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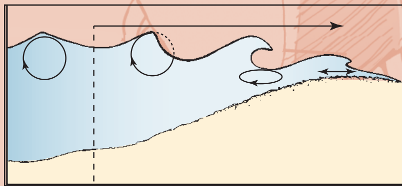
The Theory and Science of Massage and Manual Therapy



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Part One: General Overview

This first part provides a brief summary of the key concepts in the first two chapters. This will allow the reader to have an overview of the theory, science, and rationale for treatment before reading the more detailed material that follows.

MUSCULOSKELETAL COMPLAINTS ARE DUE TO FUNCTIONAL PROBLEMS

Musculoskeletal complaints are the most common reason for patients to visit primary care physicians and emergency departments in the United States and account for 10% to 28% of all primary care visits.[1] These conditions become "the most common cause of disability and severe long-term pain in the industrialized world".[2] The vast majority of these complaints are due not to pathology and disease, but to soft tissue injuries and functional problems. Yet, according to the American Academy of Orthopedic Surgeons, soft tissue injuries are often poorly diagnosed and inadequately managed.[3] The premise of manual therapy and massage is that loss of mobility in the soft tissue and joints creates pain and disability, and *restoration of mobility becomes the primary treatment objective.*[4]

SCIENTIFICALLY BASED PRACTICE IS ESSENTIAL FOR OPTIMUM TREATMENT

To provide the most effective treatment for our client's condition requires an understanding of normal musculoskeletal structure and function, the science of injury and repair, and the scientific basis for each technique. The therapist needs to understand the rationale for the choice of technique to create specific treatment goals that match the client's condition. The intention of treatment is to promote optimum function rather than merely to reduce symptoms.

MUSCULOSKELETAL TISSUE IS HIGHLY RESPONSIVE TO STIMULI

Research has shown that musculoskeletal tissues, including muscles, tendons, ligaments, bone, and cartilage are highly responsive to mechanical stimuli.[5] The body's tissues are "adaptable", that is, they change in response to stimulus (or lack of stimulus), and every structure in the body can improve its structure and function if given the proper stimulus.[6] Even older clients with chronic conditions can experience functional improvement because the body still contains cells (undifferentiated mesenchymal cells) that will respond to appropriate stimuli by "migrating, proliferating, and differentiating into mature cells of bone, cartilage, and dense fibrous tissue . . . including chondrocytes (cartilage cells)".[7] This is very good news for "touch" therapists because we can stimulate profound changes in the body with the appropriate treatment.

A NEW PARADIGM IN SOFT TISSUE THERAPY

The current model or paradigm in biology and medicine, which has been dominant for over 100 years and holds that the body is regulated by biochemistry, is the "lock-and-key" model, according to which molecules move randomly throughout the body to find the right receptor site. An exciting new electromagnetic paradigm is emerging that holds that these biochemical process are controlled by electromagnetic forces.[8] Research has shown that molecular and intermolecular forces are electromagnetic. Every heartbeat, muscle contraction, gland secretion, bodily movement, thought, and emotion generates an electromagnetic signal. It has also been discovered that the human body radiates a potent electromagnetic field that extends 12 to 15 feet beyond the body, and a new hypothesis is that this field can be focused for healing.[9] This has profound implications for manual therapy because touch transmits a focused electromagnetic signal that is carried throughout the entire body. This electromagnetic signal influences cellular regulation, including repair and regeneration.

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FOUNDATIONS OF THE ELECTROMAGNETIC PARADIGM

TENSEGRITY

From an architectural perspective, the body is called a *tensegrity structure* because it is a continuous, interconnected system of connective tissue and muscles that provides the force that holds the body upright, rather than the bones. Buckminster Fuller[10] coined the word *tensegrity* to describe this type of structure. Recent research has discovered a class of molecules called integrins, connecting every cell to neighboring cells and to the connective tissue throughout the body.[11] The cytoskeleton and extracellular connective tissue matrix combined with water is what Oschman calls the "living matrix."[9] The living matrix is not only structurally continuous, but also energetically continuous, as it regulates growth, form, and repair and regeneration. The connective tissue network is considered a second "nervous system" because of its ability to communicate electromechanical and electromagnetic signals.

WATER CARRIES ELECTROMAGNETIC WAVES

Water surrounds every molecule in the body and provides the energetic and structural framework for the body. Water holds the molecules of the body together. It forms an essential part of the "second nervous system," transmitting energy throughout the body. The conductivity of any tissue is highly dependent on its water content.[12] Indeed, there are 15,000 molecules of water for every molecule of protein.[9] Like protein molecules, water is highly ordered and exhibits coherence, much like a laser, in which water in the body becomes coupled to carry the electromagnetic waves. Because water is polar molecule, it greatly increases electromagnetic conductivity in the transmission of energy throughout the body.

SOFT TISSUE IS A LIQUID CRYSTAL

Soft tissue may be described as a liquid crystal, that is, a material that is a combination of a liquid and a solid. Soft tissue is composed of regularly arranged, parallel protein fibers, mostly collagen, embedded in water. Cell membranes, ligaments, tendons, muscles, bones, nerve, and the filaments that provide structure to the cells (cytoskeleton) are all crystalline lattices, meaning that the water and protein molecules are in a regularly ordered, repeating pattern. The collagen and the water are polar molecules, similar to a magnet with a north and a south pole. Because the soft tissue is electrically charged and has a tremendous degree of structural order, there is a coupling between molecules that gives them the ability to vibrate together, called *coherence*. Research has shown that these electrically polarized molecular arrays are extremely sensitive to energy fields, acting like molecular antennae, sending and receiving signals.[9,12] The new paradigm suggests that every movement, every touch, every thought and feeling is transmitted to every cell in the body at the speed of light.

MECHANOTRANSDUCTION

Mechanotransduction is a property of the soft tissue by which cells and the extracellular matrix (fibers and ground substance) convert mechanical stimuli into chemical, electrical, and electromagnetic signals. The tensions and compressions of massage and manual therapy induce mechanical signals that are transformed into electromagnetic waves, stimulating all cellular functions, including repair and regeneration.[13]

PIEZOELECTRICITY

One form of mechanotransduction is piezoelectricity ("pressure electricity"), the phenomenon in which soft tissue converts mechanical energy into electrical energy. Massage and manual therapy compress and stretch the soft tissue, creating waves of mechanical vibration that are transformed into electric currents. By their very nature, electric currents create magnetic fields. Because of the structural order or coherence of the soft tissue, these electromagnetic forces cause the molecules to vibrate together, hypothetically transmitting the energy of touch to every cell in the body.

OVERVIEW OF SOFT TISSUE INJURY AND REPAIR

Soft tissue includes muscles, tendons, ligaments, joint capsules, cartilage, bursa, skin, and fascia, as well as the body's fluids, including blood, lymph, synovial fluid, cerebrospinal fluid, cellular water, and interstitial fluids (the fluids surrounding the cells). These tissues may be broadly divided into fibers and fluids (see Part Two). Most of the fibers consist of parallel fibers of collagen, wrapped in bundles called *fascicles*. These fibers and fascicles are able to slide freely relative to each other in the healthy state. The body's fluids are a medium for the transport of cells, oxygen, and nutrition and for the removal of waste. After

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injury or repetitive strain, the fibers are pulled apart (torn). Tissue disruption creates inflammation, swelling, and congestion of fluids. Swelling increases pressure in the tissue, not only causing pain, but also decreasing movement of cells, nutrition, and oxygen needed for repair. Repair of the injury starts immediately. If the area is not mobilized in the early stages of healing, the body lays down a random mesh of fibers that develop into thick adhesions, leading to loss of motion and degeneration of the soft tissue. *Therefore, early mobilization of the soft tissue and joints is now recommended immediately after injury.*[14] Chronic musculoskeletal complaints are characterized by loss of normal motion due to adhesions of the fibers, myofascial shortening, restricted joint motion, joint misalignment, and potential degeneration. Massage and manual therapy induce normal movement in the soft tissue and joints to reduce adhesions, lengthen myofascia, and mobilize joints.

ACUTE AND CHRONIC COMPLAINTS: INJURY AND DYSFUNCTION

Musculoskeletal complaints can be divided into two broad categories: acute/injury and chronic/dysfunction. These are artificial categories, used to distinguish between inflammatory and noninflammatory conditions. In clinical practice, musculoskeletal complaints manifest on a wide spectrum between acute/inflammatory and chronic/noninflammatory in their stage of healing. This topic is discussed fully in Chapter 2. Throughout the text, the terms *acute* and *injury* will be used to describe an inflammatory condition. Inflammation may manifest with the classic signs of redness, heat, and pain, but it may also manifest subclinically with the only sign being pain at rest. The term ***injury*** may apply to a specific traumatic event to healthy tissue, such as a sports injury, household accident, or motor vehicle accident, or may apply to the result of a cumulative or repetitive stress in which the tissue eventually fatigues and weakens, resulting in an acute onset of inflammation, such as carpal tunnel syndrome from keyboard work, tennis elbow, or foot pain in runners. Injury to the soft tissue includes the sprains and strains of ligaments and muscles and means that the tissue is disrupted (torn), even if microscopically, resulting in swelling and pain.

The term ***dysfunction*** implies a chronic condition and indicates that the body is not functioning normally. The client might or might not be in pain. Loss of normal function may be due to prior injury, emotional and psychological stress, or faulty posture. It is characterized by limited joint motion, muscular weakness, sustained muscle tightness, adhesions, and shortened tissue. Examples of dysfunction include inability to elevate the arm overhead, a limp, chronic low back stiffness, chronic neck tension, and poor posture.

CHARACTERISTICS OF SOFT TISSUE INJURY

- **Pain:** Injury creates pain from damaged tissue, swelling, and inflammatory chemicals.
- **Swelling:** Injury creates swelling, which decreases the normal movement of fluids. Swelling reduces the tissue's ability to repair itself, owing to decreased cellular activity, decreased nutrition, and the accumulation of waste products.
- **Neurological dysfunction:** A vast network of nerves is embedded within the soft tissue and joints. Swelling from inflammation creates abnormal function in the nerves, leading to muscular inhibition (weakness) or spasms (guarding, splinting) and decreased coordination, balance, and muscular control.
- **Fibers lose parallel alignment:** Injury of the soft tissue on the microscopic level is a tearing apart of the fibers. The fibers are repaired in a random orientation and lose their normal parallel orientation.
- **Soft tissue misalignment:** Injury creates soft tissue misalignment relative to the neighboring soft tissue and joint (see "Soft Tissue Alignment Theory" below). This introduces an abnormal twist into the tissue and an abnormal position of the tissue.
- **Restricted joint motion:** Injury may involve soft tissue surrounding the joint, such as ligaments and joint capsules, or soft tissue within the joint itself, including the cartilage. Swelling, pain, and muscle spasms prevent normal movement, reducing joint lubrication and nutrition, which are dependent on movement.
- **Emotional distress:** Injury leads to pain that affects the emotional centers of the brain (limbic region). Pain is both a physical and an emotional experience. Depression, anxiety, and fear are common emotions associated with pain.
- **Biomagnetic field disturbance:** Electronic signaling depends on the organized structure of the system.[15] In acute injuries, the normal parallel alignment of the fibers is disrupted, which decreases the ability of the tissue to carry an electromagnetic signal, disturbing normal cellular communication. With the excessive water due to swelling, there is a decrease in the electronic transmission.

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CHARACTERISTICS OF SOFT TISSUE DYSFUNCTION

- **Soft tissue misalignment:** Soft tissue dysfunction creates misalignment relative to the neighboring soft tissue or joint.
- **Soft tissue torsion:** Misaligned soft tissue introduces an abnormal torsion or twist into the tissue. The abnormal twist decreases the water content of the tissue, leading to adhesions and abnormal function in the soft tissue and associated joint.
- **Adhesions:** Abnormal crosslinks may develop between the fibers, creating adhesions. Adhesions develop if the soft tissue and joints were not adequately mobilized after an injury, if the area adapted to the shortened position to avoid pain, or because of poor posture. The fibers stick together, losing their ability to glide. This limits normal extensibility (length) in the tissue and creates dysfunction in the muscles, joints, and nerves. Adhesions also prevent the normal broadening of the muscle fibers that occurs during muscle contraction, decreasing their function.
- **Fluid stagnation:** Sustained muscle contraction and adhesions in chronic dysfunction create fluid stagnation, disrupting the rhythmic waves of fluids that normally circulate through every region of the body. Stagnation causes decreased cellular activity, decreased nutrition, and the accumulation of waste products, reducing the tissue's ability to function normally and slowing down the body's constant cellular regeneration.
- **Neurological dysfunction:** Adhesions and fluid stagnation create abnormal neurological function, leading to muscle hypertonicity or inhibition and loss of coordination, balance, and postural stability.
- **Altered muscle performance:** Optimum function in the body for good posture and movement requires that the muscles crossing the joints are balanced in strength, extensibility (length), and normal neurological function. This is necessary for fine motor control, balance, and coordination. Dysfunction leads to patterns of sustained hypertonicity or sustained weakness (inhibition) in the muscles.
- **Joint restrictions and misalignment:** Loss of normal joint mobility is due to internal or external restrictions. Internal restrictions may be due to loss of glide between the joint surfaces. This is called *loss of joint play*. External restrictions may be due to shortened or tightened tissue surrounding the joint, such as adhesions in the ligaments and joint capsule or short and tight muscles. Joint restrictions and misalignment lead to impaired movement.
- **Emotional and psychological distress:** Clients in chronic pain are often afraid of moving, a condition called *pain avoidance behavior*, which leads to disuse, deconditioning, and abnormal function in the muscles and joints, predisposing the area to degeneration.
- **Biomagnetic disturbance:** In chronic conditions, the tissue becomes dehydrated because of the increased fiber content of the adhesions, which conduct electrical charge very poorly, owing to the decreased water content.[15]

THREE TREATMENT MODALITIES

This text introduces a unique combination of three modalities, performed in a specific protocol or "recipe" that has been found in 30 years of clinical practice to achieve the most efficient and effective success in the treatment of soft tissue conditions. How to apply these modalities varies dramatically depending on many factors, such as whether the client has an acute or chronic condition and the client's age, conditioning, and level of pain. The goal of massage and manual therapy is to provide the appropriate treatment specific to the client's condition to optimize the body's own healing potential. The underlying goal of this method of therapy is to induce profound relaxation while performing the techniques. This has been found to optimize the healing potential of the body and create the most successful outcome. The three modalities are as follows:

- **Soft tissue mobilization (STM):** This text introduces a new style of massage (soft tissue mobilization) called *wave mobilization*, which mobilizes the soft tissue transverse to the fiber in a rounded, scooping motion. These strokes are performed rhythmically and are modeled on ocean waves.
- **Muscle energy technique (MET):** MET is a method of manual therapy in which the client provides active resistance to the therapist's pressure. This technique provides rehabilitation for the nervous system.
- **Joint mobilization (JM):** The joints are the source of most of the pain and disability in chronic conditions. Passive movement induced to the joints helps to ensure their optimum function.

FOUR DIMENSIONS OF TREATMENT

The goal of massage and manual therapy is to induce change in the structure and function of the

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musculoskeletal soft tissue to promote optimum function and healing of the whole person. The goals of treatment can be artificially divided into four categories that are based on which dimension of the client we are primarily affecting: **structural, neurological, psychological** and **emotional**, and **energetic**.[16]

TREATMENT GOALS: STRUCTURAL

- **Mobility:** The loss of mobility applies to the fluids, muscles, tendons, joint capsules and ligaments, and joints. In **acute** injuries the loss of mobility is due to swelling, pain, and muscular guarding. *Our treatment goal in acute conditons is to assist repair and regeneration of the soft tissue by inducing movement in the fluids and fibers.* In **chronic** dysfunction, the loss of normal mobility may be due to adhesions, tight muscles, or degenerated joints. This loss of mobility leads to alterations of normal movement, compensations in related joints, and pain avoidance behavior. *Our treatment goals in chronic conditions are to restore mobility in the soft tissue and to restore normal range of motion in the joints.*
- **Alignment:** Injury pulls apart (tears) the collagen fibers and disrupts their normal parallel alignment. The collagen fibers are repaired in a random weave. Loss of parallel alignment not only weakens the tissue, but also decreases the electrical charge in the tissue.[9] In **acute** conditions, misalignment may also develop macroscopically in the muscles, tendons, and ligaments because of swelling, pain, and muscular guarding. *Our treament goals in acuteronditons are to help align the healing fibers, realign the soft tissue crossing the joint, and provide passive motion to the joint to help maintain normal alignment.* In **chronic** conditions, misalignment describes an abnormal torsion or twist in the soft tissue and faulty alignment of the soft tissue relative to the surrounding soft tissue structures and the joint. Misalignment may be due to adhesions from prior injury, cumulative strain, poor posture, muscular imbalances, or abnormal movement patterns. *Our treament goals are to educate the client in good posture, dissolve adhesions, balance muscular forces, and mobilize restricted joints.*
- **Extensibility (length):** In **chronic** conditions, clients may complain of stiffness, loss of motion, slumped posture, or chronic pain. Over time, the body will adapt to limited motion by developing contractures; short, tight muscles; and loss of normal joint motion. *Our treatment goal is to lengthen shortened tissue.* It is contraindicated to stretch or lengthen tissue in the acute phase of repair, because the fibers are fragile and easily torn.

TREATMENT GOALS: NEUROLOGICAL

- **Neuromuscular reeducation:** The initial response of muscle to **acute** injury is either spasm or muscular inhibition. The spasms can protect the muscle and joint by preventing further movement, but they also prevent normal movement of the fluids and joint, limiting repair. Over time, swelling and pain inhibit and weaken muscles. *The treatment goals in acute conditions are to reduce muscular spasms, and minimize muscular inhibition.* In **chronic** dysfunction, muscles develop predictable patterns of muscular tightness or muscular weakness (inhibition). *The goals of treatment in chronic conditions are to identify which muscles are tight and which are weak through isometric testing and to correct those muscular dysfunctions.*
- **Proprioception reeducation:** Sensory nerves provide information about position and movement, and their normal function is essential for balance, coordination, posture, and fine motor control. The swelling of an **acute** condition prevents normal proprioception. *The treatment goal in acute conditions is to provide active stimulation to these nerves though muscle energy technique to help maintain optimum function.* **Chronic** dysfunction leads to an atrophy of sensory nerves and a decreased sense of balance, coordination, and fine muscle control. *The treatment goals in chronic conditions are to educate the client in balance exercises and posture and to use MET to bring conscious awareness to muscle action, providing effective rehabilitation for the proprioceptors.*
- **Sensory awareness:** This goal is for **chronic** conditions. Chronic pain and dysfunction often lead to the inability of the clients to feel if they are tight or weak or how to contract specific muscles. Bringing the client's attention to these areas through touch and conscious contraction (MET) reeducates the client's sensory awareness.
- **Pain management:** Pain information is conducted into the brain through a "gate." For example, the nerves that carry mechanoreceptor information about pressure and movement "close the gate," reducing pain. Compressing the tissue during massage and mobilizing the joint through rhythmic oscillations will help to reduce pain. *In acute conditions, the therapist can reduce pain by applying gentle touch, slow rocking movements of the body, gentle MET, and mobilization to the soft tissue and joints.* In chronic dysfunction, pain can develop from degeneration, sustained muscle contration leading to ischemia (low oxygen), or abnormal function of the nervous system. The goals of treatment are to reduce muscle contraction by reeducating the muscles, improve joint function by restoring lubrication and

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nutrition to the cartilage, and reeducate the nervous system by reducing aberrant nerve signals.

- **Relaxation:** A primary goal of therapy is relaxation. Relaxation engages the parasympathetic nervous system, lowering blood pressure and heart rate, and promotes repair and rejuvenation in the body. *The goal of treatment described in this text for both acute and chronic conditions is to bring the client into a state of profound relaxation* while the other goals of therapy are being accomplished. This is achieved by gentle touch and rhythmic rocking, which engages both the central and parasympathetic nervous systems.

TREATMENT GOALS: PSYCHOLOGICAL, EMOTIONAL

It is important for the therapist to remember that the painful knee or frozen shoulder is one small part of a human being. A client's injury and pain lead to negative thoughts, such as "I'm always going to be in pain," which can lead to anxiety, depression, or irritability. In chronic conditions, pain or disability often leads to pain avoidance behavior, in which the person limits activities and movements. Negative thinking, such as "my life is ruined," and negative emotions, such as depression, can develop. Our role as therapists is to encourage the client to become proactive in taking responsibility for their rehabilitation and to help create an image of healing. Our touch can provide comfort and emotional support.

- **Healing words:** It is important for the therapist to create a mental image of healing for the client through healing words. An important aspect of therapy is to give positive feedback while working with a client. For example, when a tight musle relaxes, say to the client, "Your body is responding beautifully." When better range of motion is achieved in a restricted knee, say to the client, "Your knee is really moving better." Encourage chronic pain patients by telling them that recovery takes a long time, to be patient, and just try to move a little bit more each week. When they show slight improvement or try to move a little more, praise their efforts.
- **Nurturing touch:** A gentle, nurturing touch decreases blood pressure, decreases stress, and improves mood. One of the hallmarks of the therapy that is described in this text is that the therapist attempts to provide comfort during treatment. Working deeply does not mean working hard. Deep touch can be achieved with gentle hands and sensitivity.

TREATMENT GOALS: ENERGETIC

- **Induce electrical flow:** Areas of injury or dysfunction have disruptions in normal electrical signaling due to swelling or adhesions. Massage and manual therapy create currents of electricity (streaming potentials) by the phenomenon of piezoelectricity (see "Piezoelectricity" above). These currents are generated from the pressure of touch, from stretching and the contractions of soft tissue during MET.
- **Improve vitality:** Injury and dysfunction create loss of mobility, which leads to stasis or sluggishness in the body. Movement induces electromagnetic waves, which improve cellular communication, cellular synthesis, and energy.
- **Create inner calmness (coherence):** Therapists can be trained to establish a state of coherence within themselves before working with their client by taking a few minutes to focus on the breath or to practice prayer, meditation, or other centering practices. The therapist can entrain (couple) the client to this inner calmness.
- **Healing:** Medical research has shown that the pulsing magnetic fields that emanate from the hands of therapists (biomagnetic fields) stimulate healing. It has also been demonstrated that this biomagnetic field can be focused for healing.

Part Two: Overview of Theory and Technique

BODY COMPOSITION: MAINLY FIBERS AND FLUIDS

The soft tissues are mainly composed of fibers and fluids; even the bones are mineralized fibers. These fibers give the body its form and are akin to the steel cables that hold up a bridge. They provide the tension to keep the body upright and transmit the forces that create movement. Most of the fibers run parallel to each other and are arranged in a spiral at both the microscopic and macroscopic levels. A hypothesis that

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is developed in this text is that the spiral orientation of the fibers has a specific direction for each joint and that the normal spiral can wind into an abnormal torsion or twist.

The human body is approximately 70% water, which is contained in the fluids of the body. These fluids include the blood, lymph, synovial fluid, cerebrospinal fluid, and interstitial fluids (the fluids that surround the cells). Like the earth's oceans, water moves within the body in waves. This is due to the rhythmic contractions of the heart, respiratory diaphragm, and muscles, which form the three pumps that move the fluids through the body. There are also waves of electromagnetic energy moving throughout the body from the heartbeat, muscle contraction, compression of the bones, and other cellular functions. Unlike fluid waves, which lose strength as they travel, the waves of electromagnetic energy are propagated throughout the body because collagen and water are an "excitable medium," which means that they are a source of energy to carry the waves of energy.[9]

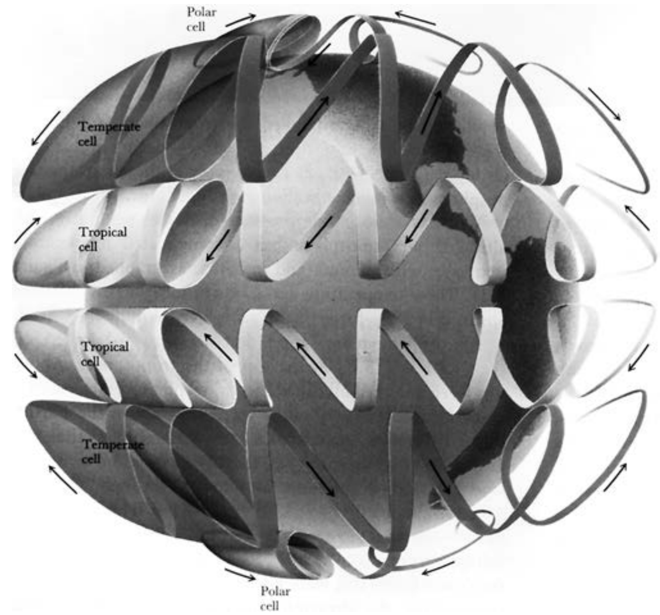

Figure 1-2. Spiraling circulation patterns of the air currents of the earth's atmosphere. (Reprinted with permission from Kaufman W. Universe, 3rd ed. New York: WH Freeman, 1991.)

SPIRALS, WAVES, AND THE HUMAN BODY

We live in a spiral universe. Our local galaxy, the Milky Way, forms a spiral (Fig. 1-1). The spiral is a fundamental shape in the movement of air currents over the surface of the earth (Fig. 1-2). Water, which covers 70% of the earth's surface, moves in a spiral pattern, not only as it snakes its way across the land, but also as it spirals internally in the form of secondary currents within the moving water (Fig. 1-3).

Figure 1-1. The galaxy we live in has a spiral shape. (Reprinted with permission from Kaufman W. Universe, 3rd ed. New York: WH Freeman, 1991.)

The spiral is also an essential pattern in the body and is present at many levels. Tendons, ligaments, joint capsules, and the fascia of muscles are composed of parallel fibers of collagen, which resemble the spiral weave of a rope. Each collagen molecule is a triple helix spiral (Fig. 1-4). Visually, the gross structure of a tendon is also a spiral (Fig. 1-5).

Many muscles such as the teres major, latissimus dorsi, pectoralis major, and levator scapula, form a spiral twist from origin to insertion (Fig. 1-6). Muscles are composed of parallel fibers organized in spirals. Actin and myosin are the two basic contractile proteins that

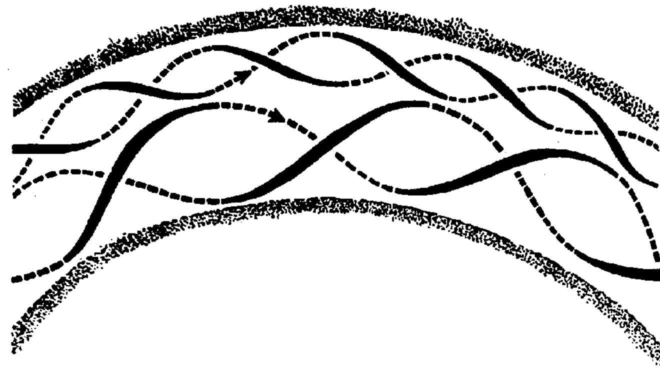

Figure 1-3. Spiraling movements within moving water. (Reprinted with permission from Schwenk T. Sensitive Chaos. New York: Schocken Books, 1976.)

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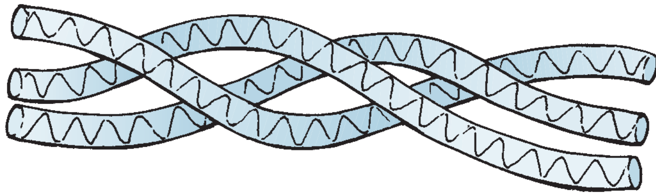

Figure 1-4. Triple helix spiral structure of collagen.

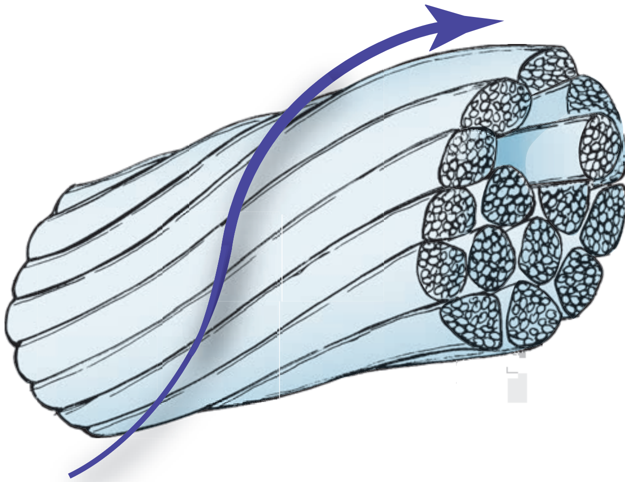

Figure 1-5. Arrangement of collagen fibers in a tendon shows its spiral orientation.

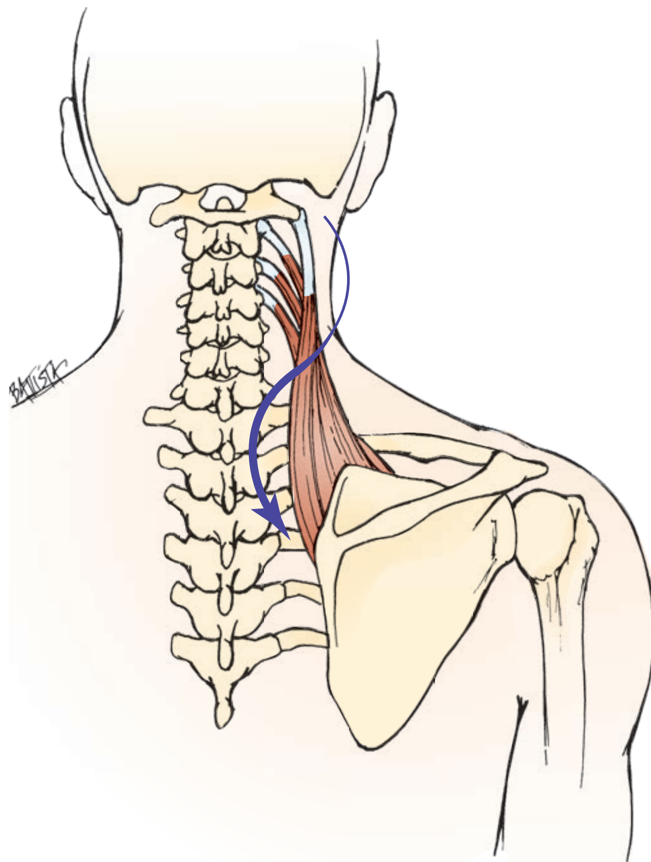

Figure 1-6. Levator scapula muscle shows the spiral orientation of the muscle from its origin to its insertion.

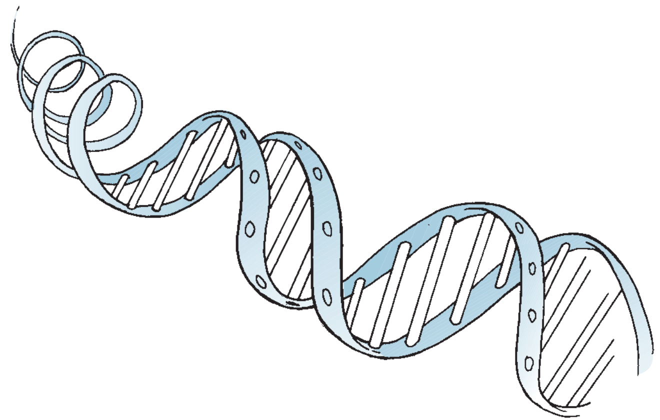

Figure 1-7. Spiral structure of DNA.

compose the functional unit of muscle contraction and form the myofibrils (literally, "muscle threads"), which are woven together in a spiral like a rope.[6] Each actin filament is a double helix that is composed of two strands that spiral around each other during muscle contraction, and myosin contains globular heads that are arranged in a spiral. DNA, the code of instructions for cellular reproduction, is also a double helix spiral (Fig. 1-7). The advantage of the spiral weave of soft tissue is that it increases the ability of the tissue to withstand stress. The twist pulls the fibers together, "preloading" the soft tissue by creating tension at the attachment points.[17] This allows the structure to withstand greater pulling forces (tensile loads).

SOFT TISSUE ALIGNMENT THEORY

This book introduces a new theoretical model of massage therapy: *Muscles, tendons, and ligaments have a normal position or alignment relative to the neighboring soft tissue and to the joint that they affect.* The author's mentor, Lauren Berry, RPT, a physical therapist and mechanical engineer, introduced this concept and also theorized that dysfunction and injury to a joint create abnormal positions or misalignment in the soft tissue surrounding the joint. The soft tissues are like guy wires holding up a tower. The bones represent the tower. In normal function, the guy wires are balanced in length and strength. Injury and dysfunction create abnormal positions for the guy wires and place excessive tension on some of the guy wires while others are slack and not functioning properly. This is analogous to joint dysfunction in which some muscles become too tight while others become too weak.

Berry's model hypothesizes that these soft tissues become misaligned and twisted. This misalignment occurs microscopically in the normal spiral alignment

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of collagen in the bundles of fibers called fascicles and macroscopically in the gross position of a muscle, tendon, or ligament. In other words, the soft tissue surrounding each joint has a normal spiral orientation of the fibers, which may wind into a torsion (twist) in dysfunction or after injury. Abnormal alignment has mechanical and neurological consequences.

One goal of manual therapy is to unwind the tissue to realign the fibers on both the macroscopic and microscopic levels.

- **Treatment implications:** From Lauren Berry's engineering experience, he discovered that if a twist developed in one of the steel cables he was working with, he could "unwind" it by rocking the cable back and forth perpendicular to the cable and reestablish the normal alignment of the steel strands. Berry discovered predictable patterns of misalignment of the soft tissue, which are described throughout this text. To correct the misalignment of the soft tissue, it is mobilized in a specific direction. Because muscles, tendons, ligaments, and other soft tissue are structured like steel cables (or ropes), our fundamental method of mobilizing the soft tissue is stroking perpendicular to the line of the fiber.

EXAMPLE OF SOFT TISSUE MISALIGNMENT

An example of the mechanisms of soft tissue misalignment can be illustrated with an injury to the knee. An injury causes swelling. To accommodate the excess fluid, the joint is held in a sustained flexion. This position pulls the soft tissue on the medial and lateral aspects of the knee into an abnormal posterior alignment. This misalignment also creates an abnormal torsion in the muscles, tendons, and ligaments on the medial and lateral aspects of the knee. The increased torsion causes a decreased flow of cells and fluids in the area, leading to a decreased ability for repair. The torsion adds excessive compression to the nerves traveling through the soft tissue, leading to potential dysfunction of muscle function, coordination, and balance. The treatment of the soft tissue on the medial and lateral sides of the knee is performed in a specific direction. The therapist mobilizes the soft tissue in a posterior-to-anterior direction to restore the normal alignment and to unwind the tissue to remove the abnormal torsion in the fascicles and fibers.

MECHANICAL AND NEUROLOGICAL CONSEQUENCES OF SOFT TISSUE MISALIGNMENT

- **Abnormal torsion (twist):** If the soft tissue develops an abnormal position owing to dysfunction or injury, it introduces an abnormal torsion or twist into the tissue. The abnormal twist decreases the water content of the tissue, leading to fluid stagnation, adhesions, and abnormal function in the soft tissue and associated joint. Stagnation reduces the tissue's ability to repair itself owing to decreased cellular activity, decreased nutrition, and the accumulation of waste products.
- **Dehydration of soft tissue:** Placing an excessive twist to the soft tissue is analogous to taking a wet washcloth and twisting it, wringing out the water. Misalignment and abnormal torsion compress the tissue, decreasing fluid content and decreasing the normal flow of fluids, which reduces the supply of vital nutrients and oxygen and the mobility of the cells. Compression to the tissue from abnormal torsions leads to adhesions and loss of normal extensibility.
- **Neurological and mechanical dysfunction in the joint:** Abnormal position and torsion of the soft tissue also create abnormal forces moving through the joint, creating joint dysfunction and potential degeneration. Joint dysfunction and degeneration cause irritation to the sensory nerve receptors in the soft tissue surrounding the joint. This irritation can create neurological reflexes that inhibit (weaken) or create hypertonicity in the surrounding muscles, leading to abnormalities of coordination and balance.

TREATMENT GOALS FOR SOFT TISSUE MISALIGNMENT

The treatment goals are fully described in Chapter 2, "Assessment and Technique." Some goals are unique to this method of massage:

- **Reposition the soft tissue:** One of our most fundamental intentions is to reposition the soft tissue. We accomplish this by resetting the soft tissue in a specific direction for each joint.
- **Unwind abnormal torsion:** The text describes the abnormal torsion patterns in the soft tissue surrounding each joint and the direction of the strokes to unwind the abnormal torsion. The ligaments, tendons, and muscles are like braided ropes or long phone cables, with tubes within tubes of fibers. The normal spiral alignment is reintroduced by "unwinding" the tissue, stroking the fibers perpendicular to their longitudinal axis.
- **Reestablish the normal parallel alignment of soft tissue fibers:** The ligaments, tendons, and muscles

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are composed of collagen fibers that pull apart after injury and repair themselves in a random weave, losing their normal parallel alignment. Chronic dysfunction is characterized by adhesions, which prevent normal alignment of the fibers. This method of treatment restores alignment.

- **Restore the ability of the bundles of fibers (fascicles) to slide relative to each other:** STM applied perpendicular (transverse) to the line of the fibers dissolves abnormal adhesions, increases lubrication, and promotes mobility of the tissue.
- **Restore the movement of fluids:** STM strokes are applied in rhythmic cycles of compression and decompression while rocking the body in oscillating waves. This technique restores the natural rhythmic movement of the body's fluids.

A NEW METHOD OF MASSAGE: WAVE MOBILIZATION

To help accomplish successful treatment, the author has created a new method of massage called *wave mobilization*. This method is based on 30 years of clinical experience and the author's 30 years of practice of tai chi. Tai chi was developed by the Taoists, who observed nature and especially water as embodying the essence of their spiritual path. Water is so yielding that it takes the shape of whatever container it is in yet so powerful that it dissolves rocks and forms canyons. The massage stroke that is used in wave mobilization is patterned after an ocean wave and is performed most effectively if the therapist is relaxed and supple, using energy (chi) rather than muscular strength. Through disciplined practice of energy exercises (see Chapter 2) and focused attention, the therapist can learn to develop a strong biomagnetic field (chi) for healing.

The energy pattern of an ocean wave is circular. The direction of the waves is perpendicular to the coastline (Fig. 1-8). The waves are repeated in rhythmic cycles, ebbing and flowing on the shore. Just as strong waves can dissolve a shoreline, massage applied in specific rhythmic cycles, perpendicular to the line of the fiber can dissolve adhesions and reintroduce normal motion in the tissue.

The wave mobilization strokes are performed while mobilizing the body in rhythmic oscillations, like the ebb and flow of the ocean. For much of the session, the client is put in a fetal position and is rocked in rhythmic oscillations at a frequency of about 60 cycles per minute, which mimics the mother's heartbeat that we all felt as waves of energy and fluids pulsating in her womb. This form of mobilization may be described as *heart-wave resonance*. Resonance is a coupling of systems to the same frequency. Rocking the body in rhythmic oscillations to the rhythm of the heartbeat sends waves of energy throughout the entire body. It is profoundly relaxing and profoundly healing.

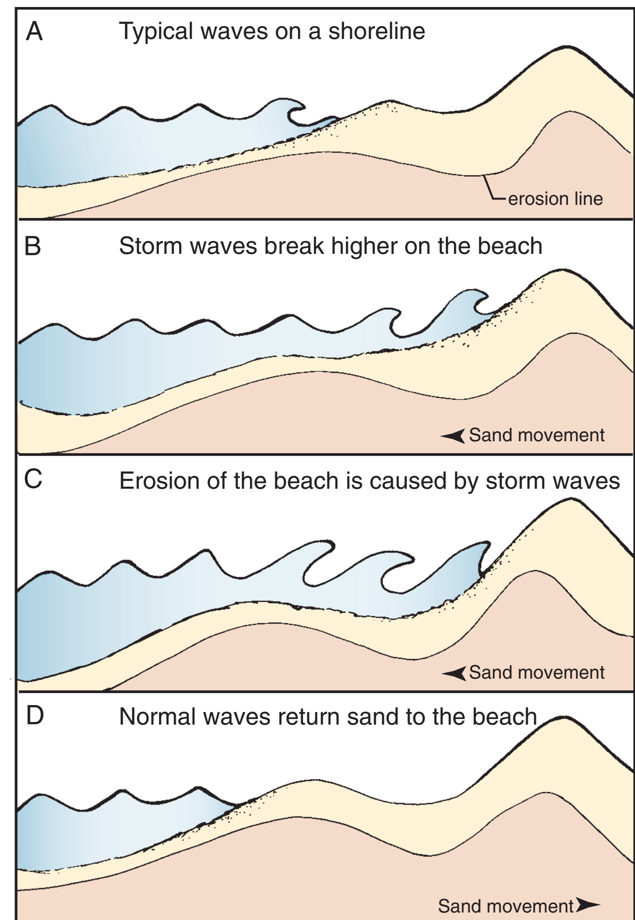

Figure 1-8. Wave mobilization stroke is modeled after the pattern of ocean waves. The ocean wave moves a molecule of water in a circular pattern. The waves move perpendicular to the shoreline, creating a digging motion.

The massage strokes are applied in a specific direction to reposition the soft tissue to its normal alignment and to remove the abnormal twist or torsion from the tissue. The strokes are applied perpendicular (transverse) to the line of the fiber to dissolve abnormal crosslinks and microscopic adhesions between the fibers and the fascicles. Dissolving these adhesions allows the fibers and fascicles to slide relative to each other, promotes the normal broadening of the muscle fibers, and helps to realign the normal parallel orientation of the fibers. We perform the strokes in cycles of compression and decompression to restore the normal waves of movement of the fluids within the body.

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MUSCLE ENERGY TECHNIQUE

The second modality of treatment described in this text is called *muscle energy technique* (MET). MET is a method of active resistance by the client against a force applied by the therapist. The author has developed a unique method of incorporating MET into the massage treatment. The clinical effects of MET are fully described in Chapter 2.

Because MET uses voluntary effort from the client to contract muscles, higher brain functions are used to reprogram neurological patterns of habitual muscle tension or muscle inhibition and weakness, helping to restore normal muscle function. MET dramatically transforms the role of the massage therapist from that of a practitioner who gives a treatment *to* someone to that of a practitioner who works *with* someone. The active participation of the client with the therapist can dramatically change chronic pain patterns.

MET also stimulates the synthesis of new cells to repair injured tissue, helps to realign and strengthen connective tissue fibers, lengthens shortened tissue, increases the range of motion of the joints, eliminates trigger points, and balances the strength of muscles crossing the joints to help evenly distribute the pressures that are moving through the joints.

Active contraction and relaxation of the muscles create a spiral winding and unwinding of the soft tissue surrounding the joint. This process of tightening and relaxation of the soft tissue promotes the movement of cells and fluids deep within the body to disperse stagnation and promotes the reoxygenation of tissue and the elimination of waste products.

JOINT MOBILIZATION

The third modality that is used in this form of treatment is joint mobilization. Joint mobilization can be defined as any form of passive movement at a joint.[18] A unique feature of wave mobilization is that STM and joint mobilization are performed with the same movement. Some techniques that are described in this text focus on specific joint mobilization. These movements are within the scope of practice for the massage therapist. The intentions of joint mobilization are to restore the normal joint play, promote the exchange of cells and fluids into and out of the joint for joint repair and regeneration, stimulate lubrication in the joint by stimulating the synovial membrane, normalize neurological function by stimulating sensory nerves of the joint, decrease swelling, and reduce pain.

Part Three: Essentials of Anatomy and Physiology for Orthopedic Conditions

The body's tissues are composed of three basic elements: cells, fibers, and body fluids. On the structural level, massage and manual therapy affect these elements in a very profound way, because they are "mechanotransducers," that is, they take mechanical information, such as touch, movement, and stretch, and translate that mechanical information into chemical energy, electrical energy, and electromagnetic energy, which promote cellular communication for optimum health. To achieve clinical success, the therapist needs to understand the structure and function of these tissues, understand the mechanisms of injury and repair, be able to perform a thorough assessment (see Chapter 2), and develop treatment goals based on which structures are being addressed and their stage of healing.

BASIC ORGANIZATION OF THE BODY

BODY, MIND, AND EMOTIONS FORM A UNIFIED WHOLE

- It is important to realize that all of the tissues form an interrelated whole and that each tissue not only influences other tissues, but also affects a person's emotions and psychology. For example, when you massage a tight muscle, you are touching skin, connective tissue, blood vessels, muscles, and nerve endings that communicate with every other part of the body. The touch stimulates sensory nerves that communicate to other muscles; to the neighboring

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joint, to the spinal cord, to the area of the highest centers of the brain that receives sensory information, and to the limbic area of the brain, which is the emotional center of the body. Touch also communicates with the autonomic nervous system, which regulates blood flow, heart rate, and respiration.

- **Treatment implications:** When you touch a person, you not only influence the local tissue that you are touching, but also influence every other aspect of the physical body, as well as the client's emotions and psychology. A nurturing and gentle touch can lower the blood pressure, slow the heart rate, relax muscle tone, and reduce anxiety, allowing for emotional and psychological healing as well as inducing the body's repair functions. An aggressive or hard touch has the opposite effect, inducing a state of anxiety, muscle guarding, and distress.

FOUR PRIMARY TYPES OF TISSUE

There are four primary types of tissue in adults:

- **Epithelium:** The epithelium consists of the skin, called the *external epithelium*, and the tissue that lines the internal organs and glands, called the *internal epithelium*.
- **Connective tissue:** The connective tissue forms the structural framework of the body. It is the basic building block of soft tissue, including ligaments, tendons, joint capsules, and fascia (forms the structural framework of muscles). These are generalized types of connective tissue, and this category also includes superficial and deep fascia, nerve and muscle sheaths, tissue covering the bones (periosteum), and the coverings and support framework of most organs. There are also specialized types of connective tissue, including cartilage, bone, blood, and lymph.
- **Muscle:** The muscles are classified into three types: skeletal (also called *voluntary muscle*), smooth (intestinal tract and blood vessels), and cardiac (heart).
- **Nerve:** The nerves consist of long cells grouped in bundles. The nervous system includes the brain, spinal cord, peripheral nerves, and autonomic nervous system.

External Epithelial Tissue (Skin)

- **Structure:** The skin consists of a superficial cellular layer called the *epidermis* and an underlying connective tissue layer called the *dermis*. The epithelium and the nervous system are derived from the same embryological tissue, the ectoderm. In a manner of speaking, we are wearing our nervous system.
  - The skin is the body's largest organ and contains blood vessels, glands, muscles, connective tissue, and nerve endings.
  - The skin contains four types of sensory nerve receptors called *mechanoreceptors*, which communicate with every other part of the body. The mechanoreceptors are sensitive to touch, pressure, movement, superficial proprioception (positional changes), pain, and temperature.
- **Function:** The skin provides sensation and protection, helps to regulate water balance, and regulates temperature. The sense of touch is the first of the senses to become functional in embryonic life, followed by proprioception.
  - Sensory information from the skin communicates to the spinal cord, where reflex (automatic, unconscious) connections are made to muscles, internal organs, and blood vessels. Skin pain can cause a contraction in the skeletal muscles or internal organs. A calming touch applied to the skin can reflexively relax muscles and internal organs.[19]
- **Dysfunction and injury:** Adhesions in the skin can develop after a blunt injury, cut, or surgery. Because the superficial fascia in the dermis is connected to the underlying deep fascia covering the muscles, these adhesions decrease the ability of the tissue to stretch and thus limit joint function. Adhesions in the superficial fascia can also entrap cutaneous nerves, leading to pain, numbing, and tingling. A potential outcome of joint or muscle dysfunction is reflex changes in the skin. The most common example is an area of increased sensitivity called the *hyperalgesic skin zone*.[18] In this condition, an area of skin becomes painful to light touch, and the skin and underlying fascia become tight and resistant to stretch.
- **Treatment implications:** Treatment of skin zones of increased sensitivity requires assessment and treatment of the neighboring joints. STM, MET, and joint mobilization release the nerves and fascia of the skin. Although most of the massage strokes are applied with a gentle, touch, the exception to this is treatment of adhesions in the skin or deep connective tissues, which require deeper pressures and typically elicit discomfort. Perform skin rolling to treat adhesions in the skin or entrapped cutaneous nerves. Using thumbs and the first two fingers, pull the skin and subcutaneous tissue in front of the thumb, and then the thumb rolls the skin toward the fingers in a wavelike motion. The cardinal rule in applying techniques that

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could be uncomfortable is that the client needs to be able to completely relax into the treatment to achieve the greatest success.

Connective Tissue

Connective tissue is composed of cells, fibers, and ground substance. As the name implies, connective tissue connects all the parts of the body. It forms the structural walls for the heart, lungs, and blood vessels, and it binds joints together through ligaments and joint capsules. It gives shape to the body through broad sheets of fascia and compartments, called *septa*, which contain the muscles. It forms the structural framework within muscles and transmits the pull of the muscles through the tendons. Connective tissue plays an important defense and immunological role in response to injury and infection.[18] As we will see, it is the connective tissue that is primarily injured in the strains and sprains of muscles, tendons, and ligaments. Therefore, it is one of the primary tissues to be addressed in massage and manual therapy.

COMPONENTS OF CONNECTIVE TISSUE

CELLS

- The cells are responsible for maintenance and repair and are essential for healing. The cells remove damaged or aged structures and synthesize new cells, fibers, and ground substance to remodel and repair the body. There are six different types of cells in ordinary connective tissue, but only the fibroblast is important for our consideration. Important cells of specialized connective tissue are the chondrocyte and the synoviocyte.
  - **Fibroblasts:** Fibroblasts produce all of the components of connective tissue, including fibers and ground substance, and are active in inflammation and repair. These cells are found in ligaments, tendons, joint capsules, and fascia.
  - **Chondrocytes:** Chondrocytes or cartilage cells are found in the collagen matrix of cartilage. Chondrocytes synthesize new cartilage in the normal turnover of cells and in the repair of damaged cartilage.
  - **Synoviocytes:** Synoviocytes form the lining of the joint capsule, which is in contact with the joint cavity.[20] They synthesize the lubricant (synovium) for the joint cartilage, supply nutrition to the chondrocytes, and remove waste products.
- **Function:** The normal function of cells and the creation of new cells (synthesis) are stimulated by movement. Cellular activity is also increased by the inflammatory process after an injury.
- **Dysfunction and injury:** Swelling decreases cellular movement and the ability of cells to synthesize new cells, fibers, and ground substance necessary for repair. In chronic conditions, decreased movement from adhesions or immobilization causes cells to break down tissue (lysis); creates atrophy in the muscles, tendons, and ligaments; and leads to osteoporosis in the bones.
- **Treatment implications:** In acute conditions, it is critical to reduce swelling as quickly as possible to promote cellular movement. Gentle, passive motion, especially in the flexion-extension planes, MET, and gentle STM provide mechanical stimulation to increase movement of fluids and to stimulate cellular activity. Chronic conditions require the same techniques but for different goals: to dissolve adhesions and tissue stagnation and to improve joint movement to promote cellular synthesis and cellular movement, which help to remodel and regenerate new tissue.

FIBERS

The three types of connective tissue fibers are reticulin, elastin, and collagen. Reticulin is a meshlike network for support of organs and glands. Elastin is more elastic and is found in ligaments and the linings of arteries. Collagen is the main component of the tendons, ligaments, joint capsules, and fascia (the framework for the shape and function of the muscles). Connective tissue is classified by the arrangement and density of the fibers. Ordinary connective tissue is divided into loose and dense. Dense connective tissue is further divided into regular and irregular, based on the alignment of the fibers.

THREE GENERALIZED TYPES OF CONNECTIVE TISSUE

Loose Irregular

- **Structure:** Loose, irregular connective tissue consists of a meshwork, similar to a spiderweb, of collagen and elastin fibers interlacing in all directions and an abundance of ground substance and cells.
- **Function:** Loose, irregular connective tissue is found in superficial and deep fascia; forms sheaths around muscles, arteries, veins, nerves, and organs; and also forms between these structures, suspending them and connecting them to each other. This tissue has enough extensibility to allow mobility in the healthy state.

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- **Dysfunction and injury:** Inflammation, irritation, or immobilization can create adhesions between the fibers. If the area is not adequately mobilized, the tissue becomes dense and hard.[21] This inhibits the ability of these structures to slide freely within their connective tissue spaces. Excessive tension can tether (pull) the nerve, leading to parathesias (altered sensations).
- **Treatment implications:** Perform STM perpendicular to the line of the muscle or nerve. In the acute condition, these strokes provide the necessary mobility to the healing fibers to help induce normal alignment and mobility. In chronic conditions, these scooping strokes dissolve adhesions with the heat caused by tissue compression and friction and by the mechanical pressure of stretching the tissue perpendicular to the line of the fiber. By taking the tissue into tension and then releasing it with the stroke, abnormal crosslinks are reduced, and the mobility and resilience increase, allowing greater range of motion and increasing the ability of the tissue to slide relative to neighboring tissue.

Dense Irregular

- **Structure:** Dense, irregular connective tissue forms thick bundles of collagen interweaving in three dimensions. There are few cells, and there is little ground substance. This type of tissue is found in the joint capsules, periosteum, fascial sheaths, flattened tendons called *aponeuroses*, synovial tendon sheaths, connective tissue covering of muscles, and dermis of the skin. (See below for further discussion of the joint capsule, periosteum, and fascia.)
- **Function:** Because of the three-dimensional interweaving of the collagen, this tissue has considerable strength and can withstand forces from various angles.
- **Dysfunction and injury:** This type of tissue forms scars from persistent swelling or immobilization.[21]
- **Treatment implications:** Mobility must be maintained during healing. In the acute phase, edema must be reduced quickly, and pain-free motion must be introduced into the area as soon as possible. A dense, contracted scar forms with inadequate mobilization.

Dense Regular

- **Structure:** Dense, regular connective tissue primarily consists of parallel bundles of collagen fibers that form tendons and ligaments (see below). Tendons and ligaments are mostly fibers, which gives them great tensile strength (resistance to pulling). This type of tissue also has a limited blood supply, limiting its ability to repair, unlike bone, which has an extensive blood supply and a remarkable ability to repair.
- **Function:** Tendons transmit the contractile force of the muscle to the joint. Ligaments connect the joints, providing stability and a profound neurosensory function.
- **Dysfunction and injury:** Because dense regular connective tissue has a limited blood supply, it requires motion to stimulate healing.
- **Treatment implications:** Tendons and ligaments require movement to stimulate blood supply to the tissue, bringing needed cells, oxygen, and nutrition to the area (see below).

COLLAGEN

On the structural level, massage and manual therapy are primarily concerned with how to affect deep, connective tissue, which is mostly collagen. Collagen makes up one-third of all the protein in the body and forms not only the tendons and ligaments, but also adhesions and scars. Understanding its structure and function is essential to achieving effective clinical outcomes.

- **Structure:** Collagen forms approximately 80% to 99% of the dry weight of tendons, ligaments, and joint capsules and 50% to 90% of the dry weight of cartilage and bone. It is the fascia that forms the shape and structural support for muscles; blood vessels; nerve fibers, including those of the brain; skin; and internal organs. The collagen fibers are long, soft, white, tough fibers synthesized from fibroblasts, which make tropocollagen, a triple helical (spiral) structure (Fig. 1-9). Mature collagen resembles the structure of a rope, with small strands forming larger strands, all wound together in a spiral.
  - Tropocollagen molecules line up side by side, overlapping, and are chemically bound together in a parallel arrangement by intermolecular crosslinks to form fibrils. These crosslinks give collagen great strength and stability.
  - The fibrils are wound in a spiral structure like short threads. These threads are wound together in a spiral like a rope to form a fiber.[22] The fibers are generally collected into bundles called *fascicles*.
  - The collagen fibers are normally aligned in a parallel and longitudinal orientation. The fibers have a slightly wavy appearance in the relaxed state called **crimp**. This is the slack in the tissue.

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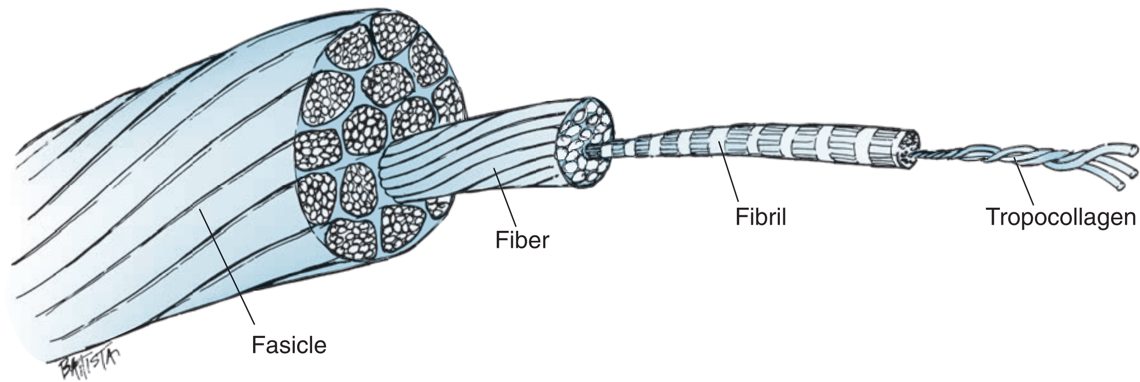

Figure 1-9. Collagen structure. Collagen fibers are organized in bundles called fascicles, which are designed to slide relative to each other in the healthy state.

The greatest strength is found when the fibers and fascicles are oriented in this parallel and longitudinal alignment along the lines of mechanical stress.

- ☐ The individual fibers and the fascicle bundles normally slide freely past one another.[23] The normal gliding of the collagen fibers is maintained by movement and the lubrication from the ground substance (see below).
- ☐ Collagen has been described as a "liquid crystal"[9] because of the ordered spatial relationship of its molecules.

- **Function:** Collagen is a dynamic tissue, synthesized in response to "stress," such as movement; and broken down (lysis) from lack of adequate stress, such as immobilization following injury. **Wolff's law** states that bone is laid down along lines of stress. This same law applies to soft tissue. Normal stresses, in the form of exercise and the activities of daily living, increase collagen synthesis and strengthen connective tissue.
  - ☐ Collagen stabilizes joints through ligaments, joint capsules, and periosteum.
  - ☐ Collagen transmits the pulling force of muscle contraction through the fascia within the muscle and through the tendon.
  - ☐ Collagen provides support in articular cartilage to resist compressive forces when the joint is loaded.

- **Dysfunction and injury:** Injuries to collagen can be artificially divided into acute, inflammatory conditions (injury) and chronic, noninflammatory conditions (dysfunction). As was mentioned previously, these categories do not reflect the fact that in the clinical setting there are many stages of injury and repair.
  - ☐ **Injury:** An injury to collagen is a tearing apart of the collagen fibers microscopically or a complete disruption of the structure (see "Mechanics of Soft Tissue Injury," p. 45). Injury can be described as an inflammatory condition that is the result of a macrotruama, that is, a specific event, such as whiplash, or a repetitive microtrauma that creates tissue disruption and inflammation over time, such as tennis elbow. Most soft tissue injuries are injuries to collagen.
    - **Traumatic injury:** Tissue disruption creates an immediate inflammatory response. The torn collagen fibers initially clot into a weak, random mesh. During the repair phase of the inflammatory cycle, the fibrils and fibers are laid down in a random orientation instead of in the normal parallel and longitudinal arrangement. This random weave decreases the strength of collagen. Eventually, the fibers pack closer together, forming abnormal crosslinks and adhesions, thus preventing the normal gliding characteristics of the collagen.[23]
    - **Cumulative or repetitive stress:** Collagen is also disrupted through repetitive mechanical stress. Low-grade irritation-inflammation signals the body to lay down more collagen in a random arrangement in the entire area of stress. These deposits of collagen contain abnormal crosslinks, forming adhesions. As with traumatic injury, the fibers pack closer together, and the lubrication is decreased, which decreases the ability of the fibers and fascicles to slide relative to each other. Cumulative stress is caused by four main factors:
      - **Posture:** Abnormal postural stress, such as a forward-head posture, creates an excessive tension or pulling force on the soft tissues around the cervicothoracic junction. The client complains of stiffness and lack of full range of motion. To palpation, the area feels thick and lacks normal tissue mobility due to excessive deposits of collagen (adhesions).
      - **Dynamic stress:** The stress of repetitive gripping of a tennis racquet and the reactive force

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of hitting the ball causes a thickening of the collagen within the muscles of the elbow, wrist, and hand and at their attachment sites.
  - **Static stress:** Excessive sitting or standing, such as working as a retail clerk, places abnormal forces on the tissue and leads to excessive deposits of collagen.
  - **Misalignment:** An example of misalignment is patellar-tracking dysfunction. The kneecap (patella) is typically pulled laterally due to pronation or other postural dysfunctions, and rubs against the lateral side of the femur. This chronic irritation creates excessive deposits of collagen, leading to loss of normal mobility and function of the patellofemoral joint, and eventual degeneration.

- ☐ **Dysfunction:** Chronic irritation to collagen creates excessive deposits, leading to adhesions. Collagen can also weaken and atrophy due to lack of adequate stress. Sedentary lifestyle and immobilization are two examples.
  - **Adhesions:** Adhesions are abnormal crosslinks of connective tissue between gliding surfaces. These adhesions can occur at every level of the soft tissue, from the ligament or tendon adhering to the bone to adhesions between the fascicles or between the fibers themselves. Adhesions decrease tissue pliability (mobility) and extensibility (length). The tissue becomes less elastic, thicker, and shorter. The client will often feel stiff in the area of adhesions.
  - **Atrophy:** Loss of collagen may be due to immobilization from injury or lack of use from a sedentary lifestyle. Lack of stress on the tissue causes a decrease in collagen production, leading to atrophy in the connective tissue and to osteoporosis in the bone. Without movement, the body begins to break down the tissue, in a process called *lysis*. New collagen is laid down in a random orientation without adequate stress, packing the fibers close together, forming adhesions. Atrophy and randomly oriented fibers create weakness in the tissue and instability in the associated joint.

■ **Treatment implications:** Collagen is extremely sensitive to mechanical load, that is, the touch, movement, contractions, and stretching of manual therapy. The manual therapist can guide how the newly synthesized collagen is laid down by stimulating the tissue appropriately. The stimulus must be dosed correctly: In the acute phase, the stimulus to the tissue must be very gentle; in chronic conditions, the stimulus can be more vigorous. The guiding principle of treatment is that motion must be maintained throughout the process of repair and rehabilitation.[24] Treatment goals are determined by the stage of healing and repair. In the early phase of healing, collagen is easily influenced because weak, unstable bonds are holding the tissue together.[18] In the later phases of healing, it takes more stimulus over a greater period of time to influence the tissue. The details of assessment to determine the stage of healing and further discussion of treatment goals are found in Chapter 2.

- ☐ For injury and inflammatory conditions the goals of treatment for collagen are as follows:
  - To reduce the swelling as quickly as possible to allow the exchange of cells, oxygen, and nutrients to the healing tissue.
  - To stimulate the cells, including the fibroblasts, which will synthesize new collagen and the other elements of connective tissue to repair the injured tissue.
  - To provide mechanical stimulation to realign the new collagen fibrils along their lines of stress and to their normal parallel alignment.
- ☐ For chronic dysfunction, the treament goals are as follows:
  - To dissolve abnormal crosslinks (adhesions).
  - To lengthen shortened tissue.
  - To stimulate the fluids to promote the movement of nutrition, oxygenation, and elimination of waste products. Stimulate the fibroblasts to synthesize ground substance and thus increase the lubrication between the fibers and the fascicles, promoting normal gliding.
  - It is essential to maintain motion for the collagen to align itself properly. Movement also promotes the normal sliding of the fascicles and helps to maintain the normal interfiber distance. If the movements of daily life are inadequate to restore function, then the abnormal crosslinks in the collagen can be reduced through STM, joint mobilization, and MET.

***CAUTION:** The treatment of injuries requires special precautions: In the early stages after an injury, the therapist must exercise great care to use only gentle massage, MET, and joint mobilization so as not to disturb the newly forming crosslinks. These normal crosslinks are essential to maintaining the strength of the tissue. Gentle isometric MET is used to help realign the developing fibrils, but excessive force of stretching is contraindicated in the first two weeks after an injury (see Chapter 2).*

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GROUND SUBSTANCE

- **Definition:** Ground substance is a transparent, viscous (thick) fluid—much like raw egg whites in appearance and consistency—that surrounds all the structures in the body and binds them together.
- **Structure:** The primary components of ground substance are water and glycoaminoglycans, which look like bottle brushes at the molecular level. Glycoaminoglycans draw water into the tissue and bind it and are electrostatically bound to the collagen fibers, increasing their strength.[18] Because glycoaminoglycans hold water, this causes the tissue to swell, giving healthy tissue the feeling of a water balloon. Water makes up approximately 70% of ground substance.
- **Function:** Ground substance acts as the medium for the transport of nutrition and removal of waste products. It also acts as a lubricant and spacer between the collagen, elastin, and reticular fibers, preventing the fibers from adhering to each other.[25] Because of the high water content, ground substance also acts as a shock absorber. Ground substance has a thixotropic quality. **Thixotropy** is the quality by which a substance becomes more fluid when stirred and more solid when undisturbed.[19]
- **Dysfunction and injury:** Injury leads to inflammation and swelling, which decrease the function of the fibroblasts, which synthesize ground substance. This causes a decrease of the glycoaminoglycans, which decreases the lubrication and spacing provided by the ground substance. The fibrils and fibers pack more closely together, leading to abnormal crosslinks and adhesions. This decreases the normal gliding of the fibers, fascicles, tendons, ligaments, joint capsules, and muscles relative to the neighboring soft tissues and bone. In chronic dysfunction and immobilization, tissue fluids stagnate and nutrition is decreased, which inhibits repair. There is a decrease in glycoaminoglycan and water content, decreasing the interfiber distance, leading to adhesions. The tissues tend to cool, and the ground substance becomes thicker and more gel-like, leading to greater stiffness and decreased circulation, nutrition, and lubrication.
- **Treatment implications:** STM, joint mobilization, and MET reintroduce motion into the tissue. Movement stimulates the synthesis of ground substance and glycoaminoglycans, and promotes the circulation of blood, lymph, and ground substance, which contains a high percentage of water. This water can then bind to the glycoaminoglycans, creating greater lubrication to the tissue. Movement also transports nutrients and promotes the exchange of waste products. As was mentioned above, heat creates a change in the ground substance from being sluggish and thick to a more fluid state. MET creates heat through muscle contraction and the pulling and release of the fascial components. MET also promotes circulation deep within the body by means of the pumping action of muscle contraction, which affects the lymph and blood flow.

EXAMPLES OF CONNECTIVE TISSUE STRUCTURES

TENDONS

- **Structure:** Tendons are a continuation of the connective tissue (fascia) of the muscle (myofascia), so the entire connective tissue of the muscle transmits the force of contraction. This fascia is called a tendon after the muscle fibers end. The muscle and tendon are therefore best described as a unit, the **musculotendinous** unit. The tendon has three distinct sections: the **myotendinous junction,** where the muscle fibers end and the connective tissue forming the tendon continues; the **tenoperiosteal junction,** where the tendon attaches to the bone by interweaving to the connective tissue (periosteum) covering of the bone; and the mid-portion or **body of the tendon.**
- Tendons are composed of long, spiraling bundles of parallel collagen fibers, oriented in a longitudinal pattern along the line of stress and embedded in a matrix of ground substance and a small number of fibroblasts. The ground substance binds with water, which forms two-thirds of the total weight of the tendon.
- Collagen molecules combine to form ordered units of microfibrils, fibrils, and fibers (Fig. 1-10). These fibers run parallel to each other and are contained in a bundle called a *fascicle*. Each fascicle is normally capable of sliding past the other fascicles in the healthy state.[3] Fascicles are bound together by loose connective tissue called the **endotenon**, which supports the blood vessels, lymphatics, and nerves. A group of fascicles together forms the gross tendon.
- Tendons and ligaments have a microscopic crimp or wavelike structure that acts like a spring and can withstand large internal forces. The crimp in the tendon imparts an elastic quality to the structure. When you stretch a muscle and "take the slack out," you are straightening out the crimp in the tissue.
  - Tendons may be a cordlike structure, such as the Achilles tendon; a flattened band of tissue, such

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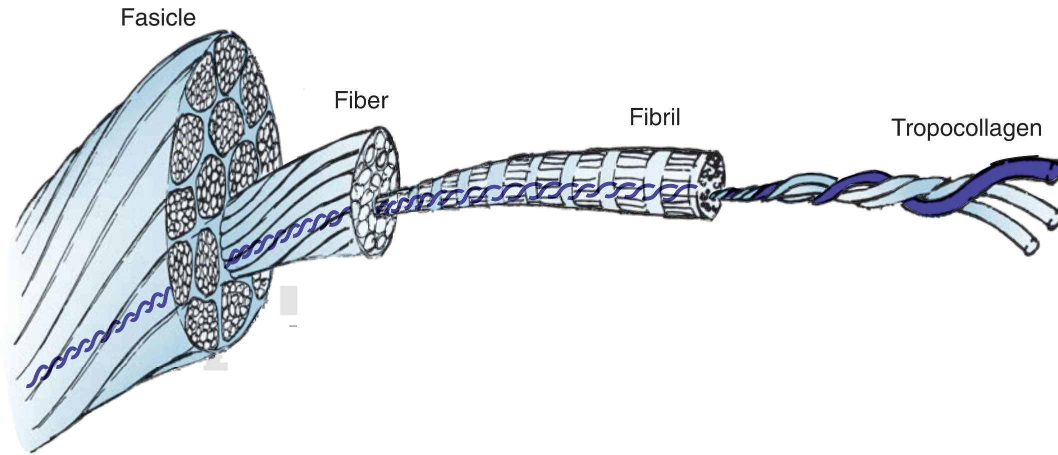

Figure 1-10. Longitudinal and parallel alignment of the collagen fibers and the crimp or wave within the fibers of a tendon and ligament.

as the rotator cuff; or a broad sheet of tissue called an aponeurosis, such as the origin of the latissimus dorsi.

- ☐ In areas of high pressure or friction, such as where tendons rub over the bones of the wrist and ankle, the tendon is enclosed within a sheath called the **epitenon**, which is lined with a synovial layer that secretes synovial fluid to facilitate gliding of the tendon (Fig. 1-11). Tendons that are not enclosed within a sheath and move in a straight line are surrounded by a loose connective tissue sheath called a **paratenon**.

- **Function:** Tendons attach muscle to bone and transmit the force of muscle contraction to the bone, thereby producing motion of the joint. The musculotendinous unit also helps to dynamically stabilize the joint by providing strength and support to the joint. Tendons act as "shock absorbers" by lengthening to absorb tension during high-impact motions.[6] The tendon also acts as a sensory receptor through Golgi tendon organs (GTOs), which sense the level of tension in the tendon. (See "The Nervous System" for more information on GTOs.)

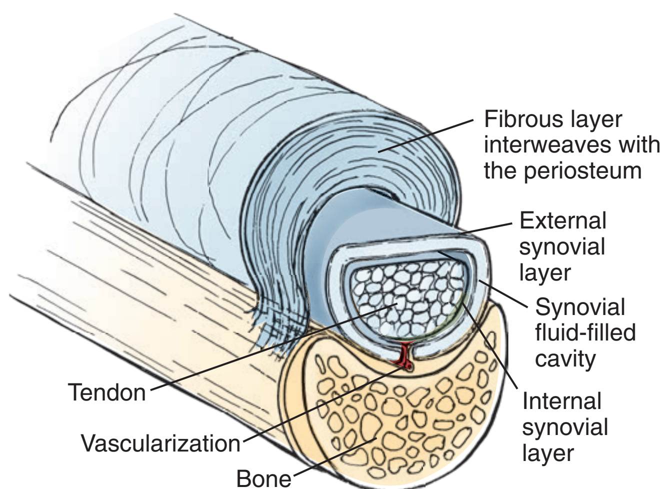

Figure 1-11. Tendon sheath structure.

- **Dysfunction and injury:** An injury to the tendon is called a **strain** and typically represents a tearing of the collagen fibers, primarily at the musculotendinous junction and secondarily at the tenoperiosteal junction. Tendon ruptures are rare within the body of the tendon itself except in chronic, weakened tendons, because tendons can withstand much higher pulling (tensile) stresses than muscle or bone. The term ***tendinitis*** is used to describe inflammation to the tendon. Inflammation may be due to a specific event; cumulative or repetitive strain; friction irritation, such as iliotibial band friction syndrome; or compression, such as impingement of the supraspinatous of the shoulder. As was previously described, injury and inflammation disrupt the normal parallel alignment of the collagen. Repair creates random weaves of collagen and abnormal crosslinks (adhesions), leading to stiffness, weakness, and loss of range of motion.
  - ☐ Reid has categorized tendinitis into five functional grades, depending on the symptoms reported by the patient:[21]
    - **Grade I:** Pain only after activity.
    - **Grade II:** Minimal pain with activity.
    - **Grade III:** Pain interferes with activity but disappears with rest.
    - **Grade IV:** Pain with rest, significant pain and swelling.
    - **Grade V:** Pain interferes with activities of daily living; chronic and recurrent pain; significant pain and swelling, signs of soft tissue changes, and altered muscle function.

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- Tendinitis is also categorized on the basis of the structures affected. **Tenosynovitis** is an inflammation of the synovial lining of the tendon sheath caused by irritation of the sheath from roughened surfaces of the tendon, and **tenovaginitis** is an inflammation with a thickening of the tendon sheath and/or an enlargement of the tendon that jams in the sheath (commonly called "trigger finger"). An injury to the tendon has neurological consequences, which are described further in the section "The Nervous System."

- Chronic overuse injuries are the result of repetitive stresses that cause disruption and disorganization of the collagen but do not necessarily lead to inflammation. The tendon can become degenerated because it has failed to heal properly through lack of inflammation and repair. Degenerated tendons are susceptible to fatigue, leading to weakness and dysfunction, a condition called **tendinosis** or **tendinopathy.** Currently, these two terms are favored over *chronic tendinitis* because surgical examination of chronic tendon lesions often reveals degenerative tissue rather than inflamed tissue.[26] The tendon might be painful, but the pain is due to ischemia and lactic acid rather than inflammation. A chronic tendon dysfunction is susceptible to reinjury, due to atrophy of the tendon.[27] Loss of normal motion and inadequate exercise in a tendon from a prior injury or immobilization create loss of collagen fibers (atrophy) and adhesions between the tendon and the surrounding structures, including the tendon sheath. This decreases the strength of the tendon.

- **Treatment implications:** Inflammation should be limited, so rest from excessive activities, ice, compression, and elevation are recommended. As with other collagen injuries, studies show that immediate, pain-free mobilization promotes tendon healing.[28] In acute tendinitis, STM in the early phases of repair stimulates collagen synthesis, improves the strength of the tendon, reduces the number of adhesions, and helps to realign the developing collagen fiber in the early stages of repair.[23] Increased DNA and cells are found in mobilized tendons compared with immobilized tendons, signifying increased repair.[16] MET helps to reduce swelling, promotes nutritional exchange, and prevents muscular inhibition. As with other collagen structures, great care must be taken in the early stages after an injury, because the collagen is fragile. Too much manual pressure can disturb the newly forming tissue, and stretching is contraindicated. Examination includes isometric contraction of the involved musculotendinous structures, which typically will be painful at the site of the lesion. The structure may also be weak, owing to either pain or muscular weakness or inhibition. Palpable tenderness at the site of the injury is also typical.

- Chronic tendon conditions are the result of failed tendon healing and are characterized by disorganized and immature collagen and degenerated tissue.[23] Although tendinopathy can be painful to the client and painful to isometric challenge, the tissue is not hot, swollen, or tender before tissue tension, so it is not inflamed. Because of this, treatment involves deep pressure, transverse to the fiber, to intentionally create a microinflammatory response to stimulate collagen synthesis, reorganize the collagen to its normal parallel alignment, and stimulate cellular synthesis to repair the degenerated tissue. The therapeutic goals are also to dissolve abnormal crosslinks and adhesions; realign the fibers and fascicles to their normal parallel alignment; restore the ability of the tendon to glide relative to the surrounding soft tissue and bone; unwind and reposition the tendon as necessary; increase the lubrication and nutrition by improving movement of the fluids in areas of thickened or congested tissue; lengthen the tissue if indicated; and help to restore neurological function with MET. If a chronic tendon lesion is reinjured and shows signs of inflammation, it is treated as an acute injury. If the musculotendonous unit has weakened through injury, immobilization, aging, or disuse, exercise is necessary to strengthen the tissue. If the therapist is not trained in exercise rehabilitation, referral to a physical therapist or personal trainer is necessary.

LIGAMENTS

- **Structure:** Ligaments are composed of dense, white, short bands of nearly parallel bundles of collagen fibers embedded in a matrix of ground substance and a small number of fibroblasts. Ligaments are two-thirds water, which is a critical component for cellular function, nutritional exchange, mechanical behavior, and transmission of electromagnetic waves. The fibers are bound together in a fascicle (see Fig. 1-10). They are both microscopically and grossly similar to tendons, except that they contain some elastic fibers, giving them greater elasticity. Ligaments are pliable and flexible. Given that there are over 120 movable bones that make up the major synovial joints, it is estimated that there are several hundred ligaments.[29] Extrinsic ligaments are located over the joint capsule, whereas intrinsic ligaments are thickened portions of the capsule itself.
  - There is a normal parallel sliding of fibers, and the fascicles are free to slide relative to each

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other in the healthy state.[23] They have a crimp or wavelike structure that acts like a spring, withstanding large internal forces and giving the ligaments a small amount of slack (see Fig. 1-11).
- ☐ All ligaments contain specialized nerve endings, including mechanoreceptors and nociceptors (pain fibers).
- ☐ Ligaments have a rich vascular supply, which must be constantly maintained for synthesis and repair. Swelling or immobilization leads to ligament atrophy and risk of rupture.[26]

■ **Function:** Ligaments attach one bone to another, help to stabilize the joint, help to guide joint motion, and prevent excessive motion. They also play an important neurological role as sensory receptors. Mechanoreceptors give information about posture, movement, and joint position; have reflex connections to the surrounding muscles; and play an important role in joint function. They help to coordinate muscular activity for stability, protection, and efficient movement of the joint. A reflex connection exists between the ligaments of a joint and the surrounding muscles, which has instantaneous effects on muscle tone.[30] Nociceptors send pain information in reaction to inflammation and harmful stimuli.

■ **Dysfunction and injury:** Ligament injuries are called **sprains** and are a tearing of the collagen fibers.
- ☐ Sprains are categorized into three grades, depending on the extent of the injury:
  - **Grade I:** Microscopic tearing of a few fibers. There is some pain but no loss of stability.
  - **Grade II:** Gross tears and some loss of structural integrity.
  - **Grade III:** Complete tearing through the body of the ligament or at its attachment. Frequently requires surgery.
- ☐ Because of their functions to help stabilize the joint and as potent neurosensory structures, injuries to the ligaments can create profound disturbances to joint function.
- ☐ Similar to the joint capsule, the ligaments might respond to an injury by becoming excessively stretched, creating joint instability; or they may become shortened, contributing to joint stiffness and loss of normal range of motion in the joint. Immobilization causes ligaments to atrophy and weaken, owing to decreased collagen content.
- ☐ Irritation or injury of the ligaments can cause a reflexive contraction or inhibition in the surrounding muscles caused by reflexive connections between the ligaments and the musculature.[31] Injured ligaments, even without laxity, lead to to muscle dysfunction, loss of proprioception, and instability.[32]
- ☐ Ligaments can twist into abnormal torsion, a concept contributed by Lauren Berry, RPT. For example, after a finger injury, the finger typically assumes a position of sustained flexion. The ligaments on the medial and lateral sides of the finger are pulled toward the palm with this sustained flexion, winding them into abnormal torsion.

■ **Treatment implications:** Clinical assessment of ligaments involves passive joint motion that stretches the ligament and palpation. Passive testing will reveal excessive joint motion with Grade II and III injuries. It is important for the therapist to distinguish ligament involvement from musculotendinous conditions because ligaments take much longer to heal. If ligaments are part of the injury, the therapist needs to tell the client that ligaments might take many months to heal. This will help to avoid frustration or impatience. The goals in treating acute ligament injuries include providing pain relief, reducing swelling, preserving as much mobility as possible, and maintaining neurosensory function.[14] STM is performed to help realign the healing fibrils; passive joint motion maintains range of motion and promotes adequate circulation; and MET provides neurosensory stimulation, reduces swelling, and promotes nutritional exchange. There might be mild discomfort with the STM strokes but no pain. Stretching after acute injury is contraindicated.
- ☐ In chronic conditions, thorough assessment is critical to differentiate whether the ligament is thick and fibrous, owing to increased collagen, abnormal crosslinks, and adhesions, or whether the ligament is too lax (atrophied), owing to degeneration from immobilization, disuse, or lack of adequate repair from a prior injury or repetitive stresses.
- ☐ For ligaments that have developed adhesions, perform gentle scooping strokes transverse to the line of the fiber. If you palpate thickened, fibrous tissue in the chronic state, transverse friction massage, as described by Cyriax,[33] is effective in dissolving these adhesions and rehydrating the tissue.[33] The author has contributed a new method of applying transverse friction massage that dramatically reduces the pain associated with transverse friction massage.
- ☐ If ligaments are too lax and degenerated, transverse STM can stimulate collagen synthesis and help to realign disorganized fibers. Exercise rehabilitation is recommended to stimulate the production of new collagen and to help restore normal integrity to the ligament.

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- ☐ Abnormal torsion in the ligaments is corrected with STM strokes applied transverse to the fiber in a specific direction for each ligament.
- ☐ To help restore the neurological function of the ligament, MET is used. Because the muscle is connected to the ligaments with a neurological reflex, isometric contractions to the muscles surrounding the ligaments can help to restore neurological communication.

PERIOSTEUM

- **Structure:** Periosteum is a dense, irregular connective tissue sheath covering the bones. The outer layer consists of collagen fibers parallel to the bone and contains arteries, veins, lymphatics, and a rich supply of sensory nerves. The inner layer, called the *osteogenic layer*, contains osteoblasts—cells responsible for new bone formation.
- **Function:**
  - ☐ The bone cells in the periosteum generate new bone during growth and repair when the periosteum is stimulated.
  - ☐ The periosteum interweaves with the joint capsule and ligaments, and stretching of the periosteum gives mechanoreceptor information regarding movement and position of the joint.
  - ☐ The periosteum blends with the tendons, forming the tenoperiosteal junction, which is the site where the muscle pulls on the bone for joint movement.
  - ☐ The sensory nerves in periosteum include pain fibers and nerves that are extremely sensitive to tension (i.e., a pulling force).[34]
- **Dysfunction and injury:**
  - ☐ Because the myofascia interweaves with the periosteum, repetitive stress can excessively stimulate the osteogenic layer to create bone spurs, a common problem in runners, who develop heel spurs from excessive or repetitive stress to the plantar fascia that interweaves with the periosteum of the heel.
  - ☐ Excessive tension on the periosteum caused by an abnormal position of the joint increases collagen deposition, creating abnormal crosslinks and adhesions. For example, as a result of forward-head posture, the excessive tension leads to the development of fibrous thickening at the lower cervical and upper thoracic vertebrae, contributing to a "dowager's hump." Increased collagen deposition leads to stiffness and loss of normal motion in the joint and diminished function of the mechanoreceptors, potentially causing problems with balance and coordination.
  - ☐ A common site of soft tissue injury is at the tenoperiosteal junction. An acute tear or cumulative microtearing of the periosteum can cause the orientation of the collagen in the area to become random, leading to the development of the abnormal crosslinks and adhesions described above. Discomfort or pain can result when the muscle contracts and pulls on the adhesions in the periosteum.
- **Treatment implications:** The periosteum should feel smooth and glistening to the touch. If adhesions are palpated, first perform MET to the muscles that attach to the involved site. This increases the extensibility of the periosteum at the tenoperiosteal attachment. Adhesions are treated manually with transverse STM strokes or brisk transverse friction strokes for chronic conditions. Although the primary direction of the strokes is perpendicular to the shaft of the bone and therefore perpendicular to the periosteum, strokes are performed in all directions because the interweaving tendons and ligaments form oblique angles to the bone. The therapist "looks" with his or her hands to feel for a line of adhesions in order to stroke perpendicular to that line, akin to stroking across a guitar string. Performing strokes perpendicular to the fiber will dissolve all but the most thickened nodules.

FASCIA

- **Structure:** Fascia is a fibrous connective tissue that is arranged as sheets or tubes. There are several types of fascia: thick, dense regular connective tissues; thin, loose irregular, connective tissue; and thin, filmy membranes. Fascia is an uninterrupted, three-dimensional web that interweaves with every structure in every region of the body.
  - ☐ Superficial fascia lies under the dermis of the skin and is composed of loose, irregular connective tissue.
  - ☐ Deep fascia is a dense connective tissue that surrounds muscles, bones, nerves, and blood vessels and forms fascial compartments called **septa,** which contain muscles with similar functions (Fig. 1-12). These compartments are well lubricated in the healthy state, allowing the muscles inside to move freely past each other and relative to the fascial envelope.
- **Function:** The superficial fascia gives shape to the body, surrounds the organs and glands, and acts as a packing material throughout the body, facilitating movement between structures. The deep fascia

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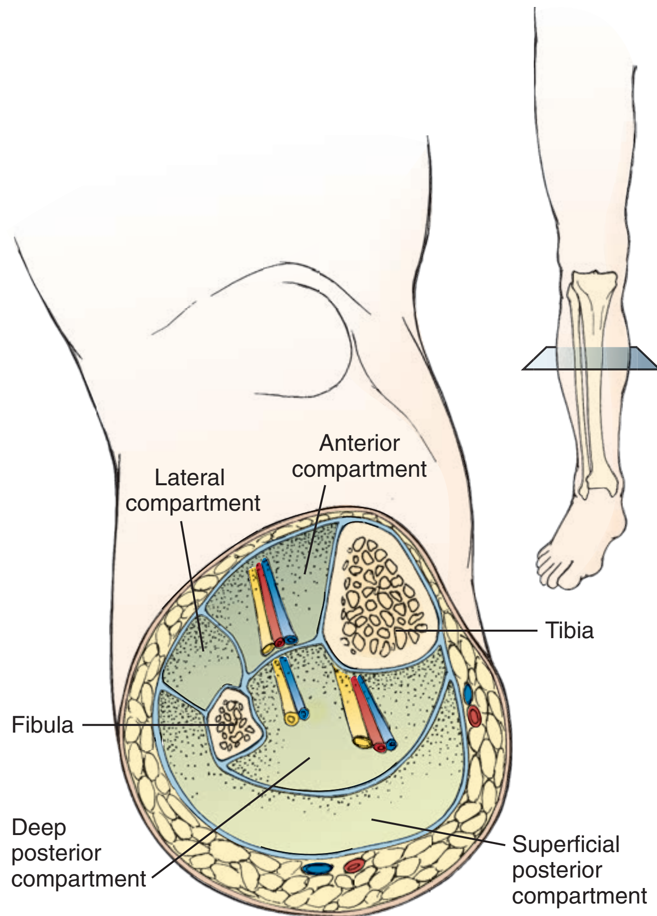

Figure 1-12. Deep connective tissue forms compartments in the body to organize muscle groups. This upward view is of the compartments of the right leg.

forms aponeurosis, ligaments, tendons, retinacula, joint capsules, and septa. It also forms the periosteum that covers bone, cartilage (perichondrium), and blood vessels; and forms the structural support of muscles (epimysium, perimysium, endomysium) and nerves. Fascia maintains structural integrity and assists in stabilization, provides support and protection, and acts as a shock absorber. It is richly endowed with nerves, reporting changes in movement, stretch, tension, and pressure through mechanoreceptors and reporting pain through nociceptors.

- **Dysfunction and injury:** Inflammation or repetitive stresses lead to abnormal crosslinks (adhesions), and structures begin to adhere to each other, decreasing their ability to glide. The ground substance becomes more dense, decreasing venous and lymphatic return. Adhesions also affect the nerves, creating disturbances of coordination and balance.[18]
- **Treatment implications:** As with other connective tissues, fascia is very responsive to mechanical stimulation, including STM, MET, and joint mobilization (see the treatment implications for collagen, above).

PROPERTIES OF CONNECTIVE TISSUE

VISCOELASTICITY

Viscoelasticity describes the mechanical behavior of soft tissue, which contains both elastic fibers and ground substance.

- **Elasticity** is the ability of a tissue to be stretched and to return to its previous length. This is like a spring. Collagen has a wavelike crimp in it that lengthens when it is stretched a small amount and that springs back to its original length.
- **Viscosity** is the resistance of fluids to movement. The ground substance of soft tissue has the viscosity of egg whites. The degree of viscosity of a fluid depends on how quickly or how slowly it is moved. For example, if you move your hand slowly through water, little resistance is encountered. If you move your hand rapidly, greater “fluid friction” is encountered.
- **Treatment implications:** If the ground substance of the soft tissue is thick, the massage strokes need to be slowed down. It is helpful to perform MET to thick tissue, which increases the heat in the tissue and helps to make the ground substance less viscous (more liquid), which, in turn, decreases the friction of your strokes. If soft tissue is stretched slowly, it will lengthen more easily. When a more rapid force is applied, soft tissues become stiff and more easily injured. This helps to explain why rapid acceleration in a car accident is damaging to the soft tissue.

PIEZOELECTRICITY

- **Definition:** As was mentioned in the first section, piezoelectricity is the ability of a tissue to generate electrical potentials in response to mechanical deformation. Piezoelectricity is a property of most, if not all, living tissue.
- **Dysfunction and injury:** Adhesions create a resistance to normal electrical flow.[35] This decrease in electrical currents conducted in the connective tissues interferes with the normal repair and rejuvenation process.
- **Treatment implications:** Massage strokes mechanically deform the collagen fibers by compressing and crossing the fibers. This creates electric potentials, which help to realign the collagen fibers in

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their normal parallel array. Massage also increases the negative charge in the soft tissue, which has a strong proliferative effect, stimulating the creation of new cells to repair the injured site.[36] MET provides mechanical stimulus that also generates piezoelectric currents.

MUSCLE STRUCTURE AND FUNCTION

GENERAL OVERVIEW

Muscle Structure

- There are more than 600 skeletal muscles making up 40% to 45% of the total body weight, and they are responsible for all of the body movements (Fig. 1-13).[37] There are two distinct elements of the muscle's structure: the muscle fiber and the connective tissue. We will address each of these separately.
- **Structure of muscle fiber:** The structural unit of skeletal muscle is the muscle fiber, which is a long, thin, threadlike, cylindrical cell, less than the diameter of a human hair. Unlike other musculoskeletal tissues, muscle consists primarily of cells, contained within a highly organized matrix of connective tissue.
  - ☐ The fibers are arranged in tightly packed, highly ordered parallel arrays, like collagen, and are collected in bundles called **fascicles**.
  - ☐ Each fiber is composed of thousands of myofibrils (literally, "muscle threads"), which are wound in a spiral like the weave of a rope.
  - ☐ The myofibril is subdivided into functional units known as the sarcomeres, composed of thousands of strands of proteins, also arranged in parallel, called *myofilaments*. The myofilaments are composed of actin and myosin, the proteins of contraction.
  - ☐ Microscopically, the actin is arranged in a spiral, and recent studies show that muscle fibers and the associated connected tissue rotate (spiral) during contraction.[6]
  - ☐ There are two types of skeletal muscle fibers:
    - The **extrafusal fiber** is under voluntary control. This is the typical muscle fiber.
    - The **intrafusal fiber,** or **muscle spindle,** lies embedded within the other fibers. This fiber functions as a sensory nerve receptor and operates without conscious control.
  - ☐ In addition to the muscle fiber, every muscle contains **satellite cells**, which are stem cells, able to regenerate new muscle fibers in the event of injury to the muscle fiber.
- **Structure of connective tissue:** The muscle fibers are so interwoven with connective tissue that a more accurate term for muscle is ***myofascia.*** Three layers of connective tissue surround and support a muscle (see Fig. 1-13):
  - ☐ Epimysium, a fascia of fibrous connective tissue that surrounds the entire muscle.

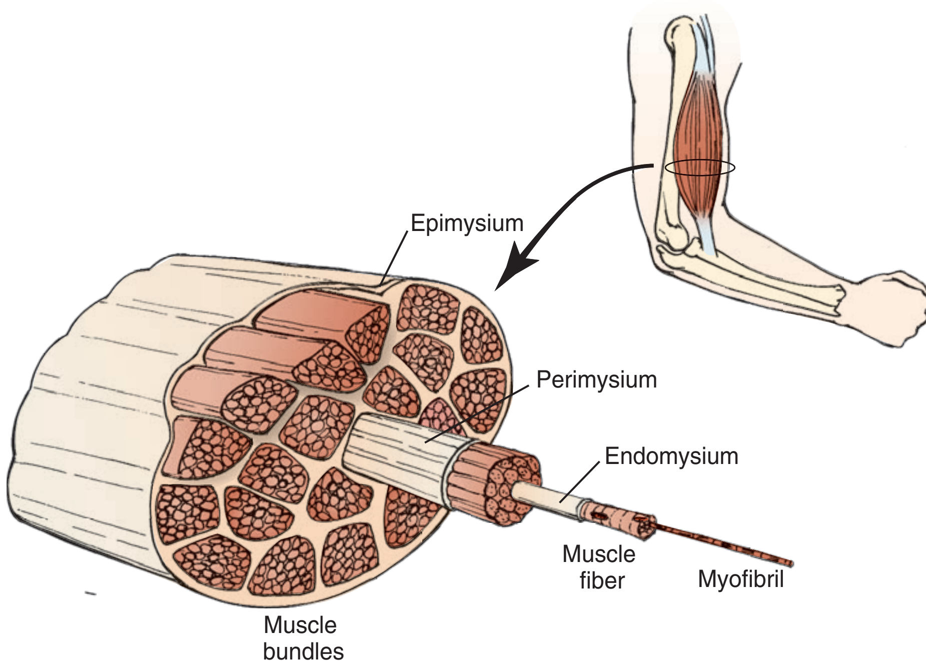

Figure 1-13. Anatomy of a muscle showing the layers of the connective tissue.

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- ☐ Perimysium, a dense connective tissue, arranged in a spiral that surrounds each fascicle, a major component of the elastic quality of muscle. The perimysium is essential in maintaining the proper position of the muscle bundles.[37]
- ☐ Endomysium, a delicate, meshlike sheath that surrounds each individual fiber, providing mechanical support and acting as an elastic device, adding to the springy quality of muscle.

- **Function of connective tissue:**
  - ☐ The connective tissue of muscle transmits the pull of the contracting muscle cells and gives the muscle fibers organization and support.
  - ☐ The collagen fibers of these three layers of connective tissue form the tendon, which attaches the muscle to the bone. The tendon fibers interweave with the connective tissue of the periosteum, joint capsule, and ligaments.
  - ☐ All of these connective tissue layers are lubricated in the healthy state. Muscles as a whole are designed to slide relative to each other, and each fascicle within the muscle is also capable of sliding relative to the other fascicles in the healthy state.

Muscle Function

- **Movement:** Muscles are responsible for all the movements of the body.
- **Proprioception:** There are three types of sensory nerve receptors in muscles (see below) that give the central nervous system information about the length, tension, pressure, movement, and sense of joint and body position in space.
- **Protection:** Muscles are connected to the nerves in the skin and to the nerves in the neighboring joint's capsule and ligaments through neurological reflexes; therefore, if the skin or joint is irritated or injured, the muscle can go into a reflexive spasm (called *splinting*) or into inhibition (weakness).
- **Pump:** The muscles are called a *musculovenous pump* because the contracting skeletal muscle compresses the veins and moves blood toward the heart.[34] This process of contraction and relaxation of the muscles is essential to normal health in that it is used to eliminate the body's waste products and to bring in nutrition, including oxygen.
- **Pain receptors:** Muscles have pain receptors (nociceptors) that fire with chemical or mechanical irritation.
- **Posture and stability:** Muscles are called *dynamic stabilizers* of the joints because they actively hold the joints in a stable position for posture and movement.
- **Signal transduction:** Muscle fibers and the associated connective tissue are highly ordered, tightly packed, parallel arrays. This arrangement can be described as a "liquid crystal," an ideal arrangement for the transmission of mechanical, electrical, and electromagnetic energy throughout the body.

Viscoelastic Property of a Muscle and Its Fascia

- Tension in a muscle and its fascia is created by active and passive elements. The passive elements include the collagen fibers and ground substance, and the active components include the contractile proteins—actin and myosin—and the nerves.
- The ability of a muscle to lengthen is termed *flexibility*, and the term *stiffness* describes resistance to lengthening. The limitation of a muscle's ability to stretch (lengthen) is primarily dependent on the connective tissue.[38]
- The connective tissue fibers of the muscle compose the **elastic** component. As was described previously, the connective tissue (fascia) of the muscle becomes the tendon. This fascia has a crimp or wavelike structure, similar to a spring. The tissue can be stretched within its normal limit and return to its resting length, in much the way that a spring can be pulled and released. When you stretch the fascia or pull on the fascia as you contract a muscle, energy is being stored, as in pulling a spring. The stored energy is released to create mechanical work or heat when the stretch or muscle contraction is released.
- Because muscle contains ground substance, it demonstrates **viscous** behavior. It becomes thicker and stiff when it is stretched quickly, is cold, or is immobilized. It becomes more fluid if the myofascia is stretched slowly or is warmed up.

The Muscle as Part of a Tensegrity Structure

Muscle is the tension member of the body that transmits the force of muscle contraction to the connective tissue to move the body and dynamically stabilize its posture. The bones are the compression members and cannot keep the body upright without the muscles and connective tissue. In other words, it is the tension members of the structure, not the bones, that hold the body upright. Buckminster Fuller[10] coined the word *tensegrity* to describe this type of structure. The strength and stability of a tensegrity structure, such as the human body, depend on the soft tissues, including muscles, fascia, tendons, ligaments, and joint capsules.

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Role of Muscle in Movement and Stability

- **Agonist:** The muscle(s) that contracts to perform a certain movement is called the *agonist(s)*. This muscle is also called the prime mover. For example, the biceps is an agonist for elbow flexion. Keep in mind that all movements in the body are accomplished by more than one muscle.
- **Antagonist:** The muscle(s) that performs the opposite movement of the agonist is called the *antagonist(s)*. The triceps is the antagonist for the biceps, because the triceps extends the elbow.
- **Co-contraction:** When the agonist and antagonist are working simultaneously, they are co-contracting. For example, when you make a fist, the flexors and extensors of the wrist are co-contracting to keep the wrist in a position that ensures the greatest strength of the fingers. Typically, however, when the agonist is working, the antagonist is relaxing.
  - **Sherrington's law of reciprocal inhibition** states that there is a neurologic inhibition of the antagonist when the agonist is working. When we contract the biceps to flex the elbow, the triceps is being neurologically inhibited (relaxed), which allows it to lengthen during elbow flexion. Co-contraction is an exception to this rule.
- **Synergist:** The muscle(s) that works with another muscle to accomplish a certain motion is called a *synergist(s)*. The term includes *stabilizers* (i.e., muscles that support a joint to allow the prime mover to work more efficiently) and *neutralizers* (i.e., muscles that prevent a certain motion as the agonist is working).

Tonic and Phasic Muscles

- **Structure:** Muscles can also be divided on the basis of which muscles have primarily a stabilizing role and which muscles have primarily a dynamic role. These categories are controversial because most muscles can function in both roles. However, it has been proved clinically useful because muscles react to pain in predictable ways, which are discussed below in the section "Dysfunction Due to Impaired Muscle Function."
  - **Tonic (postural):** Muscles that play a primary role in maintaining posture and therefore function essentially as stabilizers are called *tonic muscles* or *postural muscles*.
  - **Phasic:** Muscles whose primary roles are to perform quick movements are called *phasic muscles*.
- **Dysfunction and injury:** It has been found that tonic (postural) muscles react to stress by becoming short and tight and that phasic muscles react to stress by becoming inhibited and weak.[39] Janda and colleagues[40] have discovered that there are predictable patterns in which muscles tend to become tight and which muscles tend to become weak. His insights are incorporated throughout this text.
- **Treatment implications:** See the treatment implications discussed in the section "Muscle Dysfunction."

Innervation

- Two types of motor (efferent) nerves supply each muscle:
  - **Alpha nerves:** The alpha nerves fire for voluntary and involuntary muscle contraction.
  - **Gamma nerves:** The gamma nerves have voluntary and involuntary functions. They unconsciously help to set the muscle's tone in addition to its resting length, and they function during voluntary activities for fine muscular control.
- Three types of sensory (afferent) nerve receptors supply each muscle: two types of mechanoreceptors and nociceptors (pain receptors). The two specialized mechanoreceptors are called **muscle spindles** and **golgi tendon organs (GTOs)**, which detect muscle length and changes in length and muscle tension and changes in muscle tension, respectively (see "The Nervous System" and Figure 1-20 for further discussion).

Three Types of Voluntary Muscle Contraction

- **Isometric:** In an isometric contraction, the muscle contracts, but its length does not change. If, while sitting, you place your hand under the seat of your chair and attempt to lift the chair, your biceps isometrically contracts, but the origin and insertion do not move toward each other.
- **Concentric:** Concentric contraction is when a muscle shortens while it contracts (i.e., the origin and insertion move toward each other). As you bring a glass of water to your mouth, your biceps is shortening while it contracts.
- **Eccentric:** Eccentric contraction is when the origin and insertion move apart while a muscle contracts. As you lower the glass back to the table, your biceps is lengthening while it maintains some contraction. The muscle generates maximum strength during eccentric contraction, but it is more susceptible to injury. Another example is the hamstrings, which contract eccentrically at the end of the swing phase, just before heel strike, to decelerate the

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lower leg and control the extension of the knee during running.

Relationship Between Muscle Length and Tension

A muscle develops its maximum strength or tension at its resting length or just short of its resting length because the actin and myosin filaments have the maximum contact (crossbridges). When a muscle is excessively shortened or lengthened, it loses its ability to perform a strong contraction. A muscle can develop only moderate tension in the lengthened position and minimum tension in the shortened position. For example, if the wrist is maximally flexed, the ability to make a fist is diminished because the finger flexors are in a shortened position.

Involuntary Muscle Contraction By Voluntary Muscles

- Withdrawal reflexes, such as pulling away from a hot stove, involve instantaneous muscle contraction.
- Righting reflexes from the ligaments and joint capsule communicate to the muscle and stimulate instantaneous muscle contraction for protection of the joint and associated soft tissue.
- Arthrokinetic reflexes create unconscious muscle contraction (or inhibition) of muscles surrounding a joint caused by irritation in the joint (see "Function of the Joint Receptors").
- Splinting or involuntary muscle contraction can be caused by muscle, bone, or joint injury.
- Emotional or psychological stress creates excessive and sustained muscle tension.
- The maintenance of posture involves unconscious muscle contraction.

MUSCLE INJURY

- A muscle injury is called a **strain** or "pulled muscle" and is usually a tear within the fibers themselves, disrupting the sarcolemma, the membrane that covers the muscle fiber.[38] More extensive injuries disrupt the connective tissue layers surrounding and imbedded within the muscle. Muscle strains typically involve excessive active muscle stretching, or eccentric contraction, especially in two-joint muscles, such a hamstrings, gastrocnemius, and rectus femoris.
- Muscle strains are classified in three grades, although it is difficult to assess the severity:[21]
  - ☐ **Grade I:** Mild injury, with minimal structural damage.
  - ☐ **Grade II:** Moderate injury, with significant functional loss.
  - ☐ **Grade III:** Severe injury, a complete tear with complete loss of function that might require surgery.
- **Areas of injury:** Injury usually occurs at the junction where the muscle and tendon meet, called the **myotendinous junction,** and secondarily where the tendon attaches to the periosteum of the bone, called the **tenoperiosteal junction.** There are two reasons why muscles are likely to fail at these sites:
  - ☐ The myotendinous junction is stiffer than other areas of the muscle, making it the weakest link. For all muscles, failure consistently occurs near the myotendinous junction.[23]
  - ☐ Junction sites of ligament, tendon, and joint capsules are relatively avascular and have an increased stiffness. These junctions, therefore, are more prone to injury.[23]
- Tearing of muscle initiates an inflammatory reaction, and the typical stages of healing (see, "Stages of Inflammation and Repair" below). Two processes are initiated: the regeneration of new muscle fibers and the repair of connective tissue.
- Within days of injury, satellite cells become activated and are transformed into new muscle fibers. At the same time, fibroblasts increase the production of collagen and ground substance to generate a new connective tissue framework. Because of the development of abnormal crosslinks in the collagen and adhesions within the muscle's fascia, a muscle typically shortens and loses some of its extensibility after an injury. Without adequate movement, adhesions form between the connective tissue layers, leading to decreased function. With severe injuries involving large ruptures, formation of excessive collagen results in contractures or dense, nodular scars, severely limiting motion.
- Symptoms vary from severe loss of function, such as the inability to bear weight with a severe gastrocnemius tear, to a mild soreness. If a muscle injury is painful at rest, the area is inflamed. There may be swelling, bruising, and spasm. Examination reveals pain with isometic challenge of the involved muscle and pain to palpation.
- **Treatment implications:** The key to treatment is to promote pain-free mobility. Early mobilization promotes rapid capillary ingrowth, regeneration of muscle fibers, and a more parallel orientation of

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the fibers compared with immobilization.[26] For **acute** injuries, the first treatment goal is to reduce the swelling. If circulation is decreased because of swelling, the repair process is compromised. Gentle passive motion in flexion-extension planes and very light contract-relax (CR) or reciprocal inhibition(RI) MET help to pump excess fluid out of the site of injury. STM, joint mobilization, and MET minimize adhesion formation, promote circulation for the delivery of oxygen and removal of waste products, increase lubrication for the normal gliding of the structures, and promote proper parallel alignment of the collagen and muscle fibers. Movement also stimulates the regeneration of new connective tissue and muscle fibers. MET promotes muscle regeneration that is stimulated by the longitudinal pulling force of muscle contraction.[16] As with all acute injuries, care must be taken in the first few days after injury that excessive motion is not applied, because it can result in further disruption and excessive scar formation. For **chronic** muscle conditions, the treatment goals are to use STM, joint mobilization, and MET to restore flexibility by dissolving adhesions and lengthening connective tissue, eliminating muscle hypertonicity, restoring normal muscle firing patterns, restoring strength, and promoting neurological function through sensory awareness and reeducating proprioception (See Chapter 2, “Assessment and Technique”). Immobilization causes decreased cellular activity, decreased collagen in the fascia, and loss of muscle fibers (atrophy).

MUSCLE DYSFUNCTION

Muscle Dysfunction: A New Concept in Orthopedics

- **Definition:** Muscle dysfunction is defined as loss of normal function of the muscle. There are many types of dysfunction: sustained hypertonicity, sustained inhibition (neurological), sustained weakness (deconditioning or atrophy), adaptive shortening (contractures of connective tissue elements), myofascial trigger points (hypersensitive palpable nodules), abnormal position, and abnormal torsion.

Causes of Muscle Dysfunction

- **Poor posture:** Sitting or standing with poor posture creates cumulative stress. Because of the viscoelastic properties of muscle and connective tissue, they will remodel (adapt) to the stresses that are placed on them. For example, rounded-shoulders posture leads to a shortening of the fascia of the anterior chest and tightening of the pectoralis minor. There are also lengthening and weakness of the posterior fascia and muscles.
- **Static stress:** Sitting or standing for long periods is fatiguing. As with poor posture, muscles and fascia adapt to stress by depositing excessive connective tissue in areas of excessive stress and creating atrophy of the muscle and soft tissue in areas of reduced stress.
- **Muscle injury:** A muscle can become hypertonic owing to injury (strain), leading to involunatry guarding or reflex spasms; or it can become weak from injury or posttraumatic atrophy.
- **Joint dysfunction or injury:** Injury or dysfunction to the joint can lead to a reflexive increase in tone (hypertonicity) or decrease in tone (hypotonicity) depending on the specific muscles around the joint, called the *arthrokinetic reflex* by Wyke.[41] Predictable patterns of hypertonicity and inhibition are fully described by Janda (see below).
- **Emotional or psychological stress:** Anxiety and anger can create sustained muscle contraction, and depression can cause sustained weakness in the muscles.
- **Chronic overuse:** A muscle fails to relax after intense use, leading to ischemia and tension myositis (pain in the muscle caused by sustained contraction).
- **Disuse:** Deconditioned syndrome is a phenomenon in which a muscle is weakened owing to lack of use. This phenomenon precedes muscle atrophy.
- **Viscerosomatic reflexes:** An irritation or inflammation in a visceral organ can cause a muscle spasm. For example, a kidney infection can cause a spasm of the lumbar muscles.

Three Common Types of Muscle Dysfunction

Myofascial Pain Syndrome (Trigger Points)

- Myofascial pain syndrome is a chronic, regional pain syndrome, characterized by myofascial trigger points. The trigger point is a hypersensitive palpable nodule in a tight band of muscle, which is painful on compression. Trigger points are associated with decreased ROM, decreased muscular strength, and increased pain with stretching.
- **Treatment implications:** The method of treatment that is described in this text based on the author’s clinical experience supports studies that show that

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trigger points are effectively and painlessly treated with postisometric relaxation (PIR) MET.[42]

Dysfunction Caused by Abnormal Position and Abnormal Torsion

- As has been mentioned, Lauren Berry, RPT, contributed a revolutionary concept in manual therapy. He theorized that all soft tissue has a specific position relative to the neighboring soft tissues and the joint that they affect and that muscles, tendons, ligaments, bursae, and nerves can become malpositioned. This text describes the patterns of the abnormal position in the soft tissue and the treatment to correct positional dysfunction.
  - Abnormal position in the anterior deltoid provides an example of positional dysfunction. In the rounded-shoulders posture, the anterior deltoid rolls or winds into a more anterior-inferior position relative to the shoulder joint (the glenohumeral joint). This abnormal position decreases the function of the muscle and contributes to the dysfunction of the shoulder (Fig. 1-14).
- The author has developed this concept further and theorizes that this malposition creates an abnormal torsion or twist in the muscle and fascia, including the fascicles and fibers, down to the microscopic level, creating *interfascicular torsion*.

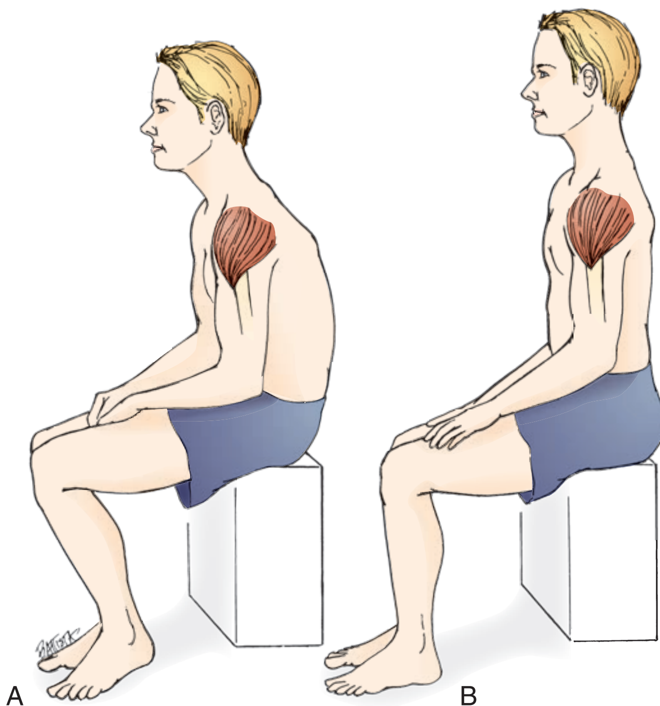

Figure 1-14. A. In a slumped, rounded-shoulder posture, the fascicles of the anterior deltoid roll into an abnormal position and abnormal torsion. The muscle twists into an internally rotated position. **B.** In the normal upright posture, the fascicles of the deltoid are aligned in a superior direction.

- **Treatment implications:** The muscle and fascia need to be stroked in a specific direction. In the case of the anterior deltoid, it needs to be stroked superiorly and posteriorly to restore its normal position and function and to release the torsion within the fascicles. This text describes each muscle's positional dysfunction and the direction of the massage strokes necessary to correct it.

Dysfunction Caused by Impaired Muscle Function

- Janda and colleagues[40] and Lewit[43] use the expression *functional pathology of the motor system* to describe unconscious reflexes from the central or the peripheral nervous system that cause sustained hypertonicity or sustained inhibition (weakness) in the muscles. Pain always creates impaired function, but impaired function can take years to develop into pain.
- The most important signs of impaired muscle function according to Janda[44] are as follows:
  - **Increased muscle tone (muscle hypertonicity):** Muscles that are held in a sustained contraction are an important factor in the genesis of pain. Hypertonicity has many causes (see "Patterns of Inhibition [Weakness] and Hypertonicity").
  - **Muscle inhibition/muscle weakness:** *Inhibition* refers to a decreased capacity of a muscle to neurologically respond to stimuli.[18] *Weakness* refers to an inability of a muscle to generate force. A short and tight muscle may be functionally weak as well as inhibited. The inhibition and weakness create joint instability and cause other muscles to become hypertonic in compensation.
  - **Muscle imbalance:** Muscle imbalance is a change in function in the muscles crossing a joint, in which certain muscles react to stress by getting short and tight and others become weak. This is an important factor in chronic pain syndromes because this imbalance alters the movement pattern of the joint.
  - **Joint dysfunction:** Muscle dysfunction creates an uneven distribution of forces on the weight-bearing surfaces of the joint, predisposing it to degeneration and dysfunction of the sensory nerves that provide critical information about the position and movement characteristics of the joint.
  - **Abnormal muscle firing pattern:** Muscle dysfunction is often expressed by abnormal patterns of contraction. For example, hip abduction should typically be performed by the gluteus medius, but the tensor fascia lata often substitutes for this action because of a weak gluteus medius.

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- **Treatment implications:** Impaired muscle function is best treated with MET. Having the client actively contract muscles in a precise and controlled way engages the higher brain centers, the sensory-motor cortex, to override unconscious patterns in the lower brain, and reeducates the reflexes between the muscle, joint, and spinal cord. For example, it is typical for the gluteus maximus to be weak and inhibited in clients with chronic low back pain. It is important to "recruit" the muscle by having the client consciously contract the muscle to reeducate the neuromuscular connection. Refer to "The Nervous System" below and to Chapter 2 for further discussion.

Patterns of Inhibition (Weakness) and Hypertonicity

- Janda and colleagues[40] discovered clinically that muscles react to pain or excessive stress in two opposite ways in predictable patterns. He found that certain muscles tend to become overactive, short, and tight, and he described these muscles as having a postural or stabilizing function, similar to tonic muscles. He found that other muscles tend to become inhibited and weak. He noticed that most of these muscles were concerned with movement rather than stability; therefore, he grouped inhibited and weak muscles as phasic muscles. An example of muscle imbalance is what Janda and colleagues[40] calls the **upper crossed syndrome** (Fig. 1-15). The terms *postural* and *phasic* have led to some confusion among clinicians and researchers, and more accurate terms have been suggested for these two groups: **tightness-prone** and **inhibition (weakness)-prone** muscles.[45]
- In addition to the causes of muscle dysfunction listed previously, soft tissue injury, chronic pain, and inflammation create disturbances in normal muscle function and can stimulate a neurological-based tightness or weakness in a muscle.
- An important difference between the two muscle groups is that a small reduction of strength in an inhibition-prone muscle initiates a disproportionately larger contraction of the antagonist tightness-prone muscle.[43] Janda and colleagues[40] notes that many of our work and recreational activities favor tightness-prone muscles getting stronger, tighter, and shorter as the inhibition-prone muscles become weaker and more inhibited. It is important, however, to realize that some muscles, such as the quadratus lumborum and the scalenes, can react with either tightness or weakness.
- **Muscles that tend to be tightness-prone** and react to pain or excessive stress with hypertonicity and eventual shortening are as follows:

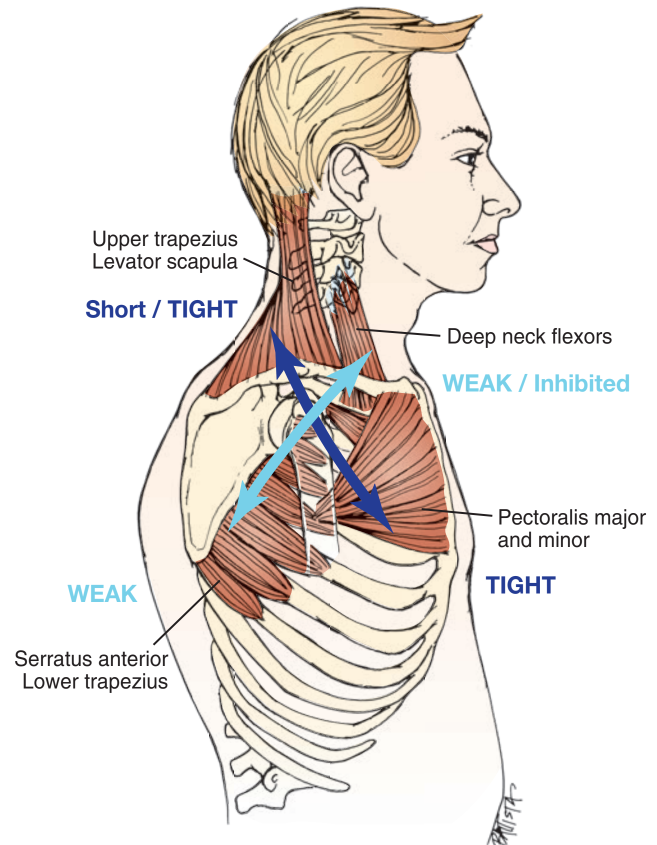

Figure 1-15. Upper crossed syndrome, a typical pattern of muscle imbalance. The upper trapezius and pectoralis major and minor are usually short and tight, and the deep neck flexors and serratus anterior and lower trapezius are typically weak and inhibited.

  - ☐ Sternocleidomastoid, pectoralis major (clavicular and sternal parts), and minor, upper trapezius, levator scapulae, flexor groups of the upper extremity, erector spinae, iliopsoas, tensor fascia lata, rectus femoris, piriformis, pectineus, gracilis, adductors, hamstrings, gastrocnemius, soleus, and tibialis posterior.
- **Muscles that tend to be weakness-prone (inhibited)** and react to pain by becoming neurologically inhibited and, therefore, weakening are as follows:
  - ☐ Deep cervical flexors, extensor group of the upper extremity, pectoralis major (abdominal part), middle and lower trapezius, deltoid, rhomboids, supraspinatus, infraspinatus, serratus anterior, rectus abdominus, internal and external obliques, gluteal muscles, vasti muscles (medialis, lateralis, and intermedius), tibialis anterior, and peroneals.

Consequences of a Hypertonic Muscle

- **Definition:** A muscle that is held in a sustained contraction is also called a *hypertonic muscle*.

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This means that the muscle is constantly working. The most common causes of hypertonicity are stress, overuse, injury (pain), and joint dysfunction. This constant contraction has several effects.

- The muscle consumes more oxygen and energy than a muscle at rest and therefore contains more lactic-acid waste products, which irritate the nerves.
- Circulation is decreased because the muscle is not performing its normal function as a pump. This leads to ischemia, which is decreased oxygen, causing pain.
- The sustained tension in the muscle pulls on its attachments to the periosteum, joint capsule, and ligaments, creating increased pressure in the joint and loading the cartilage unevenly, which creates excessive wear in the joint and accelerated degeneration.
- Hypertonic muscles can compress the nerves that travel between the muscles or, in some cases, through the muscle. This leads to decreased nerve function and to paresthesias or altered sensations, typically, a "pins and needles" feeling. A common example is the compression of the sciatic nerve by a hypertonic piriformis muscle.

Consequences of an Inhibited (Weak) Muscle

- A healthy muscle functions to dynamically stabilize the joint. A weak muscle creates instability, which excessively stresses the passive stabilizers, which are the ligaments, and joint capsule. This leads to imbalanced forces moving through the joint and accelerates degeneration.
- Weakness contributes to poor posture, which creates areas of excessive tension and compression.
- Inhibition leads to loss of adequate motor control and to abnormal firing patterns in the muscle, leading to substitution of other muscles and abnormal joint movements.
- An inhibited muscle does not have adequate cycles of contraction; therefore, the pumping of the vascular system and lymphatics is diminished.

JOINT STRUCTURE AND FUNCTION

JOINT TYPES

- **Definition:** A joint is the connection (articulation) between two bones or cartilage elements. The body consists of over 150 joints, and they are classified by the type of tissue that unites the two bones.
- **Fibrous joint (synarthrodial):** A fibrous joint is united by fibrous tissue (e.g., sutures of the skull) that has little movement.
- **Cartilaginous joint (amphiarthrosis):** A cartilaginous joint is united by fibrocartilage (e.g., symphysis pubis) and the intervertebral discs of the spine and have slight movement.
- **Synovial joint (diarthrosis):** The most common joint in the body is the synovial joint. The joint has a joint cavity filled with synovial fluid, and the two bones are surrounded by a joint capsule and are characterized by having free mobility.

COMPONENTS OF SYNOVIAL JOINT

There are seven structures that are common to all synovial joints: (1) synovial membrane, (2) synovial fluid, (3) joint capsule, (4) capsular ligaments, (5) articular cartilage, (6) blood vessels, and (7) sensory nerves.[22] We will describe each of these below. Other structures that may form part of the joint are the intra-articular discs or menisci; labrum, which is a fibrocartilage rim found in the hip and shoulder; and fat pads, found between the synovial membrane and fibrous capsule in some joints, such as the knee and elbow.

Joint Capsule

- **Structure:** The joint capsule forms a fibrous cuff around synovial joints. The attachment encircles the bones that form the joint, usually at the border of the articular cartilage. It is composed of two layers (Fig. 1-16). The outer layer is fibrous connective tissue organized in parallel bundles, and the inner layer is synovial tissue. The outer layer is reinforced with intrinsic and extrinsic ligaments. Intrinsic or capsular ligaments are thickenings within the body of the capsule, whereas extrinsic ligaments lie superficial to the capsule. Many of the tendinous insertions of muscles interweave with the joint capsule. For example, the multifidus, rectus femoris (reflected head), vastus medialis and lateralis, pectoralis major, teres major, biceps, triceps, tendons of the rotator cuff, and most of the forearm flexors all interweave directly with the capsule. The inner layer is also called the *synovial membrane* and covers all the intra-articular structures except the load-bearing articular cartilage and meniscus. It has a rich network of blood vessels and lymphatics and is lined with cells called **synoviocytes**. The synovial layer also has small projections, called *villi*, which secrete synovial fluid when they are stimulated through joint movement.

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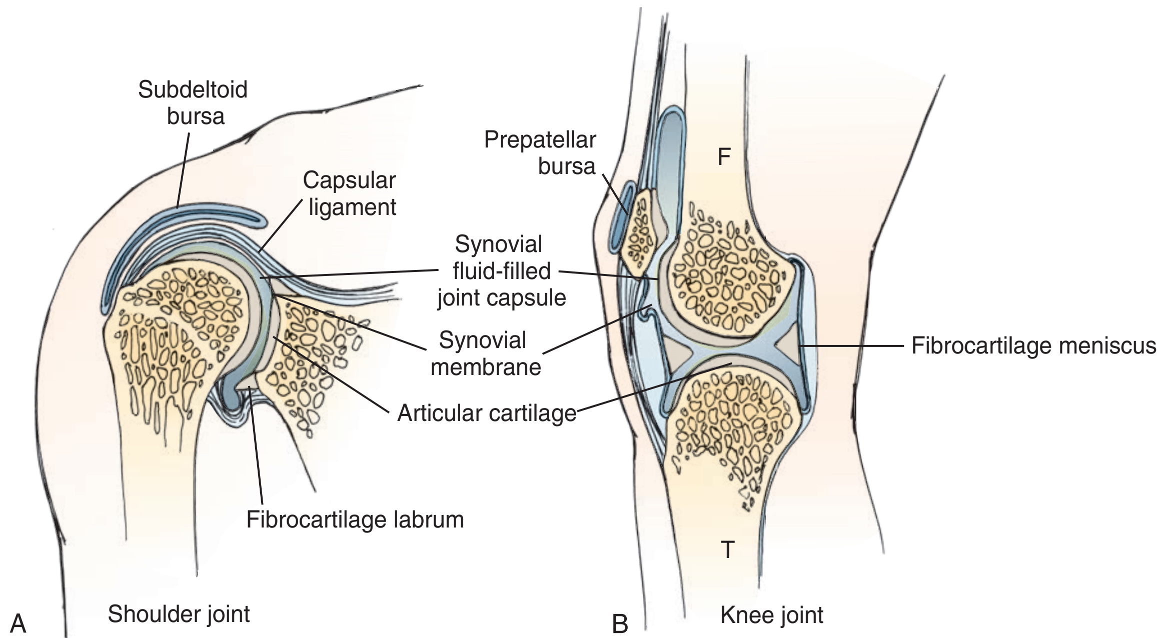

Figure 1-16. A. Typical synovial joint. **B.** Knee joint showing the fibrocartilage meniscus and bursae, which are additional features of a synovial joint.

- **Function:**
  - ☐ The outer layer helps to stabilize the joint, helps to guide joint motion, and prevents excessive motion. It is innervated with a rich supply of nerves, including mechanoreceptors and pain fibers. The mechanoreceptors sense the rate and speed of motion, position sense (proprioception), and have reflex connections to the muscles (see "Innervation" below). Irritation or injury to the capsule can create muscle contractions, designed to protect the joint.
  - ☐ The inner layer of the joint capsule is a synovial membrane that secretes synovial fluid when it is stimulated by joint motion. Maintaining joint motion is critical, because the joint dries out and degenerates if it is not moved.
- **Dysfunction and injury:**
  - ☐ **Outer fibrous layer:** Injury to the joint capsule may result from acute trauma or repetitive stress. Fibrosis or thickening of the joint capsule is caused by an increased production of collagen and by a decrease in ground substance. It occurs in three conditions: acute inflammation, chronic irritation or inflammation caused by repetitive stresses or imbalanced forces moving through the joint, and immobilization.[46] A tight, fibrotic joint capsule results in abnormal movement between the joint surfaces, leading to excessive compression in certain areas of the cartilage and to accelerated degeneration of the joint. The capsule and supporting ligaments may also be excessively stretched because of injury. If there is a loss of adequate motion owing to immobilization, the fibrous layer of the joint capsule atrophies because of a loss of collagen. This creates joint instability.
  - ☐ **Inner synovial layer:** The synovial membrane can become injured or dysfunctional because of acute trauma to the joint, cumulative stresses from chronic irritation caused by imbalanced forces moving through the joint, or immobilization. Joint swelling occurs during inflammation. The swelling typically causes abnormal muscle function controlling the joint. Immobilization, on the other hand, thickens the synovial fluid with disuse and causes an eventual decrease in the amount of synovial fluid. This leads to adhesions between the capsule and the articular cartilage, tendon sheaths, and bursae, contributing to stiffness and consequent degeneration in the joint.
- **Treatment implications:**
  - ☐ **For outer fibrous layer:** The initial treatment goal for acute injury to the capsule is to help manage the inflammation by reducing the swelling. Gentle, low force CR and RI MET and gentle, pain-free passive motion are used to pump the swelling out of the joint and promote the circulation of cells, oxygen, and nutrition and the removal of waste products. Gentle STM is begun immediately to help realign the healing fibers and to prevent adhesions. For chronic conditions, PIR MET is performed on the muscles of

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the associated joint. As the muscle's fascia interweaves with the joint capsule at the tenoperiosteal junction, isometric muscle contractions pull on the capsule and increase its extensibility. STM and joint mobilization are used to reduce adhesions. The massage strokes are directed in all directions, owing to the irregular alignment of the collagen. This stroke process is analogous to removing a tuck from a sheet: You spread it in all directions to smooth it out.

- PIR MET is performed to help restore length in the shortened capsule. Because myofascia interweaves with the joint capsule, a lengthening response of the capsule can be induced with muscle contractions. This has proved very effective clinically. For example, osteoarthritis of the hip is associated with loss of internal rotation due to shortening of the joint capsule. By performing MET to increase internal rotation, the capsule is lengthened, and the range of motion is improved, often with dramatic functional improvement.
- **For an atrophied or excessively stretched capsule:** A capsule that is too loose needs exercise rehabilitation to help lay down new collagen fibers, restore normal length, and stimulate the synthesis of chondrocytes and synviocytes and needs coordination and proprioception exercises to help restore neurological function.
- **For an acute, swollen synovial layer:** A swollen capsule is called *synovitis* and is treated with CR MET to use the muscle contractions to help pump the excess fluid out of the capsule. Pain-free, passive range of motion is also used in the flexion-extension plane to act as a mechanical pump. If there is too little fluid in the joint, the MET and passive mobilizations of the joint help to stimulate the synovial membrane, increasing synovial fluid and therefore increasing lubrication and nutrition in the joint. STM is used to disperse the excess fluid.

Ligaments

Dense connective tissue surrounds every joint and is called **periarticular soft tissue**. It is composed of fascia, periosteum, tendons, the external layer of the capsule, and ligaments. *Extrinsic ligaments* lie over the joint capsule and attach to the bones that form the joint, and *intrinsic ligaments* (capsular ligaments) are thickenings of the joint capsule. The ligaments are fully described in "Connective Tissue" above.

Cartilage

- **Definition:** Cartilage is a dense, fibrous connective tissue composed of collagen, ground substance, a high percentage of water, and chondrocytes or cartilage cells. Synovial joints have two types of cartilage: articular or hyaline cartilage and fibrocartilage.

Articular Cartilage (Hyaline Cartilage)

- **Structure:** Articular cartilage is composed of cells, including chondrocytes and fibroblasts, and extracellular matrix, including collagen and ground substance. Articular cartilage is 70% to 80% water. Cartilage has no nerve or blood supply. The subchondral bone (the bone under the cartilage) also provides oxygen and nutrition through blood vessels.
- **Function:** Hyaline or articular cartilage covers the ends of bones and provides a smooth gliding surface for opposing joint surfaces. It also distributes loads and protects the underlying bone. It is elastic and porous and functions like a sponge, in that it has the capacity to absorb and bind synovial fluid. Intermittent compression and decompression creates a pumping action, which causes the movement of synovial fluid in and out of the cartilage. Cartilage is self-lubricating as long as it moves. As in other connective tissues, water plays a significant role in normal function. It is a medium for nutritional exchange and for lubrication and gives cartilage its rigidity to resist compressive forces. Water is also a medium for carrying mechanical, electrical, and electromagnetic energy. Even though cartilage has no nerve or blood supply, the chondrocytes and matrix of collagen and water are very sensitive to mechanical stimuli and act as mechanical signal transducers.[5] With a mechanical stimulus, such as the compression to the cartilage during walking, the stimulus is transformed (transduced) from a mechanical signal to chemical, electrical, and electromagnetic signals. With stimulation, cells synthesize new cells and matrix to maintain and repair the cartilage, whereas with immobilization and disuse, the cells and matrix atrophy and deteriorate.[47]

  There are three normal ways in which the synovial joint goes through cycles of compression and decompression: locomotion (walking, running), intermittent contraction of the muscles, and twisting and untwisting of the joint capsule.[48]

Fibrocartilage

- **Structure:** Consists of dense, white fibrous connective tissue, mostly collagen, arranged in dense bundles or layered sheets with chondrocytes, glycoaminoglycans, and about 70% to 80% water. It is innervated only at the periphery and has a rich blood supply at the outer portion where it attaches

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to ligaments and joint capsule. Nutrition is largely dependent on diffusion through the synovial fluid created by movement. As in articular cartilage, the subchondral bone (the bone under the cartilage) also provides oxygen and nutrition through blood vessels.

- **Function:** The fibrocartilage absorbs shock, lubricates the joint, distributes load, and stabilizes the joint. It has great tensile strength combined with considerable elasticity. Fibrocartilage deepens a joint space, such as the cartilage labrum or lip of the hip and shoulder; allows two bones to fit together better, such as the menisci of the knee; acts as a shock absorber, such as the intervertebral discs of the spine; and lines body grooves for tendons, such as in the bicipital groove for the long head of biceps.

- **Dysfunction and injury:** Damage to cartilage may be caused by many factors: acute trauma; cumulative stresses, either dynamic stresses, such as running, or static stresses, such as prolonged standing; obesity; immobilization; joint instability; or abnormal forces moving through the joint. Acute blunt trauma, such as falling on the knees, can damage the articular cartilage even without fracture. It is akin to a "bruise" with swelling of the cartilage and pain. The internal structure is disrupted; and without proper rehabilitation, the joint can degenerate, becoming stiff and painful, a condition called *post-traumatic arthritis*.[48] Abnormal forces are often the result of imbalances in the muscles surrounding the joint, a tight joint capsule, or joint instability due to atrophied ligaments and capsular tissues. A tight capsule creates a high-contact area in the cartilage and decreased lubrication. Imbalanced muscles create altered weight distribution through the joint, causing excessive pressures on the cartilage and fatigue in the cartilage. Atrophied ligaments and capsular tissues allow excessive joint motion, causing abrasion of the cartilage. The highly vascular synovial tissue responds with inflammation, leading to swelling and pain. Because there is a blood supply in the outer third of the cartilage, repair can occur in this region through the normal inflammatory response. But the inner portion of cartilage lacks blood vessels, and damage does not initiate an inflammatory response as is the case for other musculoskeletal tissues. The cartilage degenerates, beginning with fracturing of the collagen fibers (fibrillation) and depletion of the ground substance. The cartilage then develops cracks and loses its shock absorbing function. Eventually, it wears down, and the capsule become thickened and dried out. **Osteoarthritis** is degeneration of the cartilage of a joint.

- **Treatment implications:** It has been assumed that cartilage cannot repair itself, but as Hertling and Kessler[18] point out, recent studies show that cartilage cells (chondrocytes) can stay active and lay down new cartilage and that arthritis is "somewhat reversible if managed correctly." The joint must be moved to stimulate the synthesis of chondrocytes and the secretion of synovial fluid. Joint mobilization in flexion and extension pumps synovial fluid into and out of the joint. Rhythmic oscillations and MET wind and unwind the joint capsule to pump the fluid into and out of the cartilage, rehydrating the cartilage. During STM, we wind and unwind the joint capsule and compress and decompress the area we are working on to promote fluid exchange.

Bursa

- **Structure:** Bursae are synovial-filled sacs lined with a synovial membrane that are found in areas of increased friction. Examples include the subdeltoid bursa between the deltoid muscle and the acromion process and the trochanteric bursa on the side of the hip. There are over 150 bursae in the body.

- **Function:** The function of a bursa is to secrete synovial fluid between muscles, tendons, and bones, which decreases friction.

- **Dysfunction and injury:** A bursa is susceptible to acute trauma or repetitive stress. Bursitis is typically caused by excessive friction between the muscles, tendons, and fascia, the bursa, and the bones that lie underneath. Because there are pressure receptors in the bursa, a swollen bursa can be extremely painful. A chronic bursa can remain swollen or dry out, creating adhesions within the sac. In acute bursitis, symptoms appear suddenly. There is deep, throbbing pain, and the person has difficulty moving the affected joint. Chronic bursitis manifests as pain and limited active movement and also as painful passive motion.

- **Treatment implications:** Lauren Berry, RPT, contributed an effective treatment for bursitis. The method involves a gentle, slow, continuous stroke over the bursa to help massage the excess fluid out. If a bursa has dried out, the same strokes are applied more deeply to help stimulate the synovial membrane to secrete fluid.

Innervation of the Joints

- **Structure:** Embedded within the joint capsule, ligaments, and periosteum surrounding each joint are specialized sensory nerves called *mechanoreceptors*,

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which transduce or transform mechanical stimuli into electrical, electromagnetic, and chemical signals. They are named *Ruffini endings*, *Pacinian corpuscles*, *Golgi organ-like receptors*, and *free nerve endings*.[49] They can be categorized into four types:[41]

- **Type I:** Type I receptors, also called *Ruffini endings*, are mechanoreceptors that provide information concerning the static and dynamic position of the joint. They are sensitive to tension or stretch on ligaments and capsule, including stretch due to swelling. They have a very low threshold, so they respond to very small increases in tension.[30] Type I receptors are located in the superficial layers of the joint capsule and in ligaments.
- **Type II:** Type II receptors, also called *Pacinian corpuscles*, are dynamic mechanoreceptors that provide information on acceleration and deceleration of movement. They are sensitive to changes in joint position and to compression of the joint capsule. Type II receptors are found in the deep layers of the fibrous joint capsule.
- **Type III:** Type III receptors, also known as *Golgi-type receptors*, are dynamic mechanoreceptors monitoring the direction of movement, are sensitive to mechanical stress and have reflex effects on muscle tone to provide a "breaking effect." They respond only when high tensions are generated. Type III receptors are found in the intrinsic and extrinsic joint ligaments.
- **Type IV:** Type IV receptors are free-nerve endings that serve as pain receptors (nociceptors) when the tissue surrounding the joint senses excessive mechanical stress, when the tissue is irritated by inflammatory chemicals, or when the nerve is damaged. Nociceptors are inactive under normal conditions. They have increased sensitivity and fire more easily when the joint is inflamed or swollen. Type IV receptors are found in capsules, ligaments, and periosteum.

Function: Sensory nerves innervating the ligaments, capsule, and periosteum surrounding the joint convey instantaneous information on the functional status of the joint to the surrounding muscles. They also communicate automatically with the central nervous system. The functions of the sensory nerves are as follows:

- Control posture, coordination, and balance.
- Control the direction and speed of movement.
- Give information about the position of the joint and body image.
- Report pain in the joint when the joint is irritated or inflamed.
- Provide instantaneous reflex control of the muscles surrounding the joint. This is called the **arthrokinetic reflex**.[40] The arthrokinetic reflex facilitates (strengthens) or inhibits muscles and coordinates agonists, antagonists, and synergists around the joint for posture, movement, reflexive guarding, and fine muscular control. Joint stability is dependent on the normal function of the mechanoreceptors.

Dysfunction and Injury of Joint Receptors

- Musculoskeletal injuries can lead to swelling or damage to the mechanoreceptors, which decreases arthrokinetic reflex activity. This leads to decreased proprioception (position sense); balance disturbances; abnormalities in posture, muscle coordination, and movement control; loss of fine motor control; slowed reaction times; altered movement patterns; altered muscle firing patterns; and muscle weakness. Pain from injury also causes some muscles to become weak (inhibited) and other muscles to become short and tight (facilitated) in predictable patterns. As was mentioned previously, Janda and colleagues[40] have described these patterns of muscle dysfunctions (see "Muscle Dysfunction"). Each chapter in this text will describe the patterns for each joint.
- Chronic dysfunction of the mechanoreceptors from adhesions (prior injury), immobilization, aging, or deconditioning can lead to mechanoreceptor atrophy.[49] If the dysfunction in sensory nerve function is not rehabilitated, it can lead to muscle atrophy, instability, and recurrent injuries and can contribute to degeneration of the joint.[16]
- Irritation of the pain receptors and mechanoreceptors typically causes the flexors of the joint to become facilitated or hypertonic and the extensors of the joint to become inhibited or weak.[50]

Treatment implications: Neuromuscular reeducation is also called sensory-motor rehabilitation and describes therapy to improve functional communication between the nervous system and the muscles and periarticular soft tissue. STM, joint mobilization, and MET stimulate mechanoreceptors and improve their function.[30] The clinical effects of sensorimotor rehabilitation are as follows: It induces muscle relaxation, increases muscle strength, improves posture (proprioception), improves muscle firing patterns and movement (kinesthesia), decreases pain, and increases range of motion.[30] Because MET is performed using the focused attention of the client, the higher brain centers are engaged, which helps to establish better communication from the central nervous system to the muscles and articular nerves. MET also provides feedback and guidance from the therapist that improves proprioception. Balance training is recommended not only for injuries to the lower extremeties, but also for injuries to the lumbosacral spine.

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JOINT MOVEMENT: FUNCTION, DYSFUNCTION, AND TREATMENT

JOINT STABILITY AND MOVEMENT

- For a joint to perform a full and painless range of motion, it must be stable. Otherwise, abnormal forces move through the joint, leading to excessive wear and tear on the articular surfaces. This stability is determined by several factors:
  - The **shape of the bones** that make up the joint affect stability. The hip joint sits deeply within the socket (acetabulum) of the pelvis; therefore, it is much more stable than is the glenohumeral joint of the shoulder, because the fossa of the glenoid cavity is shallow.
  - **Passive stability** is provided by the ligaments and joint capsule. Because the ligaments and joint capsule do not have contractile fibers, their role is passive.
  - **Dynamic stability** is provided by the muscles. As has been mentioned, it is important for the muscles that cross a joint to be balanced, or the forces that move through the joint will create uneven stresses, leading to dysfunction and eventual degeneration of the cartilage.

NORMAL JOINT MOVEMENTS

- Movement of the body can be described as movement between the two bones, called *osteokinematics*, or between the joint surfaces, called *arthrokinematics*. Elevation of the arm describes the motion of the humerus relative to the glenoid fossa, an osteokinematic movement. During elevation, the head of the humerus is rolling and sliding on the glenoid fossa, an arthrokinematic movement. The three fundamental motions between joint surfaces are roll, slide, and spin.[22]
- Normal joint movements open and close the joint surfaces, which wind and unwind the joint capsule and ligaments, keeping the ligaments and joint in a relatively open and relaxed position, or creating compression of the joint surfaces and tightening the capsule. Most of the manual therapy that is described in this text is performed with the joint in the open or resting position, so it is important for the therapist to know when a joint is in the open or closed position.
  - When a joint is in the **close-packed position,** the joint surfaces are most compressed, and the joint capsule and ligaments are tightest.
  - When a joint is in the **loose (open)-packed position,** the joint is most open, and the joint capsule and ligaments are somewhat lax. Generally, extension closes the joint, and flexion opens the joint surfaces.
- John Mennell, MD,[51] has introduced the concept of **joint play,** which describes arthrokinematic movements that can be produced passively (i.e., by the therapist) but not voluntarily. In most joint positions, a joint has some "play" that is essential for normal joint function. For example, you can move the distal part of your index finger from side to side, a movement that cannot be accomplished actively.
- Arthrokinematic movements are also called **accessory movements**, and are essential for normal range of motion. As discussed below, an essential goal of joint mobilization is to restore passive, accessory joint motion (joint play).

JOINT DYSFUNCTION

- Mennell[51] also introduced the concept of **joint dysfunction** as a cause of pain and disability. He defines *joint dysfunction* as "a loss of joint play movements." This definition is the same as the chiropractic concept of **joint fixation.** Joint dysfunction has many causes, but may be divided into two broad categories:
  - From within the joint, including intra-articular adhesions, roughened surfaces of the joint cartilage, meniscoidal entrapment in the facet joints of the spine, and degenerative joint disease.
  - From the surrounding soft tissue, including adhesions or shortening of the joint capsule or ligaments (periarticular adhesions), sustained muscle contraction, strength/weakness imbalances of the muscles crossing the joint, and abnormal firing patterns of the muscles moving the joint. Korr[52] hypothesized that sustained muscle contraction could be the major factor in decreased mobility of the dysfunctioning joint.
- **Treatment implications:** Therapists need to be able to distinguish between pain and dysfunction arising from within the joint and pain and dysfunction arising from the surrounding soft tissue. For dysfunction that arises within the joint, MET and joint mobilization are performed (see below). For soft tissue restrictions surrounding the joint, STM and MET are applied. Short and tight muscles must be lengthened and relaxed, and muscles that are weak and inhibited need to be reeducated to regain their normal firing pattern and strength. Muscles cannot be restored to normal if the joints they move are restricted, and the joints will not regain their normal movement characteristics if the muscles that move the joint are not relaxed and strong and if the

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ligaments and joint capsule are not normalized. It is important to realize that a joint can have too much play, owing to a loss of stability in the ligaments or muscles. These conditions are treated with exercise rehabilitation to strengthen and stabilize the area.

JOINT DEGENERATION

- Joint degeneration refers to the degeneration of the cartilage but affects all of the structures of the joint, including the capsule, ligaments, muscles, blood vessels, and nerves. The fibrous capsule, ligaments, and synovium become thickened, leading to capsular tightness. Muscles become either inhibited (weakened) or facilitated (hypertonic), and blood vessels and sensory nerves atrophy. Degeneration is caused by trauma; cumulative stress, including joint dysfunction and posture; and muscular and movement imbalances.
- Most conditions that are called *arthritis* are in fact noninflammatory and should be referred to as **arthrosis**, meaning "joint degeneration." The terms *osteoarthritis* and *degenerative joint disease* are typically used interchangeably to describe a chronic degeneration of a joint.
- One common cause of joint degeneration is joint dysfunction, a loss of normal movement of the joint. This altered movement can occur as a result of a prior trauma or cumulative stress on the joint, leading to restrictions within the joint, or from the surrounding soft tissue, described above.
- **Treatment implications:** Therapists can improve the function of most cases of joint degeneration. The primary goals of treatment are to rehydrate the cartilage, lengthen capsular tissues, reduce excessive muscular tension, facilitate inhibited muscles, and improve function of the sensory nerves. STM is performed to dissolve adhesions, and MET is used to lengthen capsular tissues, wind and unwind the capsule to stimulate the movement of synovial fluid within the joint, and improve the range of motion. Joint mobilization is used to remove restrictive barriers within the joint to improve accessory motion. Clients with degenerated joints need instruction in exercises to improve muscle strength and balance.

JOINT MOBILIZATION

- **Definition:** Joint mobilization is any form of passive movement at a joint.[18] Passive mobilization techniques are graded from I to IV and are usually performed as rhythmic oscillations. These movements are within the scope of practice for the massage therapist. Grade V is a high-velocity, low-amplitude thrust and is not within the scope of the massage therapist. The grades of joint mobilization are:[53]
  - ☐ **Grade I:** Small-amplitude rhythmic oscillations performed at the beginning of the range.
  - ☐ **Grade II:** Large-amplitude rhythmic oscillations perfomed within the free range and not moving into any resistance.
  - ☐ **Grade III:** Large-amplitude rhythmic oscillations perfomed up to the limit of the range and into tissue resistance.
  - ☐ **Grade IV:** Small-amplitude rhythmic oscillations performed at the limit of the range and into tissue resistance.
  - ☐ **Grade V:** A small amplitude, high-velocity thrust.
- **The goals of joint mobilization are as follows:**
  - ☐ To restore the normal joint play. Accessory motion must be normalized to allow for full range of motion and to prevent degeneration.
  - ☐ To promote the exchange of cells and fluids in and out of the joint to promote joint repair and regeneration.
  - ☐ To stimulate normal lubrication in the joint by stimulating the synovial membrane and promoting rehydration of the articular cartilage.
  - ☐ To normalize neurological function by firing type III joint receptors and GTOs, resulting in a relaxation of the muscles surrounding the joint[54] (see "The Nervous System").
  - ☐ To decrease swelling, which can cause pain, decreased motion, and tissue stagnation.
  - ☐ To reduce pain. Mechanoreceptor stimulation overrides pain information in the brain, and studies suggests that joint mobilization in pain-free ranges can have an analgesic effect.[30]

THE NERVOUS SYSTEM

GENERAL OVERVIEW

The nervous system could be described as having two parallel and distinct systems: the connective tissue–water system, which carries electric and electromagnetic waves, and the "classic" nervous system, which carries chemical (ionic) currents.[10] As was described previously, the new paradigm in biology proposes that the electromagnetic signals are the primary way in which the cells communicate and control biochemical reactions. We have previously described the connective tissue–water "nervous system"; we will now discuss the "classic" nervous system.

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The nervous system is anatomically and functionally connected throughout the entire body, but it can be structurally divided into the central nervous system and the peripheral nervous system and can be functionally divided into the somatic nervous system and the autonomic nervous system.[34] Massage and manual therapy affect every part of the nervous system, thus inducing profound changes in every other system in the body. One guiding principle of this method of therapy is that *it is essential that the treatment promote relaxation*, even though areas of pain and disability are being treated. By focusing on relaxation during treatment, the therapist creates positive systemic changes by lowering blood pressure, reducing stress, and promoting the repair and rejuvenation functions of the nervous system. For clients who present with pain and disability in the musculoskeletal system, treatment is focused on the somatic nervous system (see below) (Fig. 1-17).

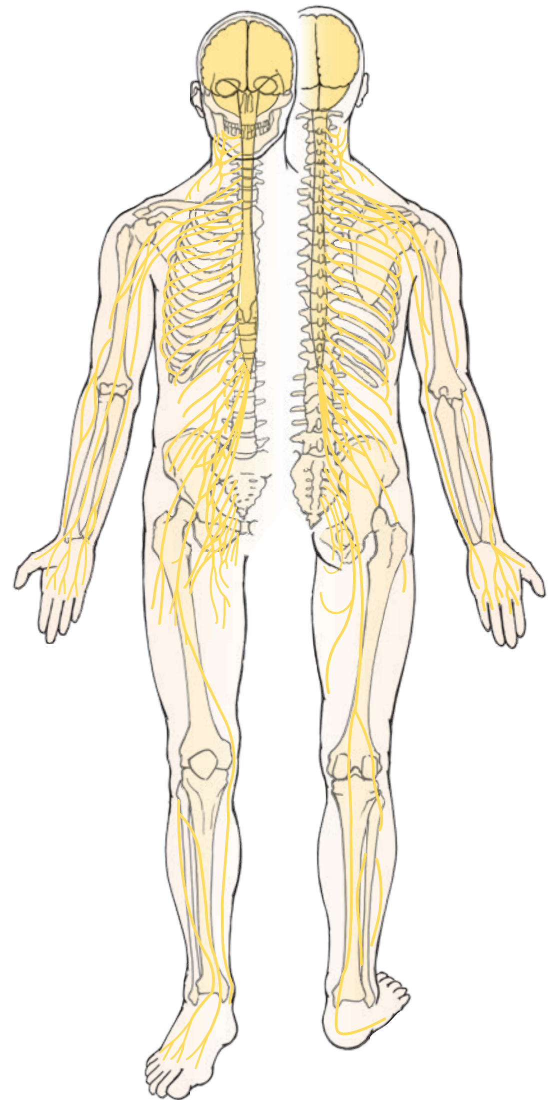

Figure 1-17. Overview of the somatic or motor nervous system, which includes the central nervous system and the peripheral nervous system. The central nervous system includes the brain and spinal cord, and the peripheral nervous system includes the cranial nerves (not shown) and the 31 pairs of spinal nerves that extend into the arms and legs. **Left.** Anterior view. **Right.** Posterior view.

CENTRAL NERVOUS SYSTEM

The central nervous system consists of the brain and spinal cord.

The Brain

- **Structure and function:** The brain has 100 billion neurons, each of which has 10,000 to 15,000 connections (synapses). Three million synapses can fit on a pinhead![55] The brain is divided into three sections: the cerebrum, brainstem, and cerebellum.
  - ☐ The cerebrum is the largest portion and the most recently developed part of the brain. It is responsible for higher mental functions, such as thinking, learning, and personality. The frontal lobe area of the cerebrum also contains the **motor cortex,** which controls voluntary movements.
  - ☐ Another area of the cerebrum, the parietal lobe, contains the **sensory cortex,** which receives information about touch and proprioception. Some proprioceptive signals, however, go only to the spinal cord.
  - ☐ The limbic system and hypothalamus integrate emotional states, visceral responses, and the muscular system.[16] Emotions can alter muscular tone. States of anxiety create sustained increased tone (hypertonicity), and depression creates loss of muscle tone (hypotonicity).
  - ☐ The brainstem is the center for the automatic control of respiration, heart rate, posture, balance, and many automatic movements of the body.
  - ☐ The cerebellum functions to control muscle coordination, muscle tone, and posture.

The Spinal Cord

- **Structure and function:** The spinal cord is a continuation of the medulla portion of the brain and travels within the vertebral canal from the opening in the skull, called the *foramen magnum*, to the lumbar spine. After the cord ends at approximately the second lumbar vertebra, it continues as a collection of nerve roots called the *cauda equina*.
  - ☐ The spinal cord is divided into gray matter, which contains the neuron cell bodies, and white matter, which contains the nerve fibers. One portion of the cord receives information

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from the sensory receptors, and another portion transmits motor information from the muscles. An interneuron communicates and amplifies information between the sensory and motor portions of the cord.

- ☐ A reflex arc is the simplest communication between the sensory and the motor nerves. The classic example is the deep tendon reflex that occurs when you tap the quadriceps tendon. When the tendon is tapped, the quadriceps automatically contracts. However, information from all four classes of sensory receptors—the mechanoreceptors, proprioceptors, thermoreceptors, and nociceptors—unconsciously send information to the cord, which stimulates countless automatic (reflexive) adjustments in the muscular system. Irritation of the sensory receptors can cause reflexive hypertonicity or reflexive inhibition (weakness) in the muscles (Fig. 1-18).
- ☐ The spinal cord becomes individual spinal nerves as they exit the vertebral column through openings between the sides of the vertebra called the intervertebral foramen. (See Chapters 3 to 5 for more information on the spinal nerves.)

■ **Dysfunction and injury:** When a person is under excessive or ongoing stress, the central nervous system may send unconscious signals to the muscular system, causing sustained muscular contraction. It is a common clinical experience that a client who is under chronic stress has habitually contracted muscles without any awareness that those muscles are tight. This condition is commonly experienced in the upper trapezius. When the therapist touches this muscle, the client is often surprised that it is tight and tender. Unconscious hypertonicity represents a loss of sensory awareness.

- ☐ Another common clinical experience is to find that the client has lost the ability to voluntarily contract a muscle that is held in an involuntary contraction. The therapist asks the client to contract a muscle against resistance, and the client is unaware of how to engage that muscle. These conditions describe what Thomas Hanna[56] calls "sensory motor amnesia."
- ☐ The muscles may be held in sustained tension because of overuse, poor posture, or psychological or emotional stress. States of anxiety and anger, for example, can create sustained muscular hypertonicity. Emotional stress, such as depression, can also create a decrease in muscular tone and a loss of sensory motor communication.

■ **Treatment implications:**

- ☐ MET is used to bring sensory awareness to the muscles, guiding the client to feel the muscles working. MET also educates the client to bring conscious awareness to the muscles through voluntary contraction. Using the higher brain by having the client actively participate in muscle movement through MET can alter unconscious habits of muscle tension and help normalize muscle function. Facilitating sensory-motor integration helps to correct sensory-motor amnesia.
- ☐ Studies show that stroking an animal's back stimulates the limbic system and leads to muscular

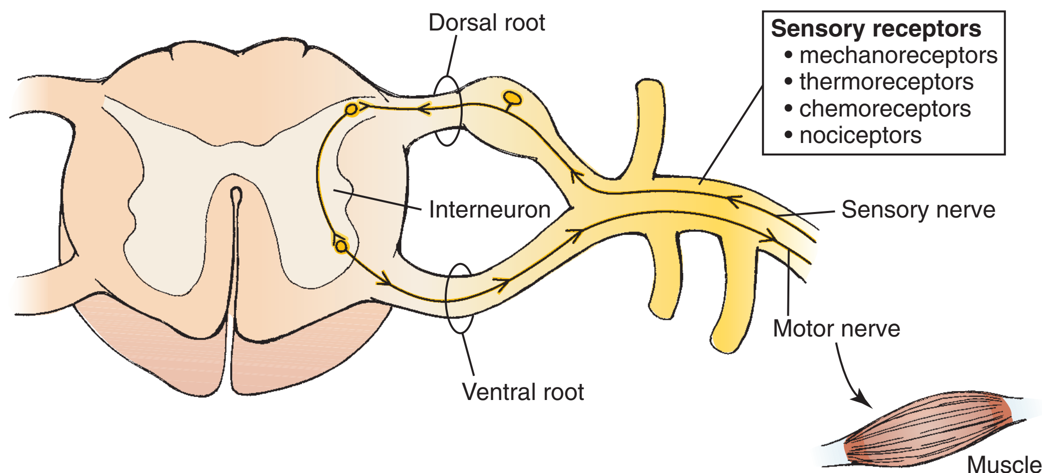

Figure 1-18. Reflex arc. The afferent or sensory nerves receive information from four broad classes of receptors: mechanoreceptors, proprioceptors, chemoreceptors, and nociceptors (pain receptors). The information is sent to the spinal cord and stimulates an interneuron and then the efferent or motor nerves. One motor nerve, the alpha nerve, innervates the extrafusal muscle fiber. Sustained sensory stimulation from mechanical irritation (muscle or joint dysfunction), injury, or emotional tension can create increased alpha stimulation and reflex muscle hypertonicity or inhibit the alpha nerve activity and cause muscle inhibition and weakness.

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relaxation.[16] Massage can calm anxiety, and MET can engage the muscles to increase their tone in depressed clients.

- Because the brain can alter muscle function, it is important that the therapist give the client an image of healing. To create a positive image of healing, you might say, "I think you will feel a lot better after your massage" if this is a reasonable possibility. This principle of treatment is discussed in Chapter 2.

PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system consists of 12 pairs of cranial nerves and 31 pairs of spinal nerves that convey information from the central nervous system to muscles, joints, skin, and sense organs and from sensory receptors in those same structures back to the spinal cord and brain.

- **Structure:** The structure of a peripheral nerve is similar to that of tendons and muscles and consists of long parallel fibers, arranged in bundles called fascicles (Fig. 1-19). The nerves are fluid-filled cells with three connective tissue coverings: the epineurium, perineurium, and endoneurium. Unlike tough electrical wires, they are soft structures that can be injured by compression, excessive stretching (tethering), and mechanical irritation.
  - The nerves are lubricated, and the fibers, fascicles, and gross nerves are designed to slide within the connective tissue spaces. When a muscle contracts and a joint moves, the nerve slides in the healthy state.
  - The spinal nerves begin from expansions of the spinal cord that form two nerve roots: the motor (anterior) root and the sensory (posterior) root. All sensory nerves merge at the dorsal root ganglion, where they are processed. See Chapter 3 for further discussion.
- **Function:** The spinal and cranial nerves of the peripheral nervous system have four main functional divisions.
  - **Somatic sensory nerves (afferent):** There are four types of somatic sensory nerves: mechanoreceptors, thermoreceptors, chemoreceptors, and nociceptors. See "Somatic Nervous System" below for further discussion.
  - **Somatic motor nerves (efferent):** The somatic motor nerves relay information from the brain, through the spinal cord, and then to the skeletal muscles.
  - **Visceral sensory:** These nerves are part of the autonomic nervous system and send pain and pressure information from the internal organs to the central nervous system (see "Autonomic Nervous System" below).
  - **Visceral motor:** The visceral motor nerves transmit impulses from the autonomic nervous system to the involuntary muscles, such as those found in internal organs and glandular tissue.

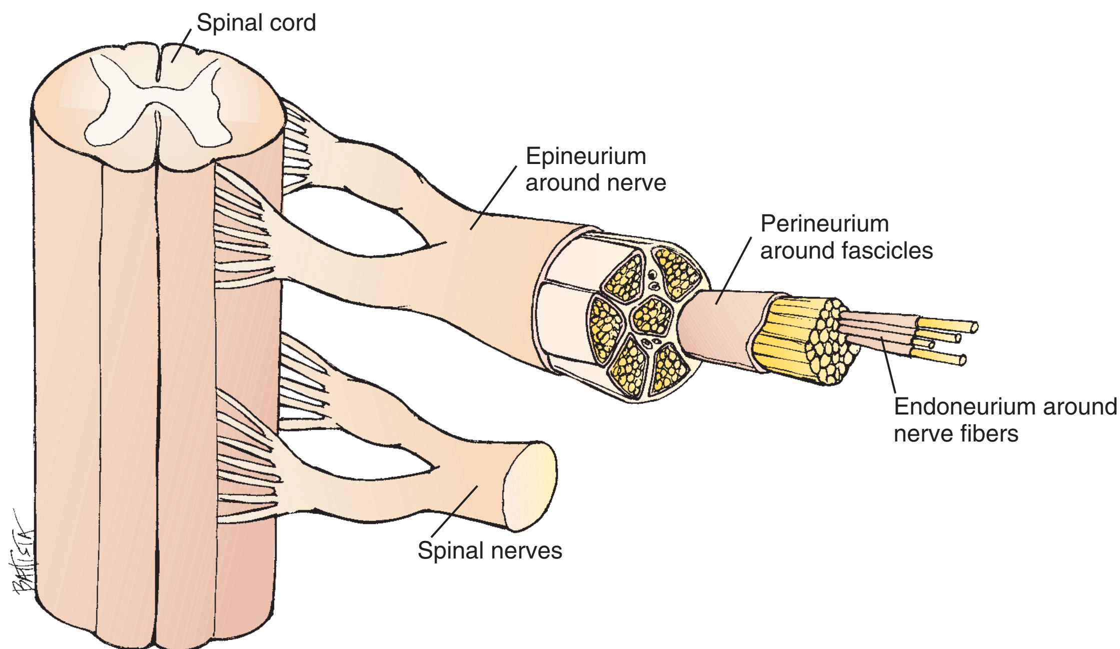

Figure 1-19. Peripheral nerve anatomy. The peripheral nerves begin as 31 pairs of spinal nerves, which then travel throughout the body. They are structured similarly to tendons, ligaments, and muscles, with long parallel fibers contained in bundles surrounded by connective tissue.

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- **Dysfunction and injury:** Information regarding dysfunction and injury to the sensory nerves was previously discussed in the sections entitled "Ligaments," "Tendons," "Muscles," and "Joint." In this section, we will describe how peripheral nerves can become entrapped as they travel through the extremities. The peripheral nerves are susceptible to irritation because of compression or tethering (pulling) at the nerve roots in the area of the intervertebral foramen. They are also susceptible to compression and irritation in the extremities:
  - Nerves can become restricted or entrapped by adhesions in the connective tissue spaces through which the nerves travel. This restriction prevents the normal gliding of the nerve.
  - Nerves can become restricted or entrapped in the connective tissue spaces of hypertonic muscles.
  - Nerves can become compressed in fibro-osseous tunnels such as the carpal tunnel.
  - Nerves can become compressed, restricted, or irritated because of compression from the swelling or inflammation caused by overuse or injury.
- **Treatment implication:** Peripheral nerves are strong and resilient,[34] and they can be gently massaged without damage. Lauren Berry, RPT, insisted that all massage strokes on the peripheral nerves should be transverse (perpendicular) to the line of the nerve. This releases the adhesions in the connective tissue of the nerve itself and also releases the adhesions in the loose connective tissue that suspends the nerve. This method has proved a safe and comfortable treatment with excellent clinical results. The treatment to decompress the area of the nerve roots of the spine is addressed in each of Chapters 3 to 5, and the manual release of peripheral entrapment of the nerves in the extremities is addressed in the subsequent chapters.

AUTONOMIC NERVOUS SYSTEM

- **Structure:** The autonomic nervous system is the part of the nervous system that innervates the heart, blood vessels, diaphragm, internal organs, and glands and influences every other part of the body, including the muscular system. It unconsciously, automatically regulates the heartbeat, respiration, digestion, and many other functions . Although it functions unconsciously. it is also affected by conscious awareness, such as consciously slowing the breath. There are two main divisions: the sympathetic and the parasympathetic.

Sympathetic Nervous System

- **Structure:** The cell bodies form a cord called the *sympathetic trunk*, which borders the vertebral column on both sides and extends from the base of the skull to the coccyx.
- **Function and dysfunction:** The sympathetic nervous system is responsible for the "fight-or-flight" response and is active when a person is under stress. It releases adrenaline into the blood, causes constriction of the peripheral blood vessels, increases the heart rate, and inhibits the normal movement of the intestines (peristalsis) so that blood is available to the skeletal muscles.[34] When a person is experiencing chronic stress or chronic pain, there is an increased level of adrenaline, which causes sustained tension in the muscles and magnifies pain signals from the nociceptors.[55]

Parasympathetic Nervous System

- **Structure:** The cell bodies are located in the cranial and sacral regions.
- **Function and dysfunction:** The parasympathetic nervous system is responsible for energy conservation, cellular rebuilding, and rejuvenation. It slows the body down and is active when the body is at rest and during recuperation. It decreases the heart rate, stimulates the normal movement of the intestines (peristalsis), and promotes the secretion of all digestive juices. A person can be in parasympathetic override, which would contribute to lethargy and loss of normal drives. Most people in Western cultures have an underactive parasympathetic nervous system and an overactive sympathetic nervous system.
- **Treatment implications:** The method of treatment described in this text is given in a relaxing, calm manner to stimulate a parasympathetic state. It can be described as a moving meditation. This induces a state of relaxation in the client and therapist and promotes the healing and rejuvenation functions of the parasympathetic nervous system. To induce a relaxing, parasympathetic treatment, the therapist needs to have soft hands and a calming voice. Although the STM strokes may be deep, the therapist's hands are kept soft, and the strokes are applied rhythmically so that the client can relax into the treatment. The therapist's emotions and attitudes also play a role in the relaxation of the client. Acceptance and support for the client enhance treatment outcome.

SOMATIC (SENSORIMOTOR) NERVOUS SYSTEM

- **Structure:** The somatic nervous system is composed of sensory and motor nerves that convey

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information back and forth between the skin, muscles, and joints and the spinal cord and brain.[34] The somatic senses are distinguished from the special senses of vision, hearing, taste, smell, and equilibrium. The sensory information enters the spinal cord and goes in two directions: (1) back to the muscles during unconscious, automatic activity, such as posture, and (2) to higher centers, including the brain, where sensory information is evaluated.[57] The motor part of the somatic nervous system innervates only skeletal muscles, controls both voluntary movement and reflexive movement, and contributes to dynamic joint stability, coordination, posture, and balance. There are two motor nerves: the alpha and gamma nerves. Sensory nerves relay information to the central nervous system from **four types of receptors**: *mechanoreceptors*, *thermoreceptors*, *chemoreceptors*, and *nociceptors*. Mechanoreceptors are specialized sensory receptors that convert physical stimulus into chemical, electrical, and electromagnetic energy. They convey proprioceptive information to the spinal cord and brain. Mechanoreceptors are located in the skin, muscles, tendons, and soft tissue surrounding the joints. These receptors are stimulated by some action, such as stretching, pressure, and contraction. In addition to providing information about joint position and movement, they transmit length and tension information from muscles and tendons. (See below for more information, and refer to the section, "Joint Structure and Function.") Thousands of impulses are processed each second.[49] Sensory information from the *somatic senses* concerns **four categories of information**: *touch, proprioception, temperature,* and *pain*.

- **Touch:** Mechanoreceptors are located in the superficial and deep layers of the skin and communicate light touch as well as deep pressure.
- **Proprioception:** There are multiple definitions of proprioception in the literature.[58] This text uses the term *proprioception* in the broader sense of awareness of body position and joint movement. The sense of proprioception comes from the mechanoreceptors and from the special sense of equilibrium.
- **Temperature:** Sensory nerves detect hot and cold (thermoreceptors).
- **Pain:** The sensation of pain comes from the brain, which decides whether information from specialized receptors called nociceptors is harmful or potentially harmful. There are three categories of nociception: thermal, chemical, and mechanical. This topic is discussed on page 48 ("Cause of Soft Tissue Pain").

SENSORY RECEPTORS (MECHANORECEPTORS) IN MUSCLE

- Muscles are highly innervated with sensory receptors, including pain fibers and mechanoreceptors. The two types of mechanoreceptors are **muscle spindles** and **GTOs**, which function as sensory organs. Information from the receptors has a profound influence on muscle activity (Fig. 1-20). They detect the length and tension in the muscle and tendon, and they set the resting tone of the muscle.

Muscle Spindles

- **Structure:** Muscle spindles are specialized muscle fibers called *intrafusal fibers*, located in a fluid-filled capsule embedded within each muscle. The body has about 25,000 to 30,000 muscle spindles, with about 4000 in each arm and 7000 in each leg.[49] Spindles respond to slow and rapid changes of muscle length and to deep pressure. Unlike other mechanoreceptors, muscle spindles contain both contractile and sensory elements.
- **Function:** Muscle spindles detect changes in muscle *length,* so stretching a muscle will increase the rate of discharge. The spindles play an essential role in joint position, coordination, balance, fine muscular control, and proprioception.[59] Muscle spindles also help to set the tone of a muscle. The more refined the function, the greater is the concentration of muscle spindles. The greatest concentration of spindles is found in the lumbrical muscles of the hand,[60] in the suboccipital muscles, and in the muscles that move the eyes.

Golgi Tendon Organs

- **Structure:** GTOs are sensory receptors in the form of a slender capsule located along the muscle fiber at the musculotendinous junction.
- **Function:** GTOs are sensitive to changes in muscle *tension.* Originally, they were thought to have only a protective function to prevent damage to a muscle being forcefully contracted. Current research, however, suggests that the GTOs fire during minute changes in muscle tension.[57] Even a single motor unit will discharge the GTO. With excessive tension in the muscle, the GTO stimulates nerves at the spinal cord, called *inhibitory interneurons*, causing the muscle to relax.[57] Inhibitory interneurons communicate through the spinal cord to the brainstem and therefore do not

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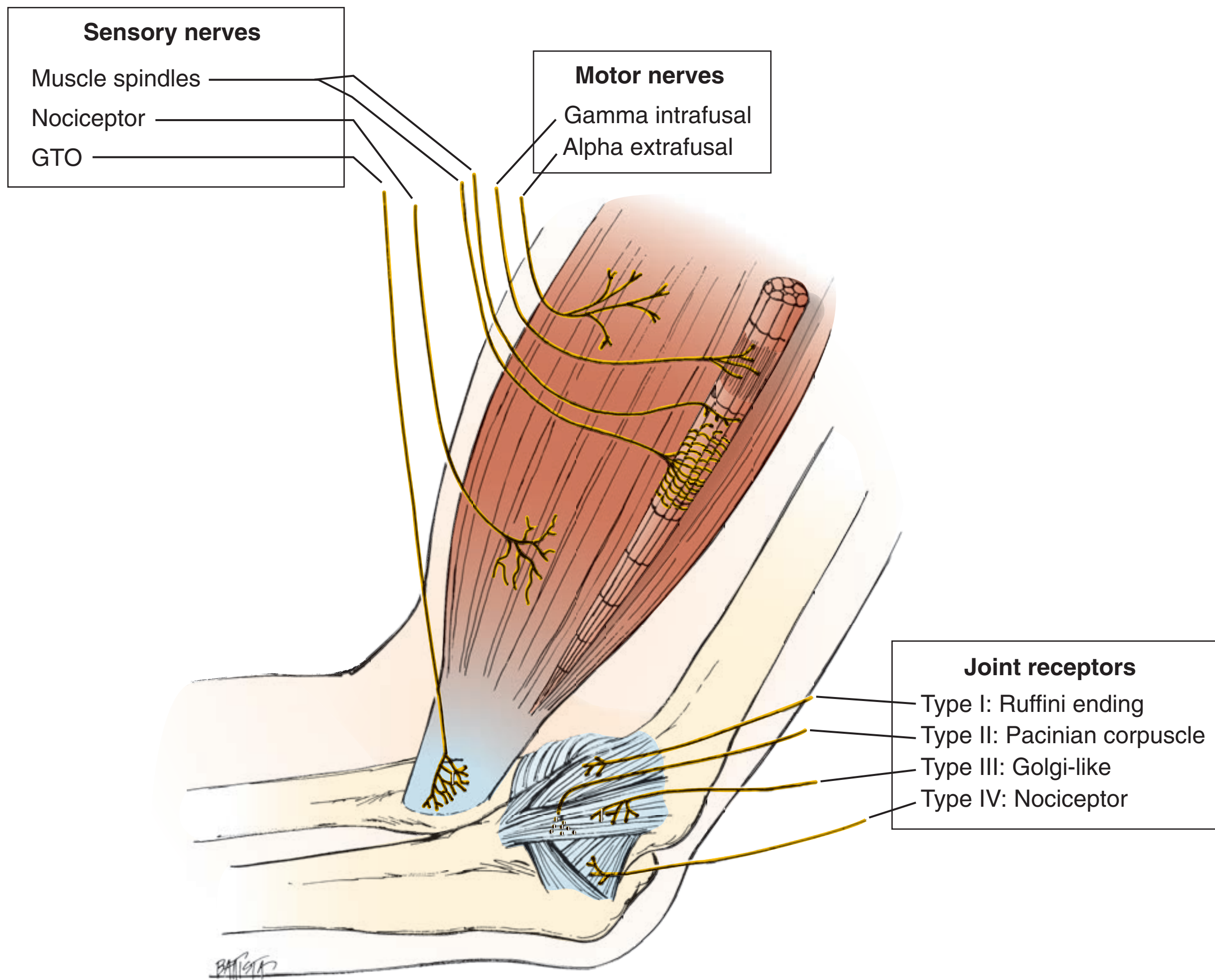

Figure 1-20. Muscle and joint receptors. The extrafusal muscle fibers are innervated by alpha motor neurons, and the intrafusal fibers (muscle spindles) are innervated by gamma motor neurons. There are three classes of sensory nerves in a muscle: the muscle spindle, GTO, and free nerve endings (nociceptors or pain fibers). Muscle spindles are sensitive to muscle length and changes in length, and the GTOs are sensitive to muscle tension. Spindle cells and GTOs also give proprioceptive information regarding position of the body. There are four classes of mechanoreceptors that innervate each joint.

reach conscious awareness. As with spindle cells, GTOs are essential for fine muscular control, because they equalize the contractile forces of agonists, antagonists and synergists. They help to adjust the tension in a muscle for joint stability, balance, and coordination. They also protect the muscle and joint through reflexes that contract or inhibit the muscle automatically. Through practice, these receptors help to adjust muscular tension to the appropriate amount in the countless activities of daily living.[19]

TWO TYPES OF MOTOR NERVES INNERVATE MUSCLES

- **Alpha motor neurons:** Originating in the motor cortex of the brain, alpha motor neurons innervate the contractile muscle fibers (extrafusal fibers). A single alpha nerve excites a group of muscles fibers called the *motor unit*. As few as three fibers form the motor unit for the lumbricals of the hand, and up to 1600 muscle fibers form the motor unit of the gastrocnemius. The alpha motor neurons convey nerve impulses to the muscles for all movements, including voluntary muscle contraction and unconscious muscle activity involved in posture, balance, and habitual movement.
- **Gamma motor neurons:** Originating in the brainstem, gamma motor neurons innervate the muscle spindle (intrafusal fibers). These nerves carry unconscious information from the central nervous system to the muscle that sets the tone of muscle and are responsible through voluntary muscle

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contraction for fine muscular control. The alpha and gamma nerves fire at the same time (coactivation) to agonists, antagonists, and synergists for smooth and coordinated muscle action.

- **Dysfunction and injury:** Musculoskeletal injuries generate pain through tissue damage, chemical irritation from inflammation, and ischemia due to swelling. Pain and swelling lead to alteration in the function of the mechanoreceptors, causing changes in muscle and joint function. The outcome is decreased proprioception (position sense), balance disturbances, abnormalities in posture, decreased coordination, loss of fine motor control, slower reaction times, altered movement patterns, altered muscle firing patterns, and muscle weakness.[49] Chronic muscle dysfunction from adhesions (prior injury), immobilization, aging, or deconditioning can lead to sensory receptor atrophy.[49] If the dysfunction in sensory nerve function is not rehabilitated, it can lead to joint instability and problems with balance and coordination, leading to recurrent injuries, and can contribute to degeneration of the joint.[16] States of anxiety or emotional or psychological tension can cause an increase in the firing rate of the spindle cells. This increase causes the muscle tone to be "set" too high, creating hypertonicity and stiffness.[52]
- **Treatment implications:**
  - Alterations in muscle activity after a painful injury do not necessarily return to normal even after the pain eventually resolves. Therefore, in the treatment of injuries and dysfunction of the sensory-motor system, it is essential for the therapist to focus on factors that improve proprioception, joint movement, muscle firing patterns, strength and stability, and sensory awareness. This neuromuscular reeducation is also called *sensory-motor rehabilitation* and involves therapy to improve the functional communication between the nervous system and the muscles.[49] Active participation of the client during treatment is much more effective for rehabilitation of the nervous system than is being passive.[16] Directing the client to concentrate during MET and bring focused attention and sensory awareness produces a reeducation of the central nervous system as well as rehabilitation of the motor and sensory nerves. Precise muscular contraction, which improves neuromuscular control, is an essential component of functional improvement.[48] It is important during MET for the therapist to provide feedback and guidance to the client to enhance proprioceptive reeducation.
  - The therapist's touch, pressure, and movement stimulate the somatic sensory nerves. Each touch and movement sends a message to the spinal cord and brain, which, in turn, communicate with every other part of the client's body, including the centers of the person's emotions and psychology. Working within the client's comfort zone and using a gentle touch and a calm voice are critical because this induces relaxation and trust and helps to heal the whole person, not just the local tissue.
  - Sustained muscle tension from injury or dysfunction indicates that the muscle spindles are set too high, like a thermostat set too high. There are two easy ways to decrease the firing rate of a spindle cell and therefore cause the muscle to relax. The first is to decrease the muscle length by bringing the origin and insertion toward each other. This method is emphasized in strain–counterstrain and positional-release techniques, which are incorporated into the STM described in this text. The second is to contract a muscle isometrically, as is done in MET. This technique causes the spindle activity to stop temporarily, allowing the muscle to be set to a new, more relaxed length.[61]

SENSITIZATION OF THE NERVOUS SYSTEM

- **Definition:** The term *sensitization* is used to describe the phenomenon in the nervous system in which there is an exaggerated response to normal stimuli. There are two principal causes:
  - The limbic areas of the brain can cause an emotional exaggeration of pain, which can trigger the central nervous system to cause the muscles to become either too tight or too loose. This emotional exaggeration is caused by many factors, including culture, family history, pain history, and individual psychology.
  - The other cause of sensitization happens at the level of the spinal cord. The area in the spinal cord that receives information about pain is next to the receptive field for movement (mechanoreceptors). Chronic inflammation can cause sensitization of the mechanoreceptors such that normal mechanical stimuli (e.g., movement of a joint within a normal range) cause the mechanoreceptor to be a pain producer.[62]
- **Treatment implications:** Massage and manual therapy, including MET and joint mobilization, can help to reeducate the mechanoreceptors. In addition to therapy, however, the client needs to gradually increase the amount of movement and learn that pain does not necessarily mean that the body is being injured.[55] Refer to the treatment implications above under "Somatic Nervous System" and to "Chronic Pain" below.

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Part Four: Injury and Repair

MECHANICS OF SOFT TISSUE INJURY

ROLE OF COLLAGEN IN SOFT TISSUE INJURY

- Soft tissues experience injury by excessive pulling (tension), compression, torsion (twisting), or shearing. There are two types of injury. One is described as *macrotrauma*, which implies a specific event. The injury is a rapidly applied load, such as a car accident, fall, or sport injury. The second type of injury is described as *microtrauma*, which is the result of repetitive or cumulative stress. Examples include tennis elbow, Achilles tendinitis, and carpal tunnel syndrome. Inflammation can result from either type of injury.
- These two types of injuries can be illustrated by a stress–strain curve (Fig. 1-21). **Stress** is defined as the force per area applied to the tissue, and **strain** is described as the percent change in length. The degree of damage to the soft tissues is affected not only by the amount of stress, but also by the rate or acceleration of the stress. The higher the acceleration, the greater is the damage. This explains the whiplash phenomenon, in which low speed (7 mph) injury can damage the soft tissue. The injurious force is not the speed, but the high acceleration (300 milliseconds). Rapidly applied loads increase the stiffness and can damage the soft tissues.

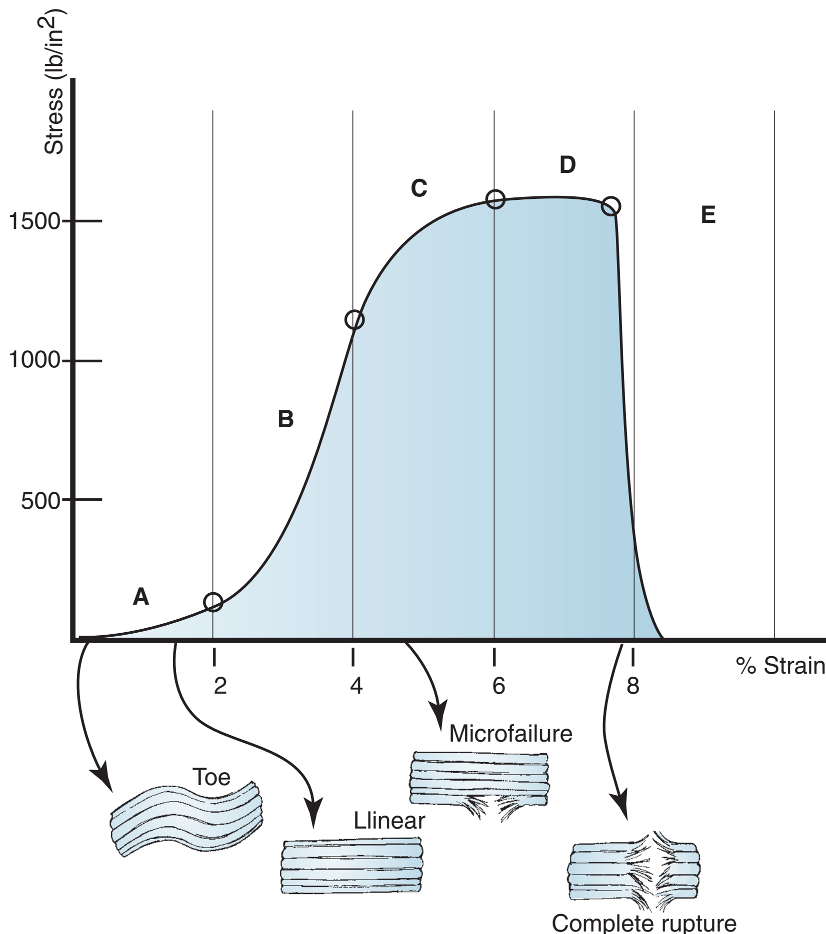

Figure 1-21. Stress–strain curve for a ruptured Achilles tendon. The five distinct regions are the **(A)** toe region, **(B)** linear region, **(C)** progressive failure region, **(D)** major failure region, and **(E)** complete rupture.

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FIVE DEGREES OF SOFT TISSUE FAILURE

- **Toe region:** If the stress is small, the tissue returns to its normal length. The stress takes the slack out of the tissue by straightening the crimp. This is represented by the toe region of the curve. Tissue may be loaded with a 1.5% to 2.5% strain and return to normal. This elastic quality decreases with age, because the amount of crimp decreases with age.
- **Linear region:** If the strain is between 2.5% and 4%, all of the fibers have straightened out, the collagen tears at its outermost fibers first, which is called *microfailure*.[63] This degree of injury is represented by the linear area of the curve. The tearing of collagen is like a rope that frays from its outer fibers to the center. The client complains of stiffness with this amount of tearing.[46] Microfailure can occur within the normal physiologic range if there is repetitive stress on weakened tissue from a previously damaged structure.[64] Even with microfailure, the cells, fibers, and ground substance matrix are damaged, and an inflammatory response is initiated.
- **Progressive failure region:** A strain between 4% and 6% is called the *yield point*, at which point major tearing occurs.
- **Major failure region:** A strain of more than 6% involves many points of rupture.
- **Complete rupture:** An 8% strain causes the collagen fibers to tear completely apart.
- Following the tear of the collagen fibers, repair and regeneration of the tissue are carried out through the process of inflammation and repair.

INFLAMMATION AND REPAIR

FOUR CARDINAL SIGNS OF INFLAMMATION

- Redness
- Heat
- Swelling
- Pain

INFLAMMATION: THE BODY'S RESPONSE TO TWO TYPES OF IRRITANTS, LIVING AND NONLIVING

- **Living irritants:** Microorganisms, such as bacteria, are an example of a living irritant.
- **Nonliving irritants:** Trauma and repetitive stress are the primary causes of inflammation. Joint dysfunction, such as knock-knees, can irritate the cartilage and periarticular soft tissues, creating a microinflammatory environment, with the same cellular responses described in this chapter.

FUNCTIONS OF INFLAMMATION

- Protects the body from infection, removes debris, and kills foreign invaders such as bacteria.
- Repairs damaged tissue by stimulating new cell growth, which then synthesizes new fibers for repair.

TWO TYPES OF TRAUMA

- **Direct:** Occurs from blunt trauma, such as from contact sports, car accidents.
- **Indirect:**
  - **Acute:** Occurs with sudden overloading.
  - **Chronic:** Occurs as a result of repetitive or cumulative stress.
  - **Acute on chronic:** Occurs as a result of a sudden tear of a chronically weakened area.

PHASES OF INFLAMMATION AND REPAIR

Vascular (Acute)

Begins within seconds of an injury and typically lasts 24 to 48 hours. In some cases, however, it may last from four to six days.

- Dilation of the arteries, veins, and capillaries causes redness and heat.
- Escape of blood plasma because of the increased permeability of the capillaries causes edema (swelling). Immediate swelling suggests a more severe injury. Swelling restricts lymph drainage and circulation, rendering an area acidic and ischemic (low oxygen), leading to pain.
- There is an increase in the number of fibroblasts. The fibroblasts increase in size and synthesize ground substance and collagen. This process begins within four hours of injury and can last four to six days. Collagen initially forms a weak, random mesh of fibers.
- Pain is produced by stimulation the pain receptors (nociceptors) from the tearing of the collagen fibers, by pressure from the swelling, and by chemical irritation.

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- Pain causes muscle spasms, which decrease circulation, reducing the ability of an area to repair.
- Inflammation leads to stimulation of pain receptors that cause compensatory adaptations that either facilitate muscles, causing hypertonicity, or inhibit muscles, causing weakness.[65]
- Typically, with joint inflammation, the flexors of the joint become hypertonic, and the extensors become inhibited.[50]

Regeneration and Repair (Subacute)

The process of regeneration and repair begins two days after injury and lasts up to six weeks.

- Scar tissue is highly cellular, and new capillaries are formed. The capillaries are laid down in a random orientation unless the area is mobilized.
- Fibroblastic activity and collagen formation increases.
- Immature connective tissue is less dense, making it more fragile and therefore more easily injured. Pain does not indicate the level of repair, so care must be taken with the amount of pressure that is applied in a massage.
- In these early stages, collagen is laid down in a random, disorganized pattern, usually in a plane perpendicular to the long axis, and therefore has little strength (Fig. 1-22).[3] The collagen develops abnormal crosslinks, leaving the tissue with less flexibility.

Remodeling (Chronic)

The remodeling process can take three weeks to twelve months.

- The term *chronic* can mean different things depending on how it is used. It can indicate the final stage of healing, although regaining pre-injury strength may take up to two years. It may apply to an injury that lasts longer than three to six months and does not appear to be improving.[66] This latter condition is discussed below under "Chronic Pain."
- In the early stages of remodeling, collagen matures into a lattice that is completely disorganized. It can be palpated as thickened or fibrous tissue. A relative decrease in cellularity and vascularity occurs as collagen density increases.
- After approximately two months, fibroblastic activity decreases, and there is less collagen synthesis.
- Random orientation of collagen provides little support for tensile loads.
- Two months to one year later, collagen may develop a functional linear alignment in response to movement and may become reoriented to the line of stress. Tensile strength slowly increases as collagen remodels itself back to its normal parallel alignment from the introduction of movement, stretching, and exercise.
- Immobilization leads to significant adhesion formations; osteoporosis or loss of bone density; and the atrophy of muscles, capsules, and ligaments.
- During the remodeling phase, the tissue is vulnerable to reinjury. Challenging the tissue too much can overload it, creating chronic irritation or inflammation, or can lead to degeneration of the tissue.
- Chronic pain can cause sensitization of the mechanoreceptors, such that normal mechanical

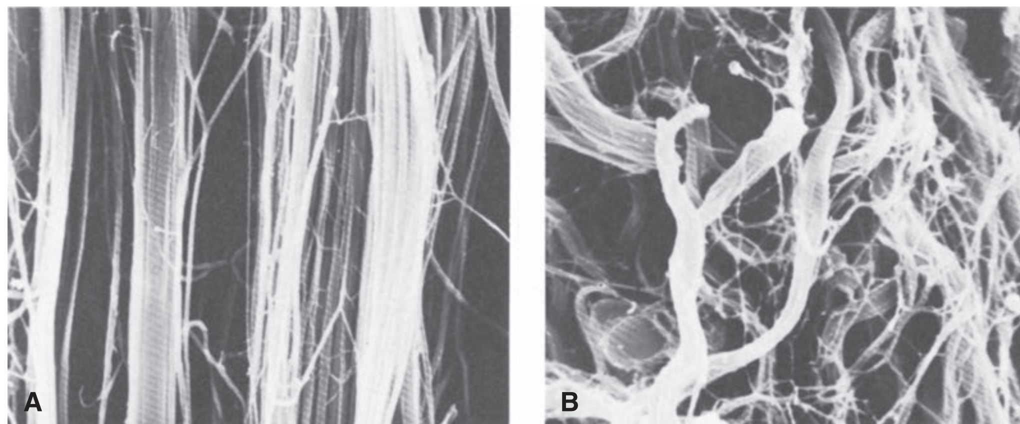

Figure 1-22. A. The normal longitudinal arrangement of a ligament. **B.** The random cross-weave of the collagen fibers in the early stages of repair after an injury to the ligament. (Reprinted with permission from Woo S, Buckwalter J. Injury and Repair of the Musculoskeletal Soft Tissues. Park Ridge, IL: American Academy of Orthopedic Surgeons, 1988.)

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stimuli (e.g., movement of a joint within a normal range) cause the mechanoreceptor to be a pain producer.[62]

PAIN AND SOFT TISSUE

SOFT TISSUE IS A COMMON SOURCE OF PAIN

Nociception means the perception of harmful stimuli.[67] *Nociceptors* are specialized nerves embedded in soft tissue that monitor the body for evidence of injury. They are normally silent but are stimulated by excessive mechanical, thermal, or chemical stimuli. A common source of musculoskeletal pain is from the deep soft tissue. These tissues include the periosteum, joint capsule, ligaments, tendons, muscles, and fascia. The most pain-sensitive tissue is the periosteum and the joint capsule. Tendons and ligaments are moderately sensitive, and muscle is less sensitive.[46]

CAUSES OF SOFT TISSUE PAIN

Pain is elicited by harmful stimuli from three different classes of receptors: **mechanical, chemical,** and **thermal** receptors. **Acute** pain from trauma or cumulative stress is caused by damage to the tissue from excessive mechanical stress, such as compression, twisting, or pulling; inflammatory chemicals released after tissue damage; or excessive heat or cold. In **chronic** conditions, such as arthritis, pain is generated from ongoing tissue irritation or damage, emotional or psychological stress, or changes in the central nervous system that continue to send pain signals even when there is no harmful stimuli (Fig. 1-23). See below for further discussion. These basic categories can be expanded into the following six fundamental causes:[68]

- **Injury** creates inflammation and ischemia (low oxygen) due to swelling. Inflammation releases chemicals that irritate the pain fibers in the periosteum, joint capsules, bone, perivascular tissue, ligaments, synovial tissue, muscle and its fascia, and other soft tissues around the joint.
- **Mechanical irritation** is due to repetitive or cumulative stress to the periosteum, joint capsules, bone, tissue around the blood vessels (perivascular tissue), ligaments, muscle and its fascia, and other soft tissues around the joint. Mechanical irritation develops from abnormal tension, compression, or torsion (twisting) of the soft tissue. Abnormal alignment of the joint creates mechanical irritation of the soft tissue surrounding the joint.
- **Neurogenic pain** is caused by the irritation or inflammation of the sensory nerves themeselves. This inflammation then releases chemicals (neuropeptides) from the nerve endings. These chemicals irritate the pain fibers in the periosteum, joint capsules, bone, perivascular tissue, ligaments, synovial tissue, muscle and its fascia, and other soft tissues around the joint (see "The Nervous System").

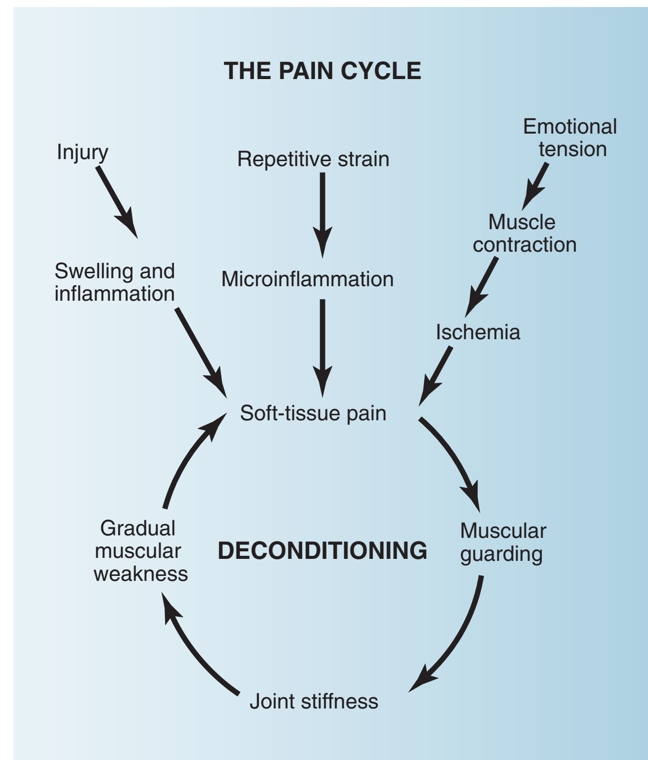

Figure 1-23. Soft tissue pain cycle. Chronic pain leads to gradual weakness and deconditioning.

- **Reflex hypertonicity** of muscles, induced by injury, stress, or arthrokinetic reflexes, creates stagnation in the tissue and decreased oxygen (ischemia), which causes pain.
- **Nerve entrapment** is caused by soft tissue swelling, adhesions in the connective tissue, or sustained muscle contraction. Entrapment of the nerve creates congestion and fluid stagnation. This reduces the flow within the nerve, leading to altered sensation (paresthesia). Entrapment also reduces oxygen to the nerve because of reduced blood flow, which leads to pain.
- **Psychological or emotional stress** stimulates the sympathetic nervous system and creates muscular hypertonicity, which leads to pain from decreased oxygen (ischemia) and increased acids in the tissue.

CHRONIC PAIN

- Chronic pain may be due to stress, degeneration in the joint, or a chronic inflammatory condition, such

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as rheumatoid arthritis. But in many clients with chronic pain, there are no objective findings, and the term *chronic* does not accurately reflect the physical condition of the body. Nerves can "backfire" in some clients and send pain impulses even when there are no harmful stimuli.

- Chronic pain often leads to depression and anxiety and pain avoidance behavior, which result in deconditioning.
- Clients who are in chronic pain need to focus on improving function and behavioral changes. They need to take several steps to reeducate their nervous system: become informed about pain and learn that "hurt does not necessarily mean harm," stay active, explore new ways to move, extend the "edges of pain" by moving a little more each week, and keep a positive attitude.[55]
- Treatment implications were discussed above in "Somatic Nervous System."

REFERRED PAIN

- Pain that originates in deep somatic tissue is usually referred into specific patterns called **sclerotomes** (Fig. 1-24). Sclerotomes are "those deep somatic tissues (fascia, ligaments, capsules, and connective tissue) that are innervated by the same spinal nerve."[46] The extent of the radiation depends on the intensity of the irritation to the tissue. When a tissue of a particular sclerotome is irritated, the pain can be perceived as originating from any and all of the tissue that is innervated by the same nerve.
- Referral of diffuse sclerotomal pain is distinguished from well-localized pain that is referred from irritation of the nerve roots. **Dermatomal pain** occurs if the sensory (dorsal) nerve root is irritated. The client will feel *sharp pain, numbing, or tingling that is well localized* in patches of skin called *dermatomes* that correspond to a specific nerve. Irritation of the motor (ventral) nerve root will elicit **myotomal pain**. Symptoms include deep, boring pain, well localized to specific muscles (myotomes), as well as potential weakness in the muscles supplied by that nerve root.[46] For further discussion of dermatomes, see Chapter 3, "Lumbosacral Spine," and Chapter 5, "Cervical Spine."

QUALITY OF PAIN FROM DEEP SOMATIC TISSUES

- Deep somatic pain is also called **sclerotomal pain** and is described as diffuse aching, numbing, and tingling.

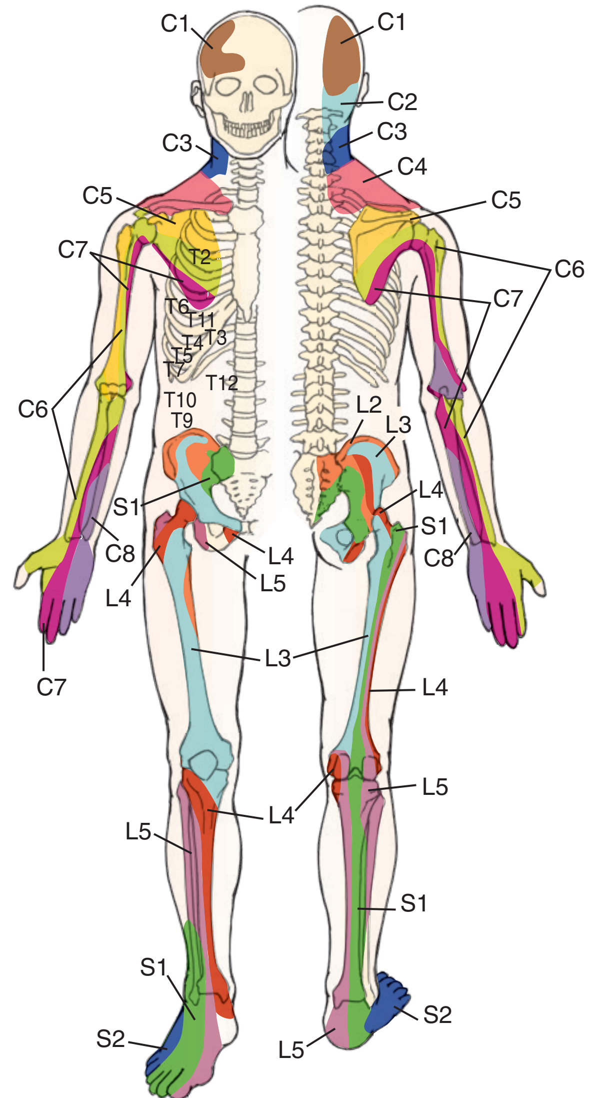

Figure 1-24. Irritation or injury of fascia, ligaments, tendons, joint capsules, or other connective tissues refers pain into regions innervated by the same spinal nerve. The pathways are called *sclerotomes*.

- Sclerotomal pain is often associated with autonomic disturbances, such as sweating, pallor, and feelings of nausea and being faint.
- Pain of sclerotomal origin and from the viscera sends impulses to the limbic and hypothalamus areas of the brain (the emotional centers) and may be responsible for emotional reactions of anxiety, fear, anger, and depression.

PAIN-GATE THEORY OF MELZAK AND WALL AND ITS RELATION TO MASSAGE

- The pain-gate theory proposes that there are two main factors that determine how pain is perceived:
  - ☐ First, it depends on the balance between mechanoreceptor information and pain fiber

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information. Touch, vibration, and joint and muscle movement stimulate mechanoreceptors, causing a decrease in the pain information received by the brain.

- ☐ Second, the brain inhibits or enhances a reaction to pain. Athletes in intense competition can ignore an injury, and fear and anxiety can exaggerate pain.

- **Treatment implication:** In the method of treatment that is described in this text, the therapist moves the entire region of the body being worked on, as well as the local tissue, to stimulate a large number of mechanoreceptors rather than pressing only at the site of the injury or dysfunction and keeping the rest of the body passive. This dramatically reduces the discomfort of working on these deep somatic tissues.

Study Guide

Level I

1. Describe the new paradigm in biology and medicine.
2. Describe the characteristics of soft tissue injury.
3. Describe the arrangement of collagen fibers and how collagen is affected in injury, and describe the treatment implications.
4. Describe the function and dysfunction of ground substance and define thixotropy and its relevance to massage therapy.
5. Describe why movement in the early stages of repair is indicated.
6. Define tensegrity and piezoelectricity and describe their relevance to massage therapy.
7. List the causes of pain from soft tissue injury and dysfunction.
8. Describe a sclerotome and the quality of pain from those tissues.
9. Describe Janda's concept of soft tissue dysfunction and its relevance to massage therapy.
10. Describe Lauren Berry's concept of soft tissue dysfunction and its relevance to massage therapy.

Level II

1. Describe the pain-gate theory of Melzak and Wall and its relevance to massage therapy.
2. Describe the structural and neurological goals of treatment.
3. Describe joint play and joint dysfunction, and list the causes of joint dysfunction and its treatment.
4. Describe the functions of the following structures: muscle spindle, GTO, and alpha and gamma nerves.
5. List the eight causes of muscle dysfunction.
6. Describe how cartilage maintains its circulation and health.
7. Define the arthrokinetic reflex.
8. Describe the signs of impaired muscle function.
9. Describe the differences between the sympathetic and the parasympathetic nervous systems and the implication for massage therapy.
10. Describe the goals of joint mobilization.

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