary enhancements are as follows:

- Online videos featuring 21 resistance training exercises demonstrate proper exercise form for classroom and practical use.
- Updated research—specifically in the areas of high-intensity interval training, overtraining, agility and change of direction, nutrition for health and performance, and periodization—helps readers better understand these popular trends in the industry.
- A new chapter with instructions and photos presents techniques for exercises using alternative modes and nontraditional implements.
- Ten additional tests, including tests for maximum strength, power, and aerobic capacity, along with new flexibility exercises, resistance training exercises, plyometric exercises, and speed and agility drills, help professionals design programs that reflect current guidelines.

These enhancements, plus an expanded ancillary package for instructors including a new, robust collection of more than 60 instructor videos demonstrating resistance training, plyometric exercises, and alternative mode exercises, brings practical content to the classroom. Working along with the instructor guide and presentation package, a test package has been added to assist instructors in evaluating students' understanding of key concepts.

Each chapter begins with objectives and includes key points to guide the reader along the way. Key terms are boldfaced and listed at the end of the chapter. Chapters

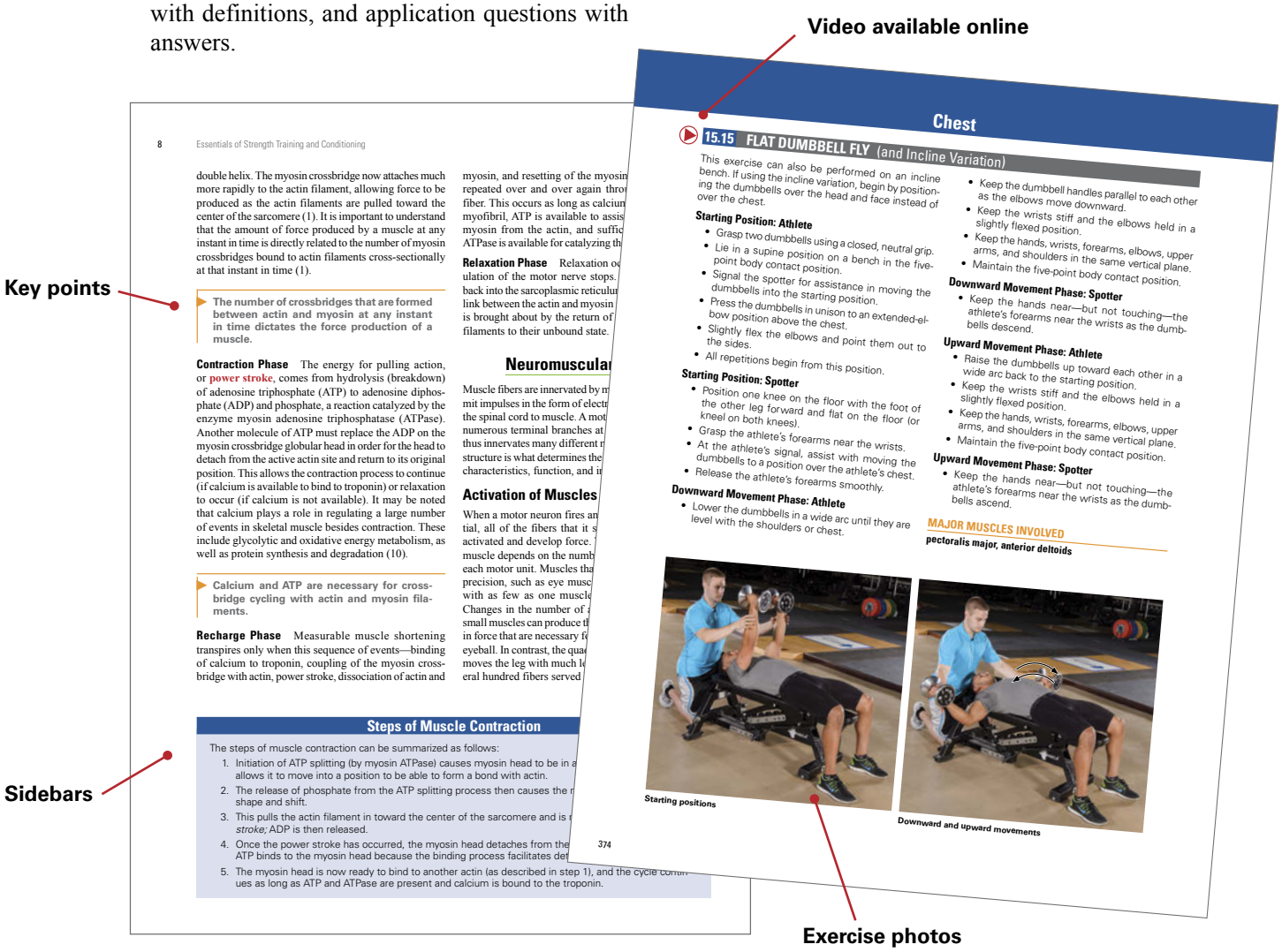
include sidebars that apply the content, and later chapters include sample resistance training programs for three different sports. Detailed instructions and photos are provided for testing, stretching, resistance training, alternative modes, plyometrics, agility training, and aerobic endurance exercise. Finally, chapters end with multiple-choice study questions, with an answer key at the end of the book.

## Instructor Resources

In addition to the updated content, this edition includes newly created instructor resources:

- *Instructor Video.* The instructor video includes video of correct technique for 61 resistance training, alternative, and plyometric exercises. These can be used for demonstration, lecture, and discussion.
- *Instructor Guide.* The instructor guide contains a course description, a sample semester schedule, chapter objectives, chapter outlines, key terms with definitions, and application questions with answers.
- *Presentation Package and Image Bank.* This comprehensive resource, delivered in Microsoft PowerPoint, offers instructors a presentation package containing over 1,300 slides to help augment lectures and class discussions. In addition to outlines and key points, the resource contains more than 600 figures, tables, and photos from the textbook, which can be used as an image bank by instructors who need to customize their presentations. Easy-to-follow instructions help guide instructors on how to reuse the images within their own PowerPoint templates.
- *Test Package.* The test package includes a bank of 240 multiple-choice questions, from which instructors can make their own tests and quizzes. Instructors can download Respondus or RTF files or files formatted for use in a learning management system.

These instructor resources can be found at www.HumanKinetics.com/EssentialsOfStrengthTrainingAndConditioning.



## Student and Professional Resources

The web resource with online video includes video of 21 resistance training exercises for use in understanding and performing correct exercise technique. Lab activities are provided to give students hands-on practice with testing and evaluation. The fillable forms make completing and submitting lab assignments easy.

The web resource can be found at www.HumanKinetics.com/EssentialsOfStrengthTrainingAndConditioning.

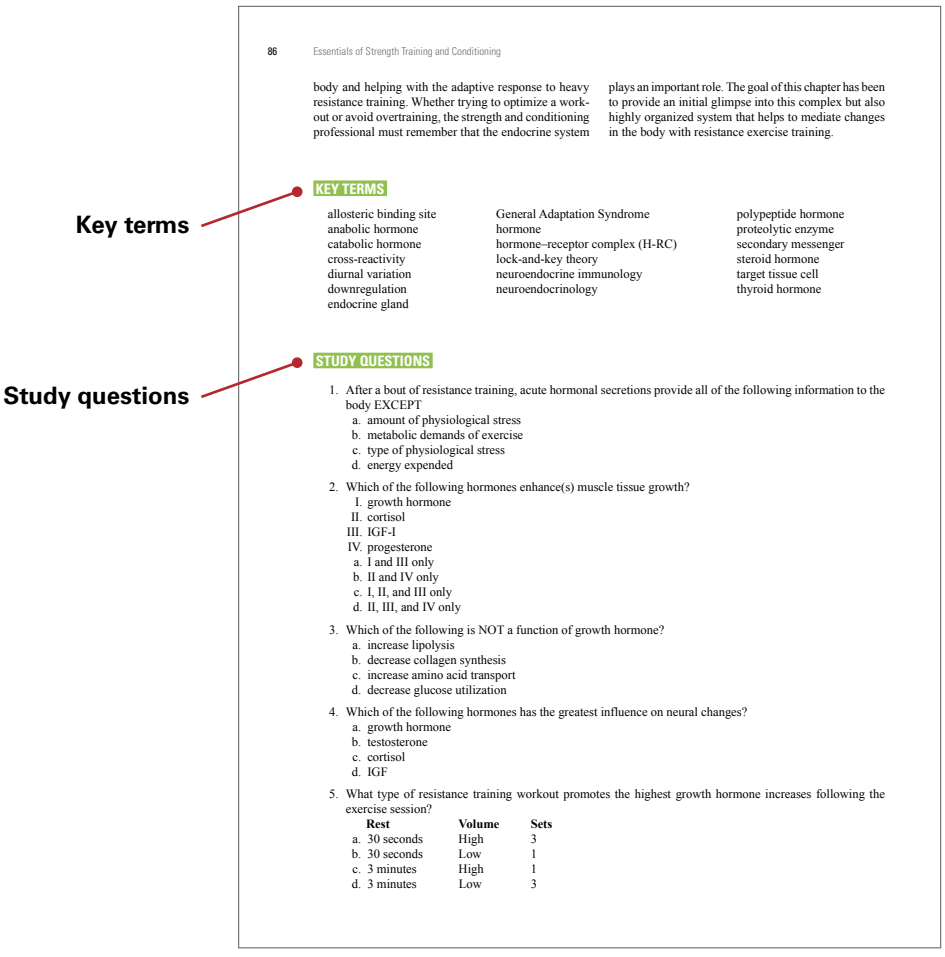
## Certification Exams

*Essentials of Strength Training and Conditioning* is the primary resource for individuals preparing for the National Strength and Conditioning Association's Certified Strength and Conditioning Specialist (CSCS) certification exam.

As a worldwide authority on strength and conditioning, the National Strength and Conditioning Association (NSCA) supports and disseminates research-based knowledge and its practical application to improve athletic performance and fitness. With over 30,000 members in more than 50 countries, the NSCA has established itself as an international clearinghouse for strength and conditioning research, theories, and practices.

The CSCS and NSCA-CPT were the first certifications of their kind to be nationally accredited by the National Commission for Certifying Agencies, a nongovernmental, nonprofit agency in Washington, DC, that sets national standards for certifying agencies. To date, more than 40,000 professionals residing in 75 countries hold one or more NSCA certifications.

Whether used for learning the essentials of strength training and conditioning, for preparing for a certification exam, or as a reference by professionals, *Essentials of Strength Training and Conditioning, Fourth Edition,* will help practitioners and the scientific community better understand how to develop and administer safe and effective strength training and conditioning programs.



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body and helping with the adaptive response to heavy resistance training. Whether trying to optimize a workout or avoid overtraining, the strength and conditioning professional must remember that the endocrine system plays an important role. The goal of this chapter has been to provide an initial glimpse into this complex but also highly organized system that helps to mediate changes in the body with resistance exercise training.

KEY TERMS

allosteric binding site
anabolic hormone
catabolic hormone
cross-reactivity
diurnal variation
downregulation
endocrine gland
General Adaptation Syndrome
hormone
hormone–receptor complex (H-RC)
lock-and-key theory
neuroendocrine immunology
neuroendocrinology
polypeptide hormone
proteolytic enzyme
secondary messenger
steroid hormone
target tissue cell
thyroid hormone

STUDY QUESTIONS

1. After a bout of resistance training, acute hormonal secretions provide all of the following information to the body EXCEPT
   a. amount of physiological stress
   b. metabolic demands of exercise
   c. type of physiological stress
   d. energy expended
2. Which of the following hormones enhance(s) muscle tissue growth?
   I. growth hormone
   II. cortisol
   III. IGF-I
   IV. progesterone
   a. I and III only
   b. II and IV only
   c. I, II, and III only
   d. II, III, and IV only
3. Which of the following is NOT a function of growth hormone?
   a. increase lipolysis
   b. decrease collagen synthesis
   c. increase amino acid transport
   d. decrease glucose utilization
4. Which of the following hormones has the greatest influence on neural changes?
   a. growth hormone
   b. testosterone
   c. cortisol
   d. IGF
5. What type of resistance training workout promotes the highest growth hormone increases following the exercise session?

| | Rest | Volume | Sets |
|---|---|---|---|
| a. | 30 seconds | High | 3 |
| b. | 30 seconds | Low | 1 |
| c. | 3 minutes | High | 1 |
| d. | 3 minutes | Low | 3 |

Key terms

Study questions

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# ACCESSING THE LAB ACTIVITIES

The lab activities are accessed through the web resource.

Individuals who purchase a new print book will receive access to the web resource via a key code.

The web resource can be accessed at www.HumanKinetics.com/EssentialsOfStrengthTrainingAndConditioning. Following is a list of the lab activities.

**Lab 1: Anaerobic Capacity Testing**

300-Yard (274 m) Shuttle Run

**Lab 2: Aerobic Capacity Testing**

1.5-Mile (2.4 km) Run

12-Minute Run

**Lab 3: Anthropometry and Body Composition**

Skinfold Measurements

**Lab 4: Exercise Testing for Athletes**

Test Selection and Order

**Lab 5: Techniques of Exercise**

Flexibility Exercise Techniques

**Lab 6: Techniques of Exercise**

Resistance Exercise and Spotting Guidelines

**Lab 7: Muscular Strength and Power Testing**

Vertical Jump Test

Standing Long Jump Test

1RM Bench Press

1RM Back Squat

**Lab 8: Techniques of Exercise**

Plyometric Exercise Techniques

**Lab 9: Speed and Agility Technique and Testing**

T-Test

Hexagon Test

Pro Agility Test

40-Yard (37 m) Sprint

**Lab 10: Muscular Endurance Testing**

Push-Up Test

YMCA Bench Press Test

Partial Curl-Up Test

**Lab 11: Facility Layout Design**

Facility Floor Plan

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# ACKNOWLEDGMENTS

The development of the fourth edition of the NSCA's *Essentials of Strength Training and Conditioning* was a massive undertaking that would not have been possible without the contributions of a vast number of people. The historic development of this iconic text has served as our guiding principle, and the hard work of the numerous authors who contributed to the three previous editions has established a strong foundation for this text. Therefore, we thank the previous editors, Thomas Baechle and Roger Earle, for their foresight over twenty years ago that has led us to where we are today and for their passionate work on all of the previous editions. This edition would not have been possible without the continued contribution of Roger Earle, who has gone beyond his role as a Human Kinetics representative. He is a true friend who has helped with many aspects of this book and our writing careers.

We would also like to thank Keith Cinea and Carwyn Sharp for their help throughout the process. These individuals have represented the NSCA well and positioned the science that underpins our profession as the standard that determines the content of this text. Because it is a key resource for current and future strength and conditioning professionals, it was essential for us to ensure that this text holds true to the NSCA mission of translating science into practice, and both Keith and Carwyn are ambassadors of this philosophy. Thanks also to the multitude of individuals at Human Kinetics who were essential to completing every phase of the publication of this book, from copyediting to graphic design. Probably the most important note of thanks goes to Chris Drews and Karla Walsh, our developmental editor and managing editor, who helped two novice book editors in countless ways. Without Chris and Karla, we would have probably been lost in the process.

## G. Gregory Haff, PhD, CSCS,*D, FNSCA

To my coeditor and long-time friend, Travis Triplett: I could think of no one else I would want to edit a book of this magnitude with. Your kind heart and easygoing style is a perfect complement to my "bull in a china shop" methodology for processes like this. Thanks for always being one of my very best friends!

I have to thank my family. My wife Erin has sacrificed everything to allow me the ability to chase my dreams and undertake projects like this. Without her support I would merely be stuck under the heavy lifting bar of life. It is a blessing to have someone strong enough to spot you when times are tough, and for that I love you more than you know. For my father, Guy Haff—I doubt you ever thought that lifting weights would become my whole life's work when you took me to the West Morris YMCA at 11 years of age to teach me to lift. Without that I cannot imagine who I would be at this moment. Finally, I must dedicate my efforts to my mother, Sandra Haff. No matter where you are now, I hope you are still proud of the man I am and the man I strive to be each and every day. I miss you much, Mom, and I wish you were here to see all the great things that have happened.

## N. Travis Triplett, PhD, CSCS,*D, FNSCA

I never dreamed that taking my first weight training class while at the university would have culminated in such a rewarding career in the field of strength and conditioning. It is difficult to thank every person who had a role in getting me to this point in my life and my career, which enabled me to enthusiastically embark on this project. I was fortunate to receive a strong foundation from my parents—I wish you could both be here to see that the example you set was followed. I also want to thank my brother and my circle of friends, who have always been supportive and have been there to brighten my day. Professionally, my two greatest influences have been Mike Stone and Bill Kraemer. I value your mentorship and friendship greatly. Numerous colleagues and former students around the world have contributed to my knowledge and success along the way, and I appreciate each and every one of you even if we don't see each other very often.

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CHAPTER 1

# Structure and Function of Body Systems

N. Travis Triplett, PhD

**After completing this chapter, you will be able to**

- describe both the macrostructure and microstructure of muscle and bone,
- describe the sliding-filament theory of muscular contraction,
- describe the specific morphological and physiological characteristics of different muscle fiber types and predict their relative involvement in different sport events, and
- describe the anatomical and physiological characteristics of the cardiovascular and respiratory systems.

The author would like to acknowledge the significant contributions of Robert T. Harris and Gary R. Hunter to this chapter.

Physical exercise and sport performance involve effective, purposeful movements of the body. These movements result from the forces developed in muscles, which move the various body parts by acting through lever systems of the skeleton. These skeletal muscles are under the control of the cerebral cortex, which activates the skeletal muscle cells or fibers through the motor neurons of the peripheral nervous system. Support for this neuromuscular activity involves continuous delivery of oxygen and nutrients to working tissues and removal of carbon dioxide and metabolic waste by-products from working tissues through activities of the cardiovascular and respiratory systems.

In order to best apply the available scientific knowledge to the training of athletes and the development of effective training programs, strength and conditioning professionals must have a basic understanding of not only musculoskeletal function but also those systems of the body that directly support the work of exercising muscle. Accordingly, this chapter summarizes those aspects of the anatomy and function of the musculoskeletal, neuromuscular, cardiovascular, and respiratory systems that are essential for developing and maintaining muscular force and power.

## Musculoskeletal System

The musculoskeletal system of the human body consists of bones, joints, muscles, and tendons configured to allow the great variety of movements characteristic of human activity. This section describes the various components of the musculoskeletal system, both individually and in the context of how they function together.

### Skeleton

The muscles of the body do not act directly to exert force on the ground or other objects. Instead, they function by pulling against bones that rotate about joints and transmit force to the environment. Muscles can only pull, not push; but through the system of bony levers, muscle pulling forces can be manifested as either pulling or pushing forces against external objects.

There are approximately 206 bones in the body, though the number can vary. This relatively light, strong structure provides leverage, support, and protection (figure 1.1). The **axial skeleton** consists of the skull (cranium), vertebral column (vertebra C1 through the coccyx), ribs, and sternum. The **appendicular skeleton** includes the shoulder (or pectoral) girdle (left and right scapula and clavicle); bones of the arms, wrists, and hands (left and right humerus, radius, ulna, carpals, metacarpals, and phalanges); the pelvic girdle (left and right coxal or innominate bones); and the bones of the legs, ankles, and feet (left and right femur, patella, tibia, fibula, tarsals, metatarsals, and phalanges).

Junctions of bones are called joints. **Fibrous joints** (e.g., sutures of the skull) allow virtually no movement; **cartilaginous joints** (e.g., intervertebral disks) allow limited movement; and **synovial joints** (e.g., elbow and knee) allow considerable movement. Sport and exercise movements occur mainly about the synovial joints, whose most important features are low friction and large range of motion. Articulating bone ends are covered with smooth **hyaline cartilage**, and the entire joint is enclosed in a capsule filled with **synovial fluid**. There are usually additional supporting structures of ligament and cartilage (13).

Virtually all joint movement consists of rotation about points or axes. Joints can be categorized by the number of directions about which rotation can occur. **Uniaxial joints**, such as the elbow, operate as hinges, essentially rotating about only one axis. The knee is often referred to as a hinge joint, but its axis of rotation actually changes throughout the joint range of motion. **Biaxial joints**, such as the ankle and wrist, allow movement about two perpendicular axes. **Multiaxial joints**, including the shoulder and hip ball-and-socket joints, allow movement about all three perpendicular axes that define space.

The **vertebral column** is made up of vertebral bones separated by flexible disks that allow movement to occur. The vertebrae are grouped into 7 cervical vertebrae in the neck region; 12 thoracic vertebrae in the middle to upper back; 5 lumbar vertebrae, which make up the lower back; 5 sacral vertebrae, which are fused together and

### What Factors Affect Skeletal Growth in an Adult?

There are several things that can positively affect the adult skeleton, and most are a result of muscle use. When the body is subjected to heavy loads (job tasks or resistance training), the bone will increase in density and bone mineral content. If the body performs more explosive movements with impact, similar changes can occur. Some of the higher bone densities have been seen in people who engage in gymnastics or other activities that involve high-strength and high-power movements, some with hard landings (11). Other factors that influence bone adaptations are whether the axial skeleton is loaded and how often this loading occurs (frequency). Since the adaptation period of bone is longer than that of skeletal muscle, it is important to vary the stimulus in terms of frequency, intensity, and type.

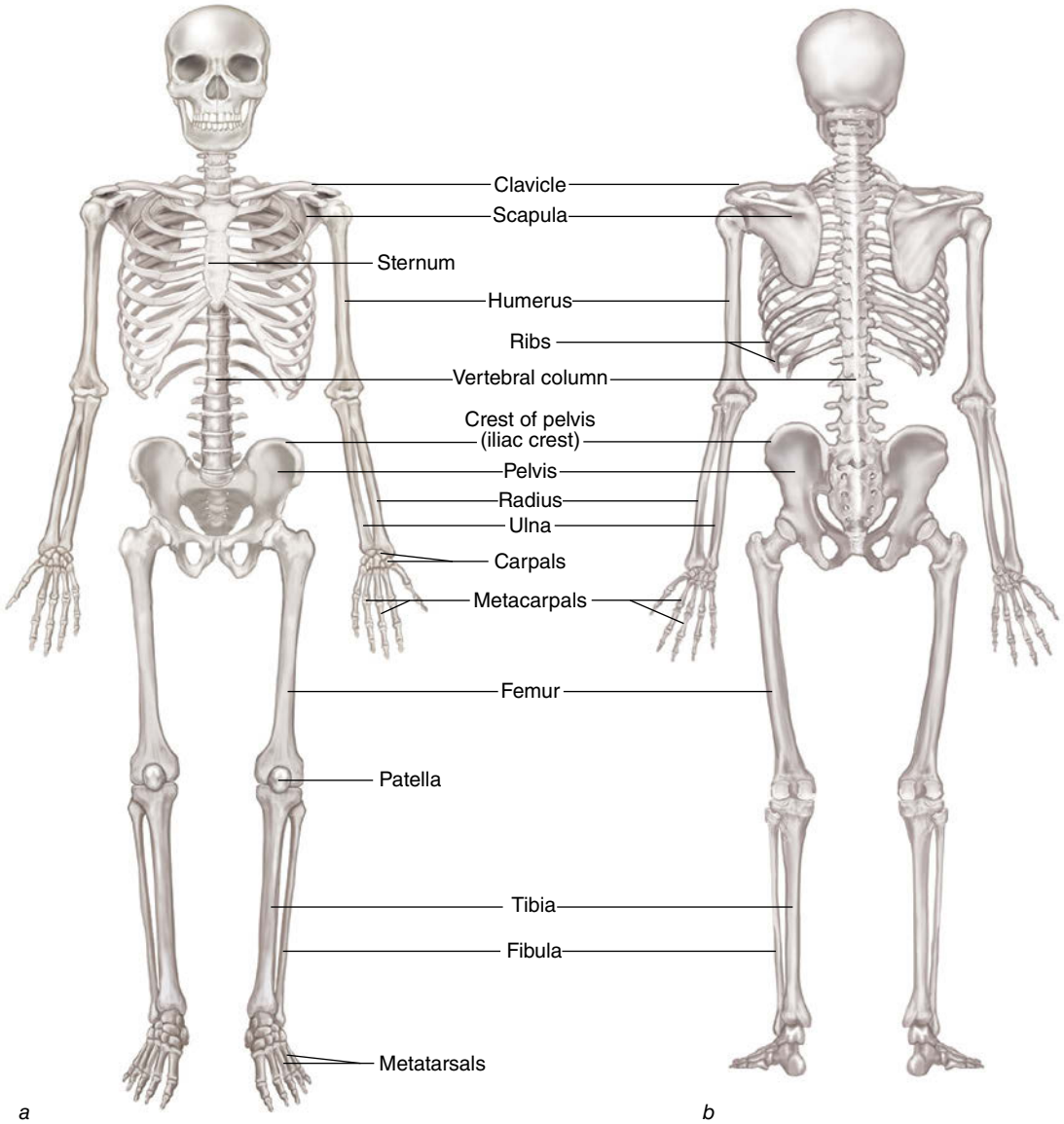


**FIGURE 1.1** *(a)* Front view and *(b)* rear view of an adult male human skeleton.

make up the rear part of the pelvis; and 3 to 5 coccygeal vertebrae, which form a kind of vestigial internal tail extending downward from the pelvis.

## Skeletal Musculature

The system of muscles that enables the skeleton to move is depicted in figure 1.2. The connection point between bones is the joint, and skeletal muscles are attached to bones at each of their ends. Without this arrangement, movement could not occur.

### *Musculoskeletal Macrostructure and Microstructure*

Each skeletal muscle is an organ that contains muscle tissue, connective tissue, nerves, and blood vessels. Fibrous connective tissue, or **epimysium**, covers the body's more than 430 skeletal muscles. The epimysium is contiguous with the tendons at the ends of the muscle (figure 1.3). The **tendon** is attached to **bone periosteum**, a specialized connective tissue covering all bones; any contraction of the muscle pulls on the tendon and, in turn, the bone. Limb muscles have two attachments to bone: **proximal** (closer to the trunk) and **distal** (farther from the trunk). The two attachments of trunk muscles are termed **superior** (closer to the head) and **inferior** (closer to the feet).

Muscle cells, often called **muscle fibers**, are long (sometimes running the entire length of a muscle), cylindrical cells 50 to 100 µm in diameter (about the diameter of a human hair). These fibers have many nuclei situated on the periphery of the cell and have a striated appearance

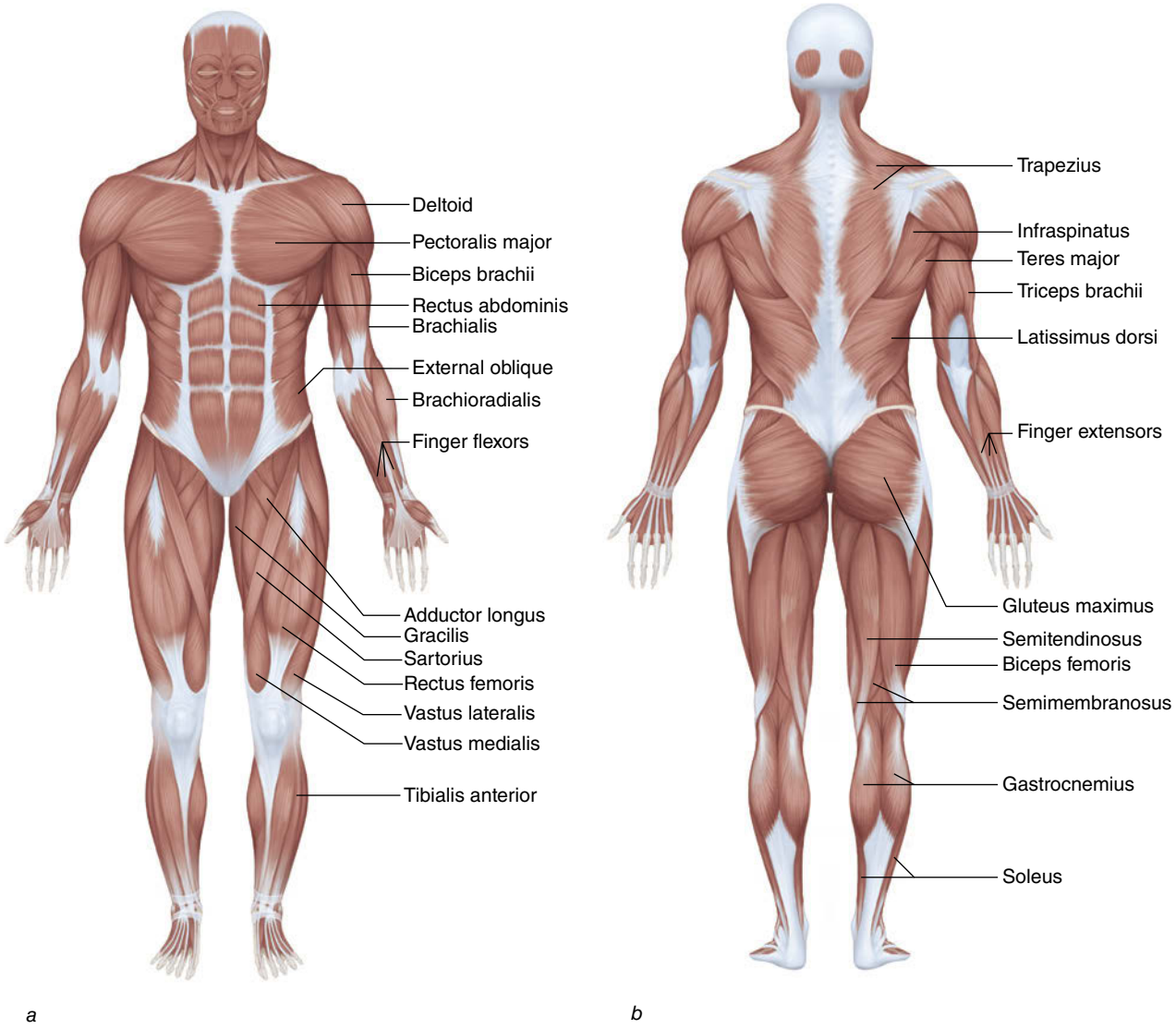


**FIGURE 1.2** *(a)* Front view and *(b)* rear view of adult male human skeletal musculature.

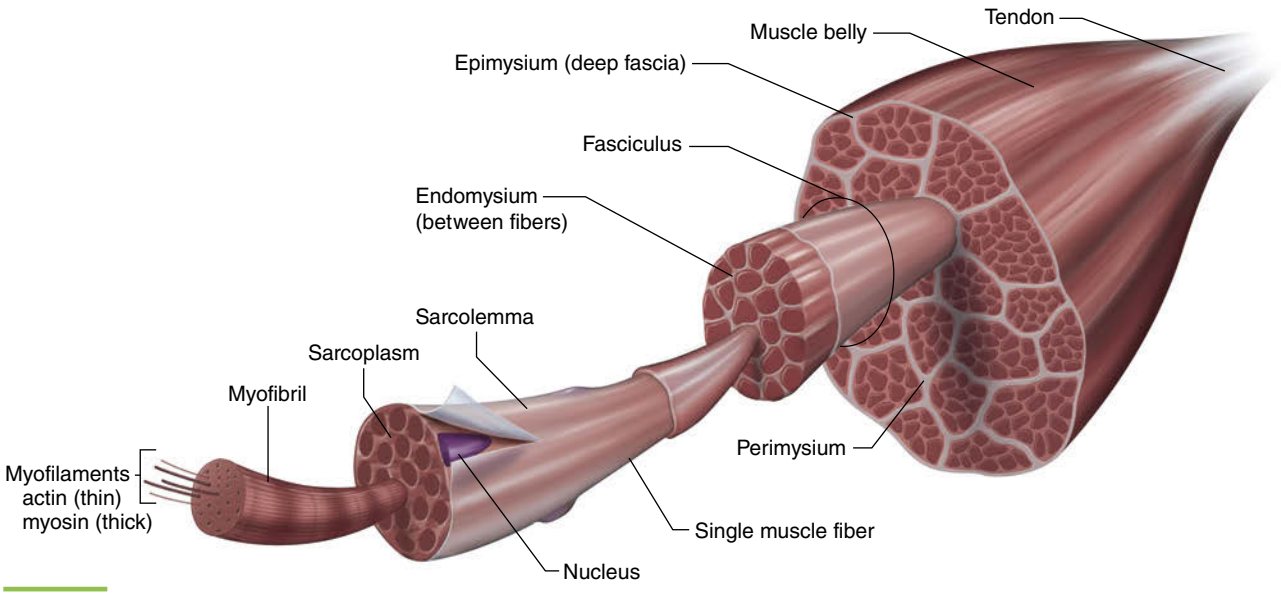


**FIGURE 1.3** Schematic drawing of a muscle illustrating three types of connective tissue: epimysium (the outer layer), perimysium (surrounding each fasciculus, or group of fibers), and endomysium (surrounding individual fibers).

under low magnification. Under the epimysium the muscle fibers are grouped in bundles (**fasciculi**) that may consist of up to 150 fibers, with the bundles surrounded by connective tissue called **perimysium**. Each muscle fiber is surrounded by connective tissue called **endomysium**, which is encircled by and is contiguous with the fiber's membrane, or **sarcolemma** (13). All the connective tissue—epimysium, perimysium, and endomysium—is contiguous with the tendon, so tension developed in a muscle cell is transmitted to the tendon and the bone to which it is attached (see figure 1.3).

The junction between a **motor neuron** (nerve cell) and the muscle fibers it innervates is called the motor end plate, or, more often, the **neuromuscular junction** (figure 1.4). Each muscle cell has only one neuromuscular junction, although a single motor neuron innervates many muscle fibers, sometimes hundreds or even thousands. A motor neuron and the muscle fibers it innervates are called a **motor unit**. All the muscle fibers of a motor unit contract together when they are stimulated by the motor neuron.

The interior structure of a muscle fiber is depicted in figure 1.5. The **sarcoplasm,** which is the cytoplasm of a muscle fiber, contains contractile components consisting

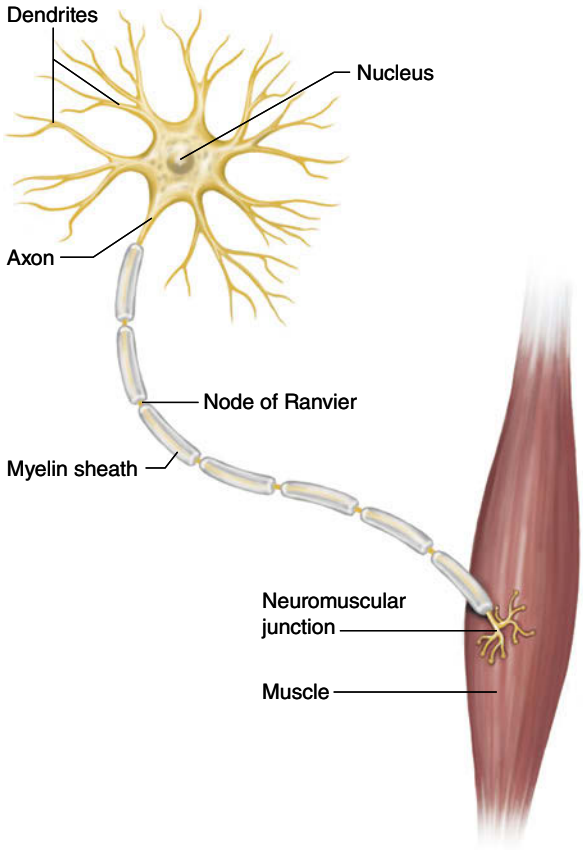


**FIGURE 1.4** A motor unit, consisting of a motor neuron and the muscle fibers it innervates. There are typically several hundred muscle fibers in a single motor unit.

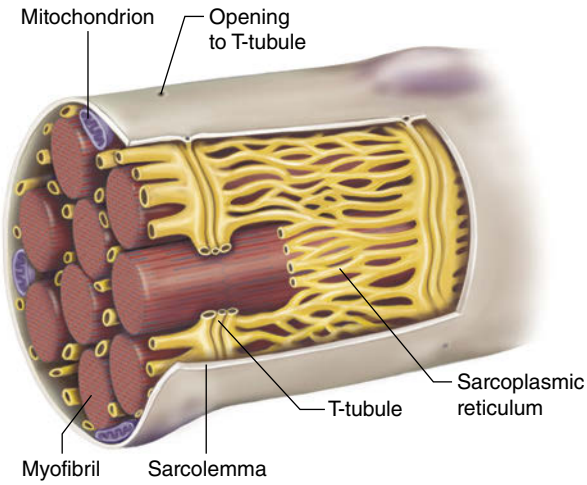


**FIGURE 1.5** Sectional view of a muscle fiber.

of protein filaments, other proteins, stored glycogen and fat particles, enzymes, and specialized organelles such as mitochondria and the sarcoplasmic reticulum.

Hundreds of **myofibrils** (each about 1 μm in diameter, 1/100 the diameter of a hair) dominate the sarcoplasm. Myofibrils contain the apparatus that contracts the muscle cell, which consists primarily of two types of **myofilament**: **myosin** and **actin**. The myosin filaments (thick filaments about 16 nm in diameter, about 1/10,000 the diameter of a hair) contain up to 200 myosin molecules. The myosin filament consists of a globular head, a hinge point, and a fibrous tail. The globular heads protrude away from the myosin filament at regular intervals, and a pair of myosin filaments forms a **cross-bridge**, which interacts with actin. The actin filaments (thin filaments about 6 nm in diameter) consist of two strands arranged in a double helix. Myosin and actin filaments are organized longitudinally in the smallest contractile unit of skeletal muscle, the **sarcomere**. Sarcomeres average about 2.5 μm in length in a relaxed fiber (approximately 4,500 per centimeter of muscle length) and are repeated the entire length of the muscle fiber (1).

Figure 1.6 shows the structure and orientation of the myosin and actin in the sarcomere. Adjacent myosin filaments anchor to each other at the M-bridge in the center of the sarcomere (the center of the H-zone). Actin filaments are aligned at both ends of the sarcomere and are anchored at the Z-line. Z-lines are repeated through the entire myofibril. Six actin filaments surround each myosin filament, and each actin filament is surrounded by three myosin filaments.

It is the arrangement of the myosin and actin filaments and the Z-lines of the sarcomeres that gives skeletal muscle its alternating dark and light pattern, which appears as striated under magnification. The dark **A-band** corresponds with the alignment of the myosin