TOPICS COVERED IN THIS UNIT

UNIT 1

HYPERTROPHY AND ADAPTATIONS TO STRENGTH TRAINING

Muscle: A group of motor units physically separated by a membrane from other groups of motor units.

Smooth Muscle: Governed by the autonomic nervous system and includes the muscles that line the digestive tract and protect the blood vessels.

Cardiac Muscle: Which includes the heart, as smooth muscle is modulated by the autonomic nervous system.

Skeletal Muscle: Blends into tendinous insertions that attach to bones, pulling on them, which generates desired movement.

Motor Unit: Consists of a single neuron and all the muscle fibers innervated by it.

Myofibrils: Small bundles of myofilaments.

Bodybuilders are known for having one thing in mind: How do I get big?

As you will discover in the pages of this book and course, you've got to eat well and train hard and smart. But there's more—much more than what you can see in the mirror.

Let's take a look at what happens to your body behind the scenes. By taking time to understand the structure of **muscle** and how it responds to training, you will be better able to develop scientifically driven programs, thus putting you and your client in the best position to succeed.

IT'S ALL ABOUT THE MUSCLE

The human body has three types of muscle: **Smooth muscle**, which is governed by the autonomic nervous system, includes the muscles that line the digestive tract and protect the blood vessels. **Cardiac muscle**, which includes the heart, like smooth muscle, is modulated by the autonomic nervous system. The functioning of smooth and cardiac muscle is largely involuntary. **Skeletal muscle**, the type bodybuilders are most concerned with building, blends into tendinous insertions that attach to bones, pulling on them, thereby generating desired movement.

When the body has to move, it responds by activating a slew of muscles. The forces generated by the body internally must overcome the forces imposed on the body externally.

During strength training, the body must overcome gravitational and inertial forces, which are magnified when a barbell is in people's hands, on their backs, or overhead. Cumulatively, strength training will make skeletal muscles stronger, make cardiac muscle more efficient, and enhance the functioning of smooth muscle.

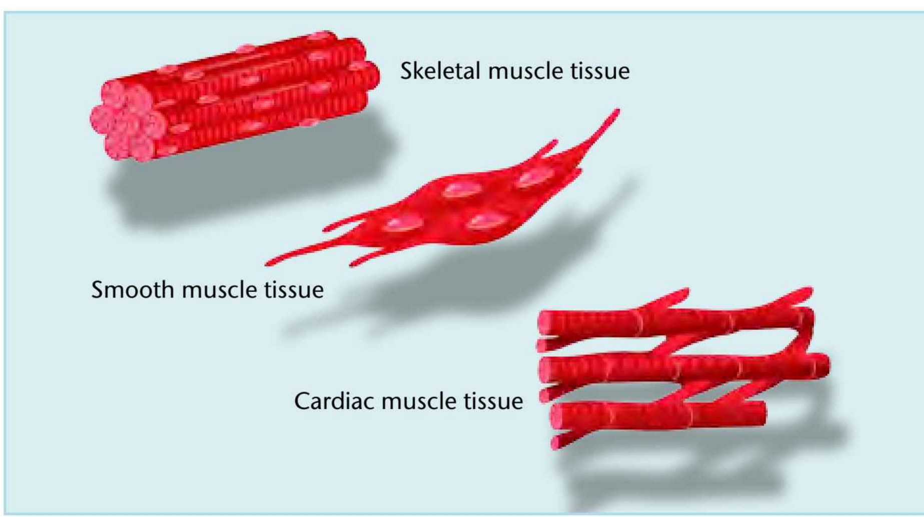

Figure 1.1 Muscle types

Adapted from Fitness: The Complete Guide*, International Sports Sciences Association. 2017.*

MUSCLE STRUCTURE AND FUNCTION

MICROSTRUCTURE

Muscles are composed largely of proteins, which are hierarchically organized from large groups to small fibers. A muscle is a group of **motor unit**s physically separated by a membrane from other groups of motor units. A muscle is connected to bones through tendons. (Refer to Figure 1.3 for a diagram of muscle composition.)

A motor unit consists of a single neuron and all the muscle fibers innervated by it. The ratio of nerves to fibers determines the fine motor control available to that muscle. For example, the hand has fewer fibers per motor unit than do the muscles of the calf.

The muscle fiber is composed of **myofibrils**, which are

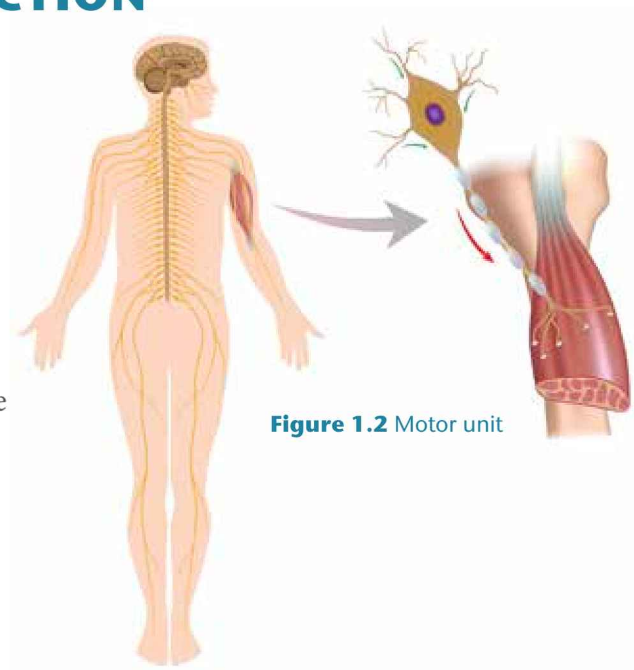

Figure 1.2 Motor unit

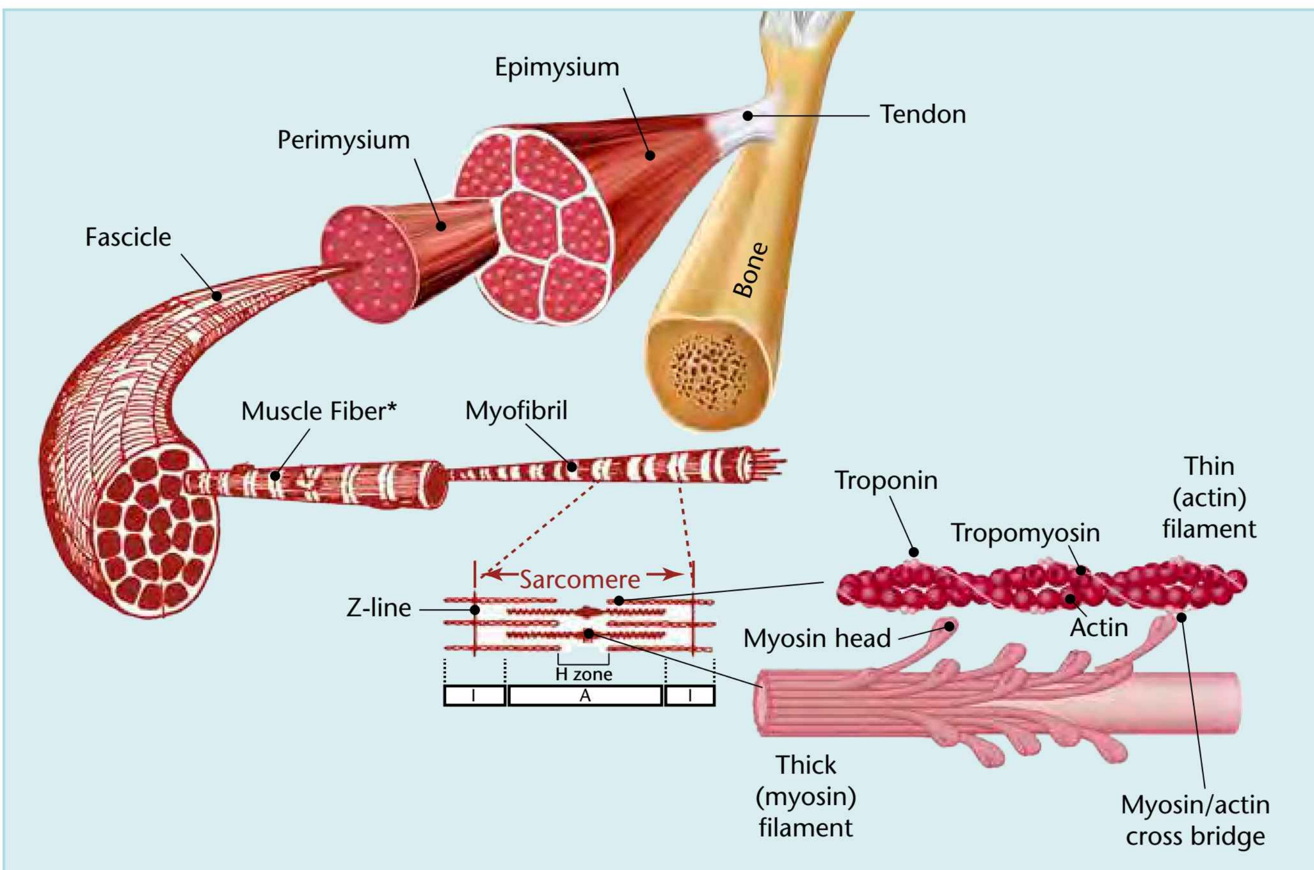

Figure 1.3 Organization of human skeletal muscle

Myofilaments: The elements of the muscle that shorten upon contraction.

Myosin: Short, thick filaments that make up part of myofilaments.

Actin: Long, thin filaments that make up part of myofilaments.

small bundles of **myofilaments**. Myofilaments are the elements of the muscle that actually shorten upon contraction. Myofilaments are mainly composed of two types of protein: **myosin** (short, thick filaments) and **actin** (long, thin filaments). Two other important proteins composing myofibrils are troponin and tropomyosin.

RECIPROCAL INNERVATION

Reciprocal Innervation: When a prime mover muscle (or group of muscles) contracts, the opposing muscle (or group) relaxes.

When a prime mover muscle (or group of muscles) contracts, the opposing muscle (or group) relaxes. When locking out a bench press, the triceps are the prime mover; the biceps relax as you push the weight to completion. This phenomenon is called **reciprocal innervation**. Without this reciprocity, muscle actions would be very jerky and weak at best or, at worst, result in no movement at all. The contracting muscle is referred to as the agonist, whereas the relaxed is the antagonist.

SLIDING FILAMENT THEORY

The strength of contraction in a muscle depends, in large part, upon the number of muscle fibers involved: the more muscle fibers, the stronger the contraction.

Sliding Filament Theory: This theory states that a myofibril contracts by the actin and myosin filaments sliding over each other. Chemical bonds and receptor sites on the myofilaments attract each other, allowing the contraction to be held until fatigue interferes.

The **sliding filament theory** states that a myofibril contracts by the actin and myosin filaments sliding over each other. Chemical bonds and receptor sites on the myofilaments attract each other, allowing the contraction to be held until fatigue interferes.

MUSCLE FIBER PENNATION ARRANGEMENT

The alignment of the muscle fibers has a distinct effect on the ability to generate force. Fusiform arrangement occurs when the fibers are parallel to the tendons and therefore can contract at great speeds without a loss in total force output.

A unipennate muscle will have fiber alignment going from one side to the other in regard to the tendon, whereas a bipennate muscle will have alignment of fibers on both sides of the muscle.

Muscles with a unipennate, bipennate, or multipennate arrangement are capable of producing higher amounts of force than a fusiform arrangement can but at the expense of contractile velocity. It is believed that fiber arrangement is determined by genetics, but it may be altered somewhat with training.

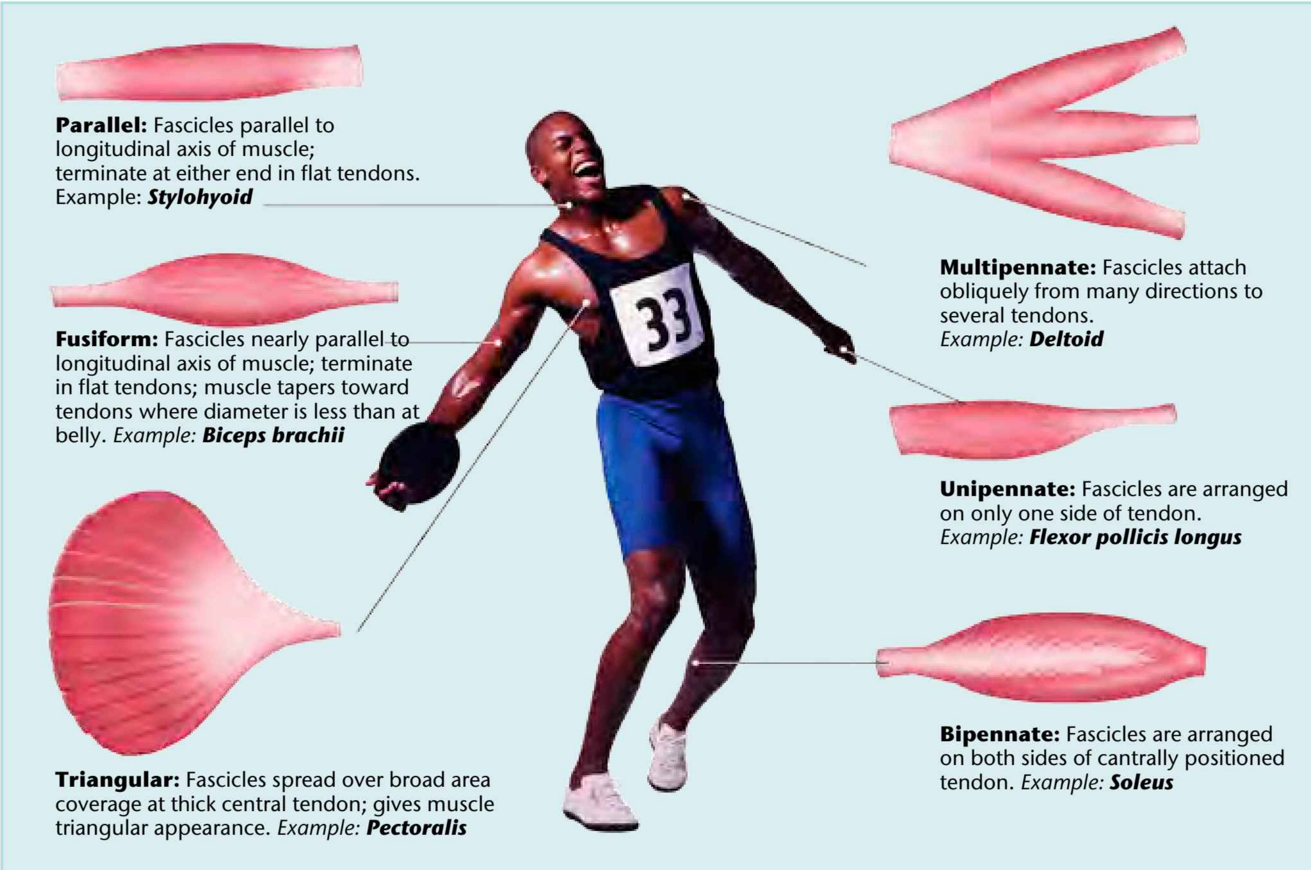

Figure 1.4 Muscle fiber arrangements

MUSCLE FIBER TYPES

Three distinct types of muscle fiber are found in skeletal muscle: Type I, Type IIa, and Type IIx. The percentage of each varies from person to person and from one muscle to another in the same person.

Type I muscle fibers (slow-twitch or red fiber) are highly resistant to fatigue and injury, but their force output is extremely low. Activities performed in the aerobic pathway call upon these muscle fibers.

Type IIa muscle fibers (fast-twitch or intermediate fibers) are larger in size and much stronger than Type I fibers are. They have a high capacity for glycolytic activity—they can produce high-force output for long periods.

Type IIx muscle fibers (fast-twitch muscle fibers) are often referred to as "couch potato fibers" because of their prevalence in sedentary individuals. Research has shown that 16% of a sedentary person's total muscle mass is of this fiber type.

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Table 1.1: Characteristics of Fiber Types				
Characteristic	**Type I Slow Oxidative**	**Type IIA Fast Oxidative Glycolytic**	**Type IIx Fast Glycolytic**	**Type IIC** Fast Oxidative Glycolytic**
Myoglobin Content	High	Intermediate	Low	Intermediate
Capillary Supply (Per Fiber)	4	4	3	4
Fiber Area	Small	Intermediate	Large	Large
Motor Neuron and Axon Size	Small	Intermediate	Large	Large
Typical Innervation	540/Units	440/Units	750/Units	----
Axon Conduction Velocity	85	100	100	100
Liability to Accommodation	Low	Medium	Medium	Medium
Mitochondrial Enzymes	Intermediate	High	Low	----
Glycolytic Enzymes	Low	Intermediate	High	----
Fat Content	High	Intermediate	Low	Intermediate
Myofibrillar ATPase	Low	High	High	High
Time To Peak Tension (msec)	80	40	30	----
Tension Developed	Low	Intermediate	High	High
Resistance To Fatigue	High	Intermediate	Low	Intermediate
Oxidative Capacity	High	High	Low	Intermediate
Liability To Recruitment	High	Intermediate	Low	Intermediate

** Type IIC (alternately referred to as intermediary fibers) possibly result from the fusion of Type IIX with satellite cells. Their properties are still under investigation.

ADAPTED FROM SHEPARD, R.J. 1982, PHYSIOLOGY AND BIOCHEMISTRY OF EXERCISE. PRAEGER PUBLISHERS, NEW YORK.

Type IIx fibers are extremely strong, but they have nearly no resistance to fatigue or injury. In fact, they are so strong and susceptible to injury, that when they are used, they often are damaged beyond repair. Unless the body can repair the muscle cell, it is broken down and sloughed off into the amino acid pool. In most cases, sedentary people immediately lose their Type IIx fibers when beginning a training program. However, neural efficiency is increased via strength training, resulting in the production of higher forces for longer periods.

A fourth type of fiber, Type IIc, is the result of Type IIx fibers' "fusing" with surrounding satellite cells.

As noted earlier, Type IIx fibers are destroyed when they are used because of their fast-twitch capacity and poor recovery ability. When muscle fibers are damaged from training stress, a highly catabolic hormone called cortisol is released to facilitate the cleanup operation.

However, if cortisol is blocked, the Type IIx fibers will fuse with surrounding satellite cells (non-contractile muscle cells that help support or bulwark the tenuous IIx fibers). The result of fusion is a Type IIc fiber. Insulin-like growth factor-1 (IGF-1) stimulates the fusion process, which has huge implications for bodybuilders.

Fast-twitch fibers are serviced with thicker nerves, giving them a greater contractile impulse

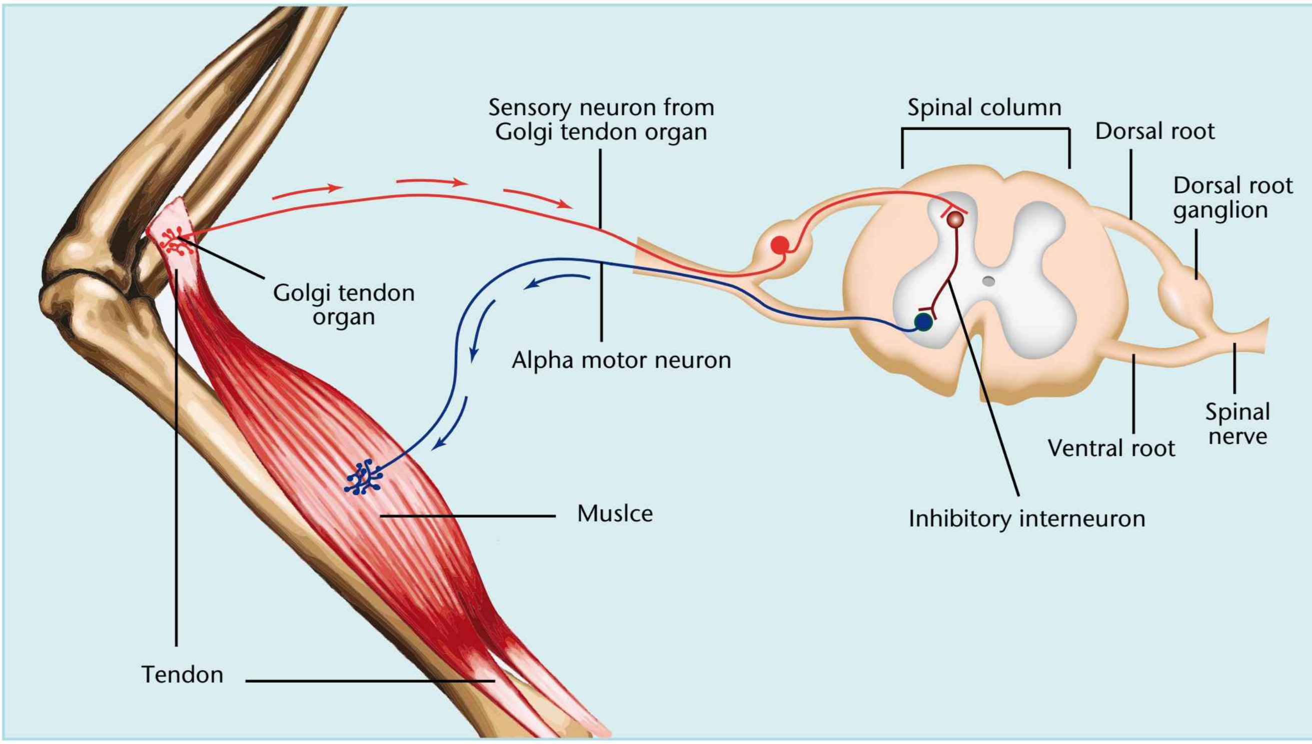

Figure 1.5 Feedback loop

(measured in number of twitches per second). Slow-twitch fibers have smaller nerves (thus twitch fewer times per second) but have a high degree of oxygen-using capacity stemming from the greater number of mitochondria (the cells' "powerhouses" where adenosine-5'-triphosphate, or ATP, is synthesized) and a higher concentration of myoglobin and other oxygen-metabolizing enzymes.

CONNECTIVE TISSUE

The primary function of **connective tissue** is to connect muscle to bones and to connect joints together. Consisting of fiber called collagen, mature connective tissues have fewer cells than other tissues do and therefore need (and receive) less blood, oxygen, and other nutrients than other tissues.

Connective Tissue:
The primary function of connective tissue is to connect muscle to bones and to connect joints together.

The positive effects of exercise on connective tissue have been well documented. Physical training has been shown to cause an increase in tensile strength, size, and resistance to injury along with the ability to repair damaged ligaments and tendons to regular tensile strength.

Tendons: Tendons are extensions of the muscle fibers that connect muscle to bone.

TENDONS

Tendons are extensions of the muscle fibers that connect muscle to bone. They are slightly more pliable than ligaments are but cannot shorten as muscles do. Various proprioceptors, the sensory organs found in muscles and tendons, provide information about body movement and position, and they protect muscle and connective tissue.

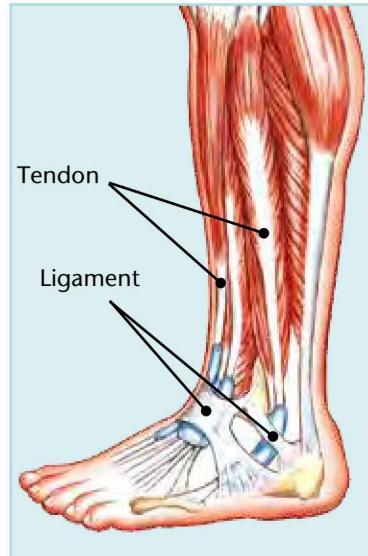

Figure 1.6 Tendons and ligaments

The Golgi tendon organ is embedded in tendon tissue and can be thought of as a safety valve. Increasing levels of muscular contraction result in feedback to the nervous system from the Golgi tendon organ. When tension becomes too great—greater than your brain can handle—this feedback inhibits the contraction stimulus, thereby reducing the likelihood of injury. This protective response is called the feedback loop.

Though this may sound debilitating to the intense weight trainer, there is some good news: training with high-speed contractions and with bands and chains can train you to somewhat inhibit the response of the Golgi tendon organ.

Ligaments: Ligaments connect bones to bones at a joint and, along with collagen, contain a somewhat elastic fiber called elastin.

LIGAMENTS

Ligaments connect bones to bones at a joint and, along with collagen, contain a somewhat elastic fiber called elastin. Although ligaments must have some elasticity to allow for joint movement, this elasticity is limited.

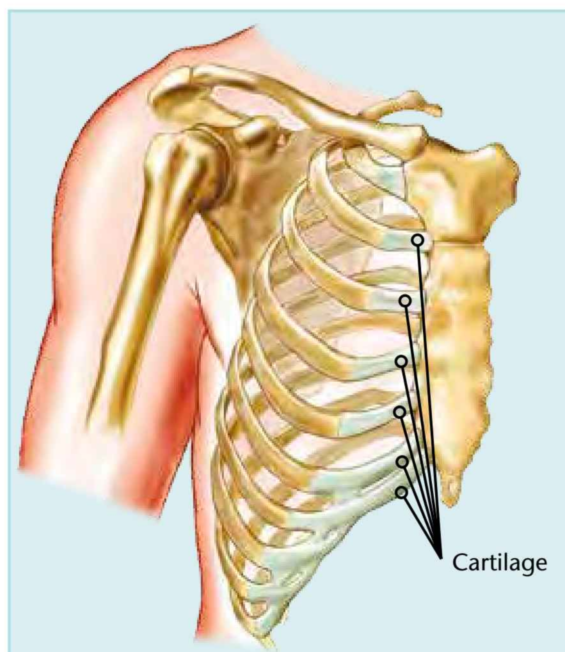

Figure 1.7 Cartilage

Cartilage: Cartilage is a firm, elastic, flexible white material. It is found at the ends of ribs, between vertebral discs, at joint surfaces, and in the nose and ears.

CARTILAGE

Cartilage is a firm, elastic, flexible white material. It is found at the ends of ribs, between vertebral discs, at joint surfaces, and in the nose and ears. As a smooth surface between adjacent bones, cartilage provides both shock absorption and structure. It also lubricates the working parts of a joint.

Unlike tendons and ligaments, cartilage has no blood supply of its own. The only way for cartilage to receive oxygen and nutrients is through synovial fluid. Because of this lack of nutrients, damaged cartilage heals extremely slowly.

NERVOUS SYSTEM: THE MIND AND BODY LINK

Your nervous system is composed of two major parts. The **central nervous system** (CNS) consists of your brain and your spinal column. You should think of these two as an integrated unit, not as separate entities.

The CNS receives messages and, after interpreting them, sends instructions back to the body. The **peripheral nervous system** (PNS) does two things: (a) It relays messages from the CNS to the body (the efferent system), and (b) it relays messages to the CNS (the afferent system) from the body. (For a deeper understanding of how Central and Peripheral fatigue affect your performance, study Unit 14.) The CNS does the following:

It senses changes inside and outside your body.

It interprets those changes.

It responds to the interpretations by initiating action in the form of muscular contractions or glandular secretions.

Obviously, the entire strength-training vernacular you've been exposed to over the years regarding the crucial link between your mind and your body all boils down to the fact that your central nervous system is linked to your peripheral nervous system.

Central Nervous System: The central nervous system (CNS) consists of your brain and your spinal column. The CNS receives messages and, after interpreting them, sends instructions back to the body.

Peripheral Nervous System: The peripheral nervous system (PNS) does two things: (a) It relays messages from the CNS to the body (the efferent system), and (b) it relays messages to the CNS (the afferent system) from the body.

THEORY OF NEUROMUSCULAR ACTIVITY

Now that you have a basic understanding of the neuromuscular system's structure and function, your next step is to understand exactly how it works.

One of the most important theories of neuromuscular activity, the sliding filament theory, was discussed earlier. Let's take a look at the other theories of neuromuscular activity.

"All or None" Theory: Each myofibril could be described as a fundamentalist in its functioning. It knows nothing less than total contraction, as it responds with an all-or-none reaction. A core point here is that a motor unit is either completely relaxed or fully contracted.

The "All or None" Theory

When a nerve carries an impulse of sufficient magnitude down to the muscle cells that compose the motor unit, the myofibrils do the only thing they know how to do—contract, or shorten.

Each myofibril could be described as a fundamentalist in its functioning. It knows nothing less than total contraction, as it responds with an all-or-none reaction. A crucial point here is that a motor unit is either completely relaxed or fully contracted.

Because muscle fiber (including its myofibrils) and the entire motor unit of which it is a part respond to a nerve stimulus with the all-or-none reaction, not all the motor units that compose a muscle are activated during any given movement.

This is why it is of paramount importance to hit muscles at different angles, speeds, and ranges of motion. Not only that, but doing the same movements habitually means becoming increasingly proficient at that movement, which is great for the strength athlete but which handicaps the potential of maximal muscle growth.

This means you are able to exercise a gradation of response by increasing or decreasing the amount of chemo-electrical impulse to the muscle. In other words, you are coordinated enough to produce sufficient force to lift a fork to your face or curl a heavy dumbbell. Being unable to control force production by lifting a fork to your face would invoke a bloody disaster.

Both are similar movements, but curling a fork involves only those motor units with a very low excitation threshold, whereas curling the dumbbell requires many more motor units. The principle that allows this to happen is known as the size principle.

Size Principle of Fiber Recruitment: States that those fibers with a high level of reliability (slow-twitch fibers with the fewest motor units) will be recruited first, and those with lower levels of reliability (fast-twitch fibers with the greatest number of motor units) will be recruited last.

The Size Principle of Fiber Recruitment

Force output of muscle is related to the stimulus it receives. Different muscle fibers have different liability to recruitment, with Type I fibers having the highest liability, Type IIa and IIc having a moderate liability, and Type IIx possessing a low level of liability.

The **size principle of fiber recruitment** (also called the Henneman principle) states that those fibers with a high level of reliability (slow-twitch fibers with the fewest motor units) will be recruited first, and those with lower levels of reliability (fast-twitch fibers with the greatest number of motor units) will be recruited last. This is why you are able to eat using Type I fibers, allowing you to safely put your fork into your mouth.

To recap, Type I (slow-twitch) muscle fibers are smaller and more endurance based than Type II (fast-twitch) muscle fibers are. Type II muscle fibers begin to be recruited when you use more than 25% of your maximum strength. Although a one-repetition max in the squat may be performed slowly, you will still be using all of your fast-twitch muscle fibers along with your slow-twitch ones to move the heavy barbell on your back.

The Stretch Reflex

As a muscle is stretched, **muscle spindles** become activated, and the brain receives a message that tells the muscle to contract. A rapidly stretched muscle stores elastic-like energy and in turn initiates an involuntary reflex. This involuntary reflex is termed the **stretch reflex**, and when used properly, it can increase the force produced during a given movement.

Stretch Reflex: As a muscle is stretched, muscle spindles become activated, and the brain receives a message that tells the muscle to contract. A rapidly stretched muscle stores elastic-like energy; this stretch reflex sparks a quick contraction.

Muscle Spindles: Muscle spindles are sensory receptors within the belly of a muscle that primarily detect changes in the length of this muscle. They convey length information to the central nervous system via sensory neurons.

Take a look at a vertical jump from a held squat position compared with one in which the athlete rapidly drops his of her butt and reverses the action as fast as possible. Numerous studies confirm athletes can jump higher using a counter movement than from a squat position. This is because the stretch reflex is used during the counter movement jump. During this counter movement jump, tension is developed during the eccentric phase (the rapid drop of the buttocks). This stored energy created by the tension developed during the eccentric phase is then used to increase the force output in the subsequent concentric contraction (when hips and knees extend to launch the person into the air). It is for this reason that the mechanism by which the stretch reflex works is compared with the snapping of a rubber band.

For the bodybuilder, an example of the stretch reflex in action is aiding a lift like the bench press. A full range of motion bench press is much easier than is a dead bench press starting at chest level due to the contributions from the stretch reflex.

A more scientific look at the stretch reflex shows it is a built-in protective function of the neuromuscular system in the muscle spindle, a proprioceptor found in the bellies of muscle.

In contrast to the Golgi tendon organ, which is in series with the force

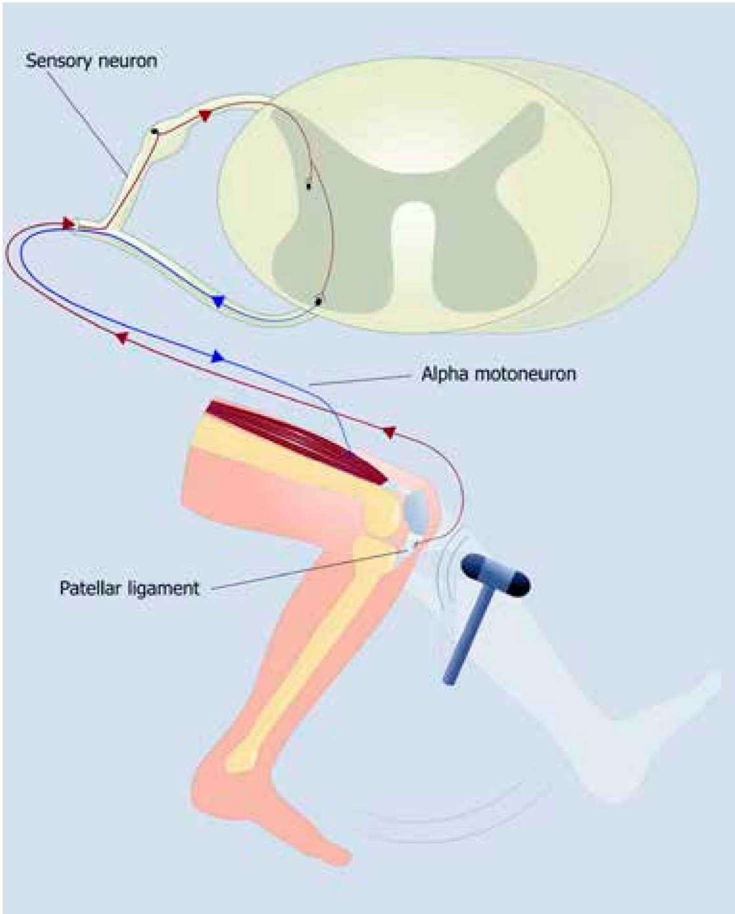

Figure 1.8 Knee jerk reaction

plane of the muscle, the muscle spindle is in parallel with the force plane. The action is similar to that of the Golgi tendon organ, in that it protects against overload and injury in what is known as the "stretch reflex" action (medical example: the knee-jerk response used by physicians to test your muscle's response adequacy).

NEURAL ADAPTATIONS

It is universally accepted that intense resistance training causes morphological changes to the physique by increased muscle mass. The question remains, can the nervous system be modified to your advantage?

The answer is yes, it can! Not only can you modify certain aspects of your nervous system function, but also the rewards in terms of training are significant.

The greatest advantages for the bodybuilder are improved strength output, better mental concentration, greater training intensity, pain management, and glandular secretions. All of these areas can be modified to at least a measurable degree and will aid you in your muscle-building quest.

Hypertrophy: Muscle hypertrophy involves an increase in size of skeletal muscle through a growth in size of its component cells.

HYPERTROPHY

Mechanical tension, muscle damage, and metabolic stress are the three factors that induce muscle **hypertrophy** from exercise, according to Brad Schoenfeld in The Journal of Strength and Conditioning Research. Mechanical tension is a product of intense resistance training and muscle stretch.

Muscle damage induces the delayed onset of muscle soreness that sets in approximately 24 hours after a workout and can peak two to three days after weight training. Metabolic stress results from the byproducts of anaerobic metabolism; this, in turn, promotes hormonal factors that induce hypertrophy.

"Everybody wants to be a bodybuilder but nobody wants to lift heavy-ass weight. But I do," said Mr. Olympia Ronnie Coleman.

The human body desires to be in a state of stability known as homeostasis; when the state of stability is disrupted, adaptations occur.

This is how your muscles grow!

Resistance training places stress on muscles that they are not accustomed to; the response is increased growth "hypertrophy."

Research repeatedly has confirmed that heavy resistance training is the most beneficial method of achieving hypertrophy. The reason seems to be that the Type II fibers are most affected by heavy resistance training (as noted in the size principle) and ultimately have the greatest potential for growth.

That is why I recommend starting with powerlifting to build a base, just as Ronnie Coleman and "The Austrian Oak" did.

Muscle hypertrophy, to those outside of the iron game, sounds like useless scientific jargon, but to the bodybuilder, it's gospel.

What exactly is muscular hypertrophy?

It is the increase of the muscle's cross-sectional area, involving the concurrent increase in myofibrilar content (contractile element).

Myofibrilar hypertrophy results from lifting maximal weights for lower reps, the way that powerlifters train. Bodybuilders who train heavy have a very dense look.

If maximal muscularity is desired, there is no way around heavy core lifts.

Sarcoplasmic hypertrophy is the accumulation of noncontractile matter, such as water, glycogen, and myoglobin—which are stored in the sarcoplasm of the muscle cell—and the densification of mitochondrial content.

Sarcoplasmic hypertrophy, the result of high-volume training, typically associated with bodybuilders, is essential to maximizing your complete physique development. Typically, this type of training and the imposed adaptations do little to enhance limit strength. On the upside, strength endurance will improve because of mitochondrial hypertrophy.

Another benefit of training for sarcoplasmic hypertrophy is the growth and strengthening of connective tissues. The bodybuilder with the complete package will have a synergistic blend of both hypertrophic elements.

Initially, adaptations to resistance training will be neurological. In other words, by performing a movement, you become more coordinated at the movement technically. And by recruiting the right muscles to lift the weight, you become more efficient at the movement. As neurological adaptations start to slow, the muscle will start to grow.

We become stronger by enhanced neural patterns; as you continually overload your muscle, the cross-sectional muscle fiber area increases, and your muscles get bigger.

HYPERPLASIA

Hypertrophy is the accepted mechanism of increased mass. In essence, you are born with a certain number of muscle fibers; these can increase in size but not in number.

But what if the number of muscle fibers could increase?

During the late '60s and early '70s, European scientists discovered that the muscle cells of some animals adapted to severe overload by splitting

Hyperplasia: The enlargement of an organ or tissue caused by an increase in the reproduction rate of its cells.

Satellite Cells: Satellite cells serve to repair damaged muscle tissue, inducing muscle growth after overload from weight training.

in two. This response, called **hyperplasia**, was subsequently followed by an increase in muscle size. Muscle fibers divided and then multiplied, thus the potential implications to the bodybuilder are enormous.

Hang on. Hyperplasia in humans remains controversial. Studies on animals have shown mixed results.

Cats were trained to move a heavy weight with their paw to receive food; hyperplasia took place as a result. Other studies on animals counter these findings: Studies on chickens, rats, and mice found that muscle fibers increased in size but not in number; hyperplasia did not take place.

However, another study performed on birds showed an increase in the number of muscle fibers in their wings as a response to being chronically stretched by a weight's attachment on the wings. The cats were subjected to heavy resistance with lower repetitions; the other animals were involved in more endurance-based activities. This might explain some of the discrepancies in results.

According to world-renowned researcher Vladimir Zatsiorsky in his book Science and Practice of Strength Training, both hyperplasia and hypertrophy contribute to muscle size increases in humans. However, the contribution of fiber hyperplasia is rather small (less than 5%).

This may not sound like much, but in the pro ranks, this could potentially mean an additional inch on your arms! Research on hyperplasia in people is not vast, but some exists.

A 1978 study reported that muscle fiber size remained constant in swimmers, but the muscle increased in size.

Researchers Nygaard and Nielsen argued that increased muscle size was a result of hyperplasia. A 1986 examination of European bodybuilders showed an abnormally high muscle fiber density on the two subjects who had trained intensely with weights for 14 years or longer, whereas those who had trained for four to six years had more normal fiber density. The abnormal fiber density, researchers theorized, may have been a hyperplasic response to long-term extreme weight training.

Assuming hyperplasia can take place, it would happen through a few mechanisms, from what research has shown. This would mean performing movement with an extreme stretch. Examples are stiff leg deadlifts for hamstrings, sissy squats for quads, dumbbell flyes for chest, incline dumbbell curls (palms supinated the whole time) for biceps, French press for triceps, cable rows for back, and inclined lateral raises or front raises for shoulders. Of course, the list could go on. You will also need to lift heavy. This means hitting the core lifts hard and, of course, long-term training. Holistic, intense, long-term training appears to be the best way to possibly induce hyperplasia.

SATELLITE CELLS

Satellite cells serve to repair damaged muscle tissue, inducing muscle growth after overload from weight training.

Satellite cells are the skeletal muscles' "stem cells." Overload from intense weight training causes trauma to the muscle. This disturbance to the muscle cell organelles activates satellite cells, which are located on the outside of the muscle cell, to proliferate at the site trauma was induced.

After satellite cells are damaged via intense resistance training, damaged muscle fibers are repaired by satellite cells' fusing together and to the muscle fibers, which leads to muscle growth. The satellite cells have only one nucleus and can replicate by dividing.

During the process of satellite cell multiplication, a small percentage of satellite cells remain as organelles on the muscle fibers. However, most will repair damaged muscle fibers or fuse to muscle fibers, forming new myofibrils. For the bodybuilder, this is exciting because the myofibrils of the muscle cell increase in number and size.

What does this mean?

After satellite cells fuse with muscle fibers, muscle fibers can synthesize more proteins and create a greater number of contractile proteins, meaning muscle will grow and get stronger.

Let's take a practical look at how you can take advantage of satellite cell proliferation.

A 2006 study in the The Journal of Physiology titled "Creatine Supplementation Augments the Increase in Satellite Cell and Myonuclei Number in Human Skeletal Muscle Induced by Strength Training" for the first time showed that creatine supplementation in conjunction with strength training amplified the effects of strength-training-induced increases in satellite cell number and myonuclei concentration in human skeletal muscle fibers—enhancing muscle fiber growth in response to strength training.

"The Effects of Eccentric Versus Concentric Resistance Training on Muscle Strength and Mass in Healthy Adults: A Systematic Review with Meta-Analysis" was published in 2009 in the British Journal of Sports Medicine, showing intense eccentric contractions were superior to concentric patterns for increasing muscle size. This is not a surprise, because intense eccentric movements force muscle fibers and surrounding satellite cells to fuse, resulting in muscle fiber growth.

For you to maximize muscle growth, intense eccentric movements will need to be a part of your regimen. Remember, these induce a greater delayed onset of muscle soreness (DOMS) and should not be a part of a deload ever.

IGF-1 is largely responsible for satellite cell proliferation, and that would explain why some bodybuilders are willing to illegally supplement with it.

A 2003 study in the American Journal of Physiology, Endocrinology, and Metabolism titled "Testosterone-Induced Muscle Hypertrophy Is Associated with an Increase in Satellite Cell Number in Healthy, Young Men" examined satellite cell proliferation on subjects who used 125 mgs, 300 mgs, and 600 mgs weekly of synthetic testosterone, along with a baseline group that did not use any synthetic hormone assistance. The groups using 300 and 600 mgs of testosterone weekly had significant increases in the number of satellite cells; the baseline and the 125 mg group did not.

Although I do strongly discourage any illegal drug use, I believe in presenting facts.

A FEW LAST WORDS

Fast-twitch muscle fibers have the highest potential for growth. This means that to get bigger muscles, you have to get stronger ones, especially as your muscle-building journey commences.

Your limit strength, as will be discussed in great detail throughout the text, is your base.

Heavy resistance training augments your being able to efficiently recruit the largest high-threshold motor units. The greater number of motor units recruited, the more that muscle fibers are stimulated. The highest motor unit stimulation stems from using heavy weights, so you are going to need to train heavy.

This all sounds great, but why do the strongest powerlifters in the world have less muscle than bodybuilders who are much weaker do?

Powerlifters generally train only in low-rep ranges, enhancing myofibrilar hypertrophy.

The bodybuilder needs to take a holistic approach, developing all components of the muscle. This is done by taking a holistic approach with high reps, low reps, high speed, low speed, compound movement, eccentrics, stretch movements, peak contraction, and time under tension: it's a balancing act to maximize hypertrophy. Later units in this book will be devoted to helping you understand how to balance these training variables to elicit optimal results.