Module 10.5 Energy Sources for Skeletal Muscle

Sources of Energy for Muscle Contraction

- In skeletal muscle, ATP is *required* for
  - *Powering* the Na^+/K^+ pumps that maintain the ion gradients involved in action potentials
  - contraction and relaxation of the muscle fiber

Sources of Energy for Muscle Contraction

- The required ATP is generated by:
  - Immediate cytosolic reactions
  - **Glycolytic catabolism** in the *cytosol*
  - **Oxidative catabolism** in the *mitochondria*
  - *All three processes* may occur simultaneously in muscle fibers during contractions, but they are used in *different proportions*, depending on the resources and needs of the cells

Immediate Sources of Energy for Muscle Contraction

- When contraction begins, the main immediate energy source of the muscle fiber is stored as ATP, this ATP is *rapidly consumed, but is regenerated almost immediately by a reaction using a molecule called* **creatine phosphate (CP).** CP is found primarily in muscle fibers and is 5–6 times *more abundant* than ATP in cytosol; ATP produced by creatine phosphate reaction provides the muscles with enough energy for about an additional 10 seconds of maximal muscle activity.

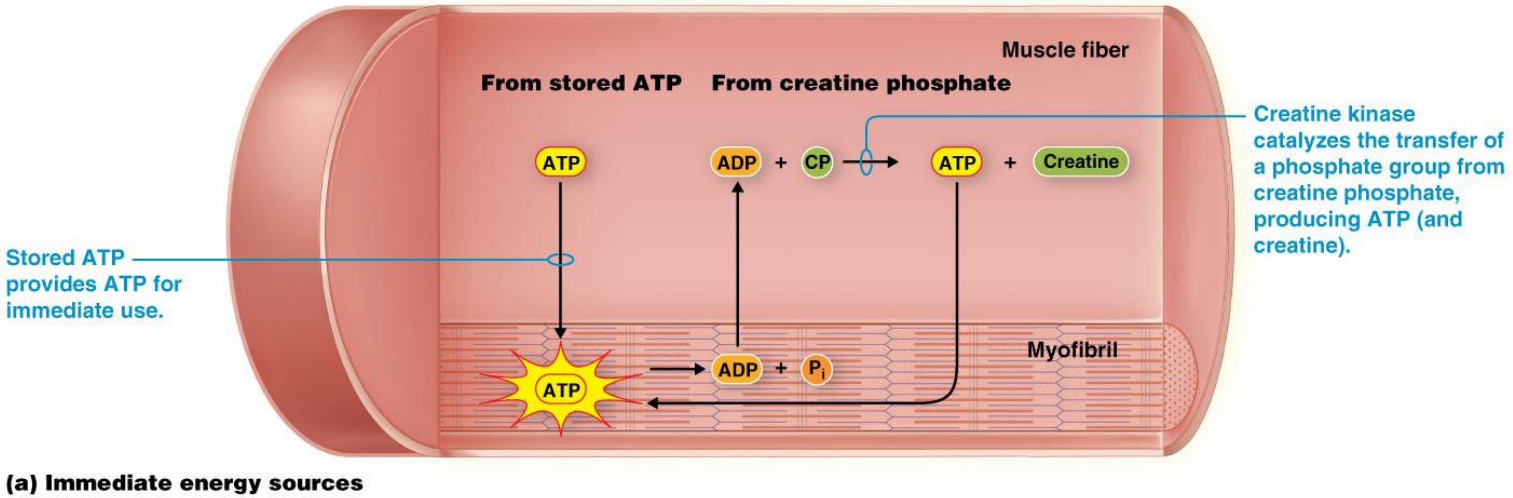


Figure 10.19a Sources of energy for muscle fibers.

Creatine Supplementation

- Dietary supplement manufacturers market creatine supplements as a way to improve muscle strength and performance. The evidence to support these claims is mixed.
- Research has demonstrated that supplementation with **creatine** does mildly *improve performance* for activities that require *short bursts* of muscle activity
- The effects on **endurance-type activities** are *minimal to nonexistent*

Creatine Supplementation

- Creatine may actually be *detrimental* to athletes in certain sports because supplementation causes weight gain from water retention.
- No long-term studies done
- **Massive doses** can have negative health implications such as **kidney damage**
- Skeletal muscles have a *maximal storage capacity* for creatine; therefore, the excess is excreted in the urine

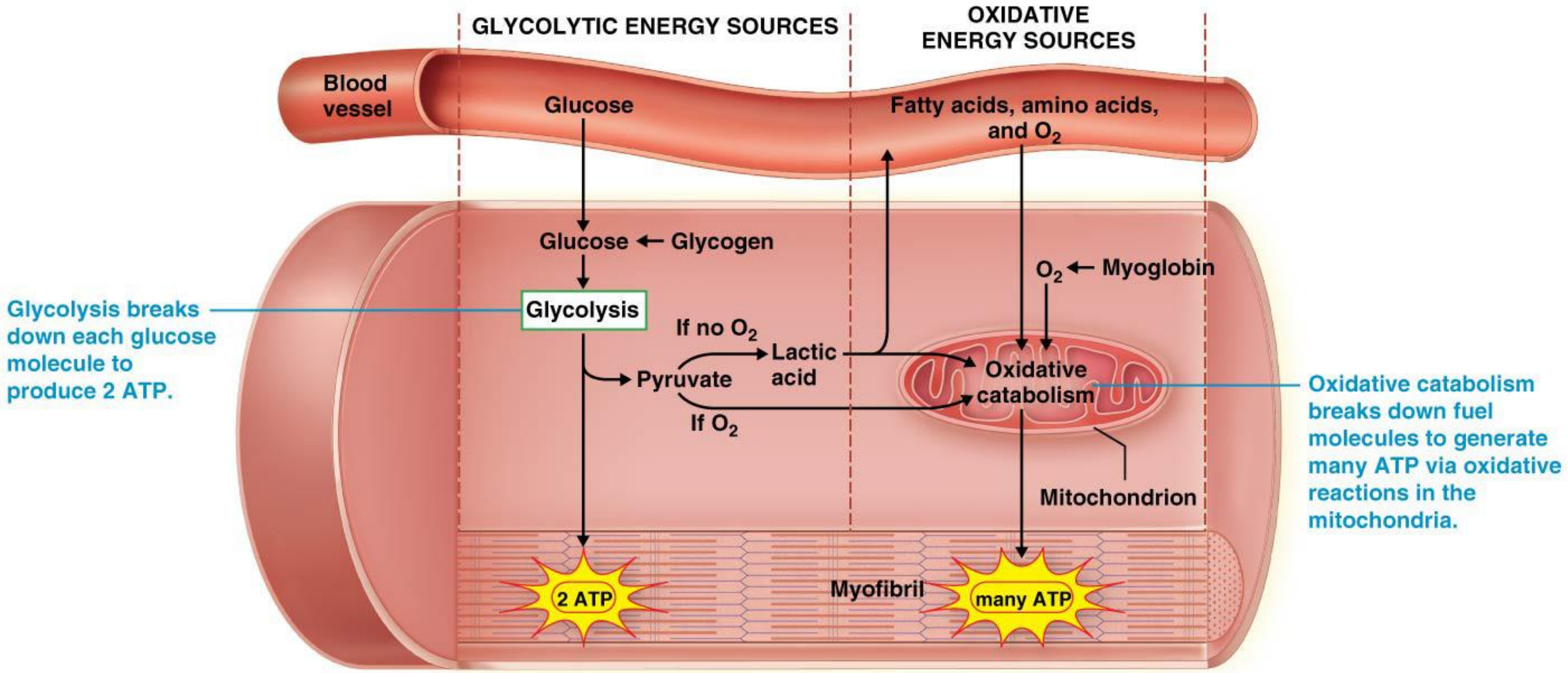
Glycolytic Energy Sources

- When immediate energy sources are depleted, muscle fibers turn to **glycolysis (glycolytic or anaerobic catabolism** to make ATP.
- **Glycolysis** is a series of reactions that occurs in the cytosol of all cells, glucose is broken down to produce **2 ATP** per molecule of glucose.
- A muscle fiber has two potential sources of glucose for glycolysis: glucose from the bloodstream and a storage form of glucose called **glycogen**.

Glycolytic Energy Sources

- **Glycolysis**, or **anaerobic catabolism**, does not require **oxygen** directly, however the fate of the product of glycolysis (2 molecules of **pyruvate**) depends on the availability of oxygen to the muscle fiber :
  - If oxygen is abundant, enters the mitochondria for **oxidative catabolism**, which will then occur *simultaneously* with glycolysis as long as glucose is available
  - If oxygen is not abundant, the pyruvate is converted into two molecules of **lactic acid (lactate),** which can either be converted back into glucose by the liver or enters the mitochondria and is used for oxidative catabolism

Glycolytic Energy Sources



(b) Glycolytic and oxidative energy sources

Figure 10.19b Sources of energy for muscle fibers.

Oxidative Energy Sources

- Combined immediate and anaerobic glycolytic energy sources are adequate for short bursts of activity (like a 400 meter race). However, longer-lasting muscle activity requires a muscle fiber to use mostly **oxidative or aerobic catabolism**
- Occurs in mitochondria
- Electrons are removed from carbon-based molecules and the energy liberated is then used to fuel the synthesis of ATP.
- **Oxidative catabolism produces MORE ATP than glycolysis**
- The amount of ATP depends on the *type of fuel* used by the fiber
  - Glucose is generally preferred fuel for muscle fibers, the one they use first, when glucose becomes less available they will catabolize **fatty acids** and **amino acids** if necessary

Oxidative Energy Sources

- Oxidative catabolism can provide ATP for hours, as long as oxygen and fuels are available, after only 1 minute of skeletal muscle activity it is the *predominant* source of ATP for almost all muscle fibers.
- After several minutes, nearly 100% of the ATP is produced is by this aerobic process

Oxidative Energy Sources

Notice the final step is the transfer of electrons to a molecule of oxygen, which is why this type of metabolism is called aerobic catabolism

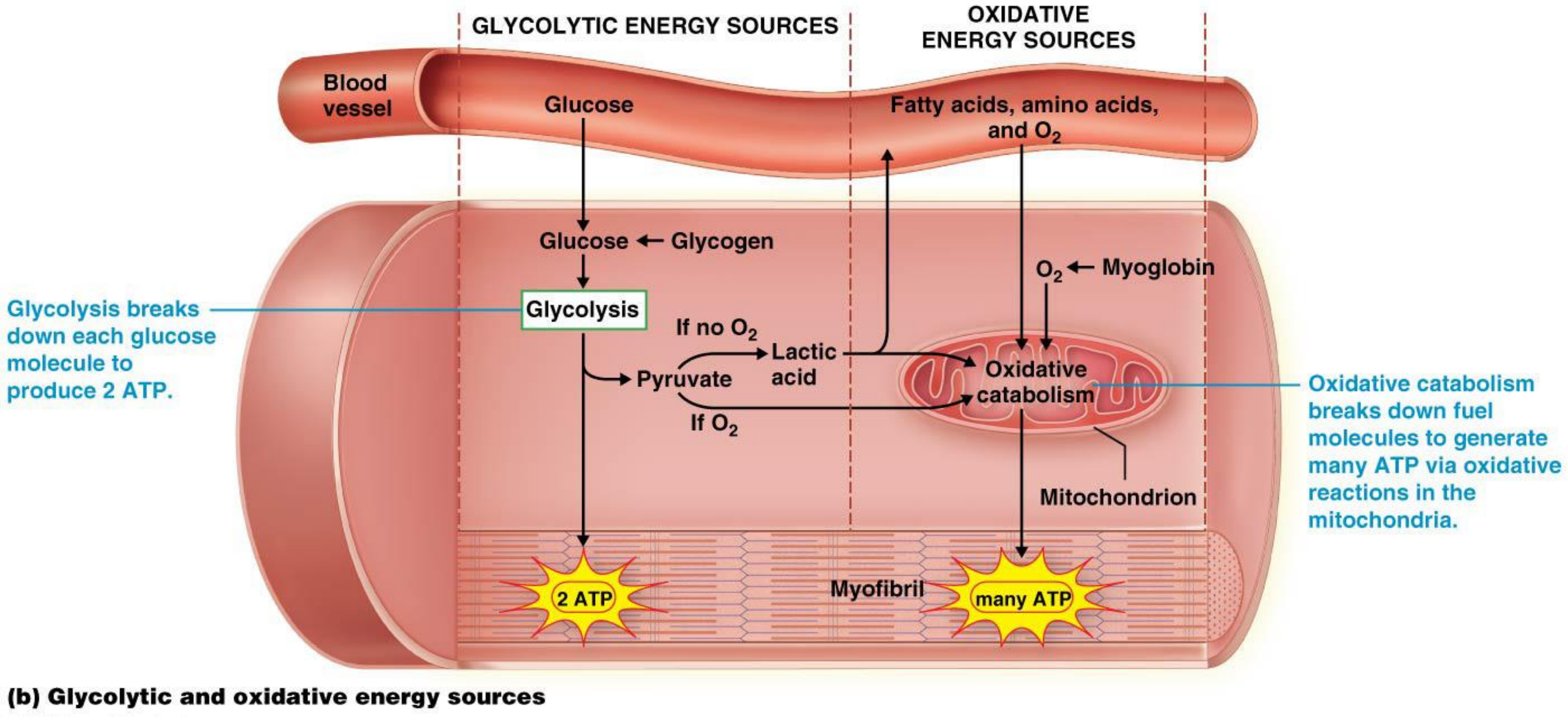


Figure 10.19b Sources of energy for muscle fibers.

FLASHBACK……..

Characteristics of Living Organisms

Living Organisms share distinct properties:

- __________ are *basic units* of life
  - Smallest unit that can carry out functions of life
  - All organisms are *composed of ______.*

Characteristics of Living Organisms

Living Organisms share distinct properties:

- **Cellular composition: cells** are *basic units* of life
    - Smallest unit that can carry out functions of life
    - All organisms are *composed of cells*

Types of Anatomy and Physiology

Study of human body (continued):

- _________ __________– studies *surface markings* of body
- _________ _________– examines structures that can be seen with *unaided eye*
- __________ ___________ – studies structures that can only be seen with aid of a *microscope*; include: **Histology** (study of *tissues*) and **Cytology** (study of *cells*)

Types of Anatomy and Physiology

Study of human body (continued):

- **Surface anatomy** – studies *surface markings* of body
- **Gross anatomy** – examines structures that can be seen with *unaided eye*
- **Microscopic anatomy** – studies structures that can only be seen with aid of a *microscope*; include: **Histology** (study of *tissues*) and **Cytology** (study of *cells*)

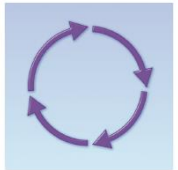
- _______ __________– study of *structure* or *form* of human body

- _________ _________– study of body's *functions*

- **Human anatomy** – study of *structure* or *form* of human body

- **Human physiology** – study of body’s *functions*

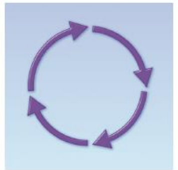
Core Principles in A&P



Feedback Loops Core Principle – two mechanisms vital to maintenance of homeostasis (**Figures 1.13, 1.14**):

- **Positive feedback loops** – less common than negative feedback loops; effector activity ________and _________ *initial stimulus*; shuts off when conditions return to the normal range

Core Principles in A&P



Feedback Loops Core Principle – two mechanisms vital to maintenance of homeostasis (**Figures 1.13, 1.14**):

- **Positive feedback loops** – less common than negative feedback loops; effector activity increases and reinforces *initial stimulus*; shuts off when conditions return to the normal range

Core Principles in A&P

- **Negative feedback loops** (continued):
  - **Negative feedback loops** – ______ *initial change* in a regulated variable; _____ *output*
  - When a change in status of a regulated variable is detected, a series of events is triggered to *return variable to its normal value*

Core Principles in A&P

- **Negative feedback loops** (continued):
  - **Negative feedback loops** – oppose *initial change* in a regulated variable; reduce *output*
  - When a change in status of a regulated variable is detected, a series of events is triggered to *return variable to its normal value*

10.6 Muscle Tension at the Fiber Level

Twitch Contraction

- A **muscle twitch** is the smallest muscle contraction; is the response of a muscle fiber to a single action potential in a motor neuron, are laboratory phenomena, they don't occur in whole muscles in the body. They are useful in experiments to study different types of contractions.
- The three phases of a twitch on a **myogram** include the following:
  - The **latent period** is the time it takes the action potential to spread through the sarcolemma
  - The **contraction period** marked by rapid increase in tension as crossbridge cycles occur repeatedly.
  - The **relaxation period** tension decreases due to the decreasing calcium ion concentration in the cytosol

Twitch Contraction

- Between the start of the latent period and start of the contraction period, there is an interval of about 5ms during which the muscle CANNOT respond to another stimulus, this period is called the **refractory period**
- Cardiac muscle and smooth muscle have refractory periods as *long as their contractions*, so the cells must *fully relax* before they can contract a *second time*

Twitch Contraction

The tension produced during a twitch varies considerably with *several factors*:

- *Timing* and *frequency* of stimulation
- *Length* of the fiber at rest
- *Type* of muscle fiber

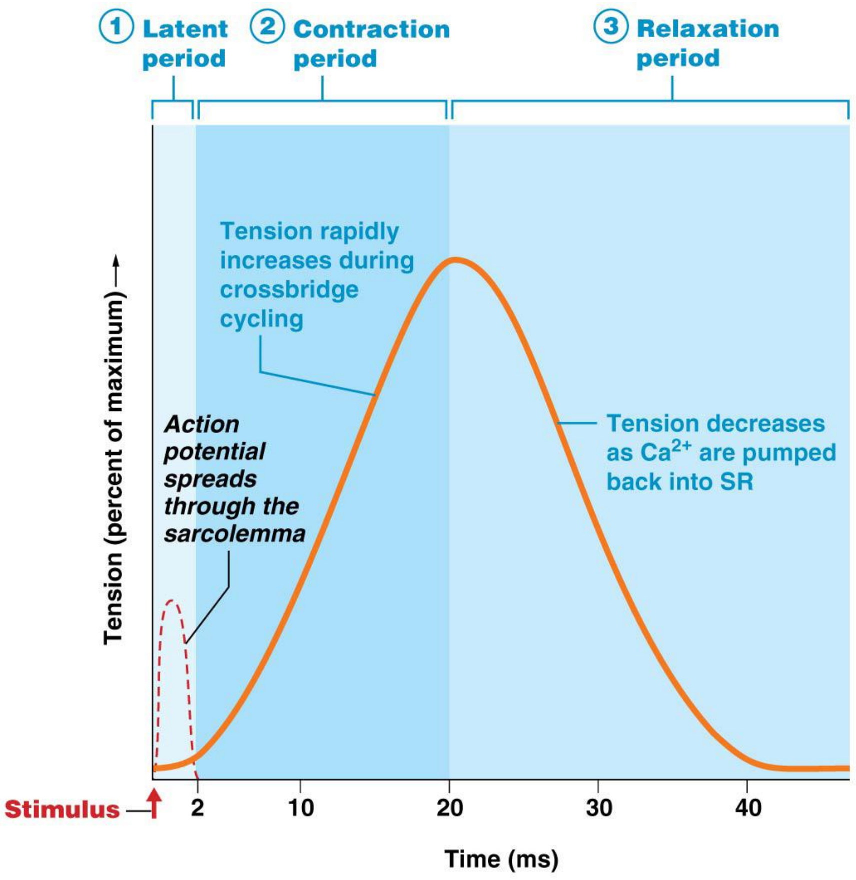


Figure 10.20 Myogram of a twitch contraction.

Tension Production and the Timing and Frequency of Stimulation

- **Wave summation-** A phenomenon in which repeated stimulation of a muscle fiber by a motor neuron results in muscle twitches with progressively greater tension.
  - The pumps in the SR membranes have *inadequate time* to pump <u>all</u> of the released **calcium** ions back into the SR before the fiber is *restimulated*
  - Therefore, the concentration of calcium ions in the cytosol <u>increases</u> with *each stimulus*

Tension Production and the Timing and Frequency of Stimulation

- The amount of tension produced depends on the **frequency** of *stimulation by the motor neuron*, 2 possible states:
  - **Unfused tetanus** –if the fiber is stimulated about *50 times per second* it can only partially relax between contractions. A sustained contraction called **unfused (or incomplete) tetanus** results. The tension pulsates until a level of maximal tension is reached.

Tension Production and the Timing and Frequency of Stimulation

- **Fused** (**complete**) **tetanus** – if the fiber is stimulated at a rate of *80–100 times per second*, the muscle fiber does not have time to relax between stimuli because the calcium ion concentration in the cytosol remains high.
  - The increased availability of calcium allows <u>more</u> crossbridges to form, contributing to the <u>increase</u> in tension
  - **Fused (or complete) tetanus- in which the tension remains constant at a maximal level.**
  - **NOTE that fused tetanus is possible ONLY because of the extremely short refractory period of the skeletal muscle fiber.**

Tension Production and the Timing and Frequency of Stimulation

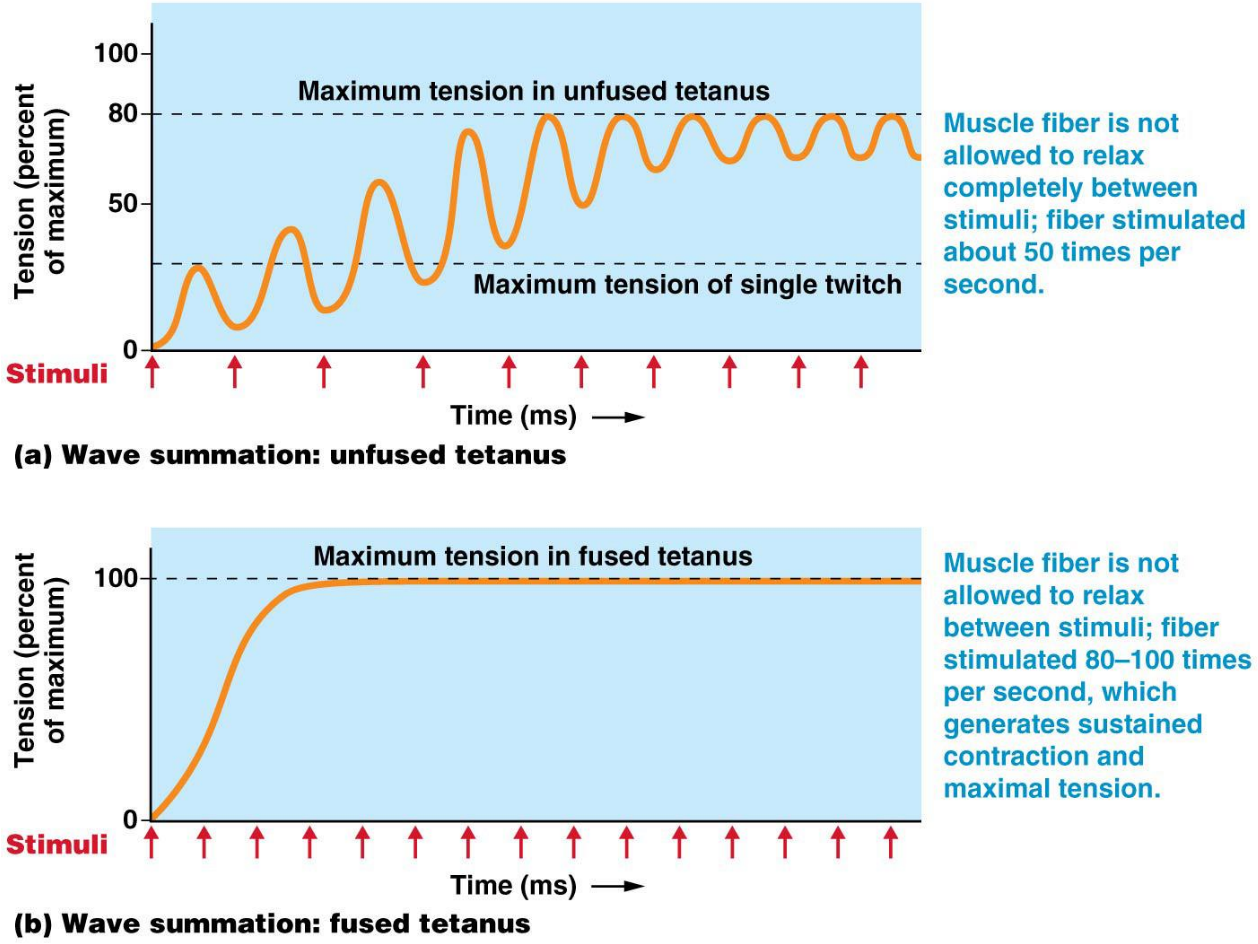


Figure 10.21 Wave summation: unfused and fused tetanus.

The Length-Tension Relationship

- **The length-tension relationship** –the relationship between the length of the sarcomeres of a muscle fiber while at rest and the amount of tension that can be generated by a contraction.
- **optimal length** of a sarcomere is the length of the muscle fiber at which the most crossbridges can form, allowing the fiber to generate almost 100% of the tension that is possible to produce.

The Length-Tension Relationship

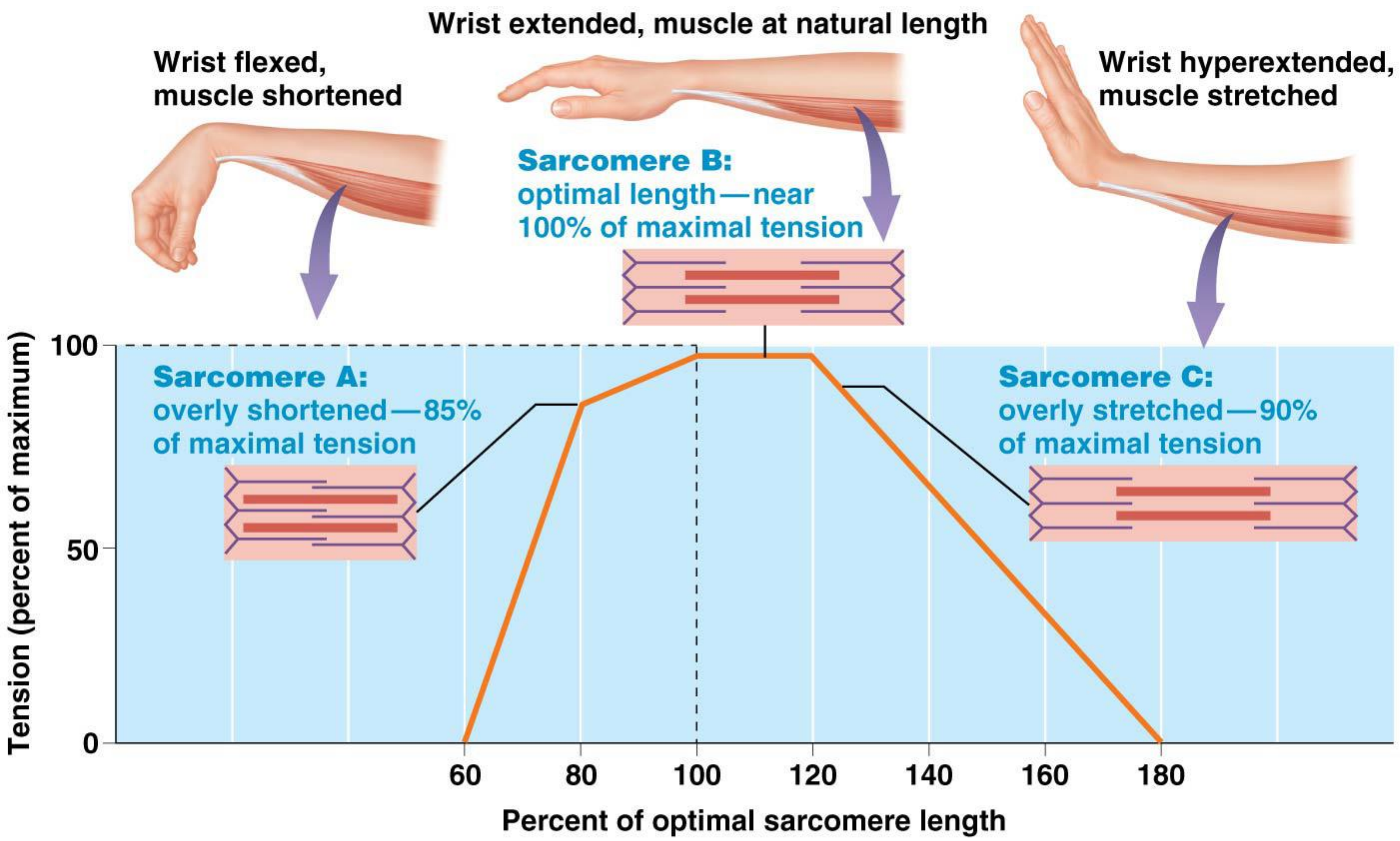


Figure 10.22 The length-tension relationship.

Concept Boost: Understanding How Events at the Myofilaments Produce Tension of a Whole Muscle

- Remember that myofibrils are connected to the sarcolemma of the muscle fiber, so any tension in the myofibrils is transmitted to the muscle fiber as a whole. The muscle fiber then relays that tension to the collagen fibers in the endomysium, which causes contraction of the fascicle as a whole. As the fascicles contract, the tension is in turn conducted from the surrounding perimysium to the epimysium and the tendons of the entire muscle. The muscle then contracts, pulling on the attached bones and causing movement.

Concept Boost: Understanding How Events at the Myofilaments Produce Tension of a Whole Muscle

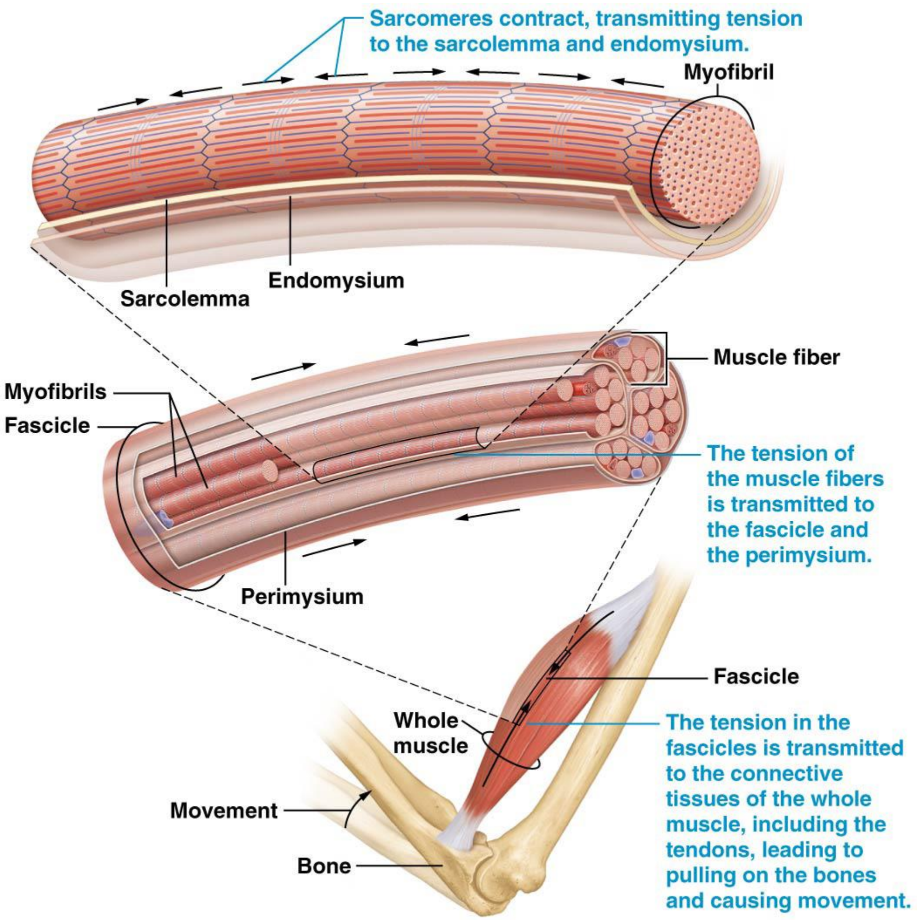


Figure 10.23 How myofilament sliding leads to whole muscle contraction.

Classes of Skeletal Muscle Fibers

- There are two main classes of skeletal muscle fibers:
  - **Type I/slow** and **Type II/fast**
  - Classified based on **myosin ATPase** activity (determines how *fast* or how *slowly* a power stroke can occur)
  - Most muscles contain all fibers classes, each of which is stimulate under different conditions

Classes of Skeletal Muscle Fibers

- **Type I fibers** are *small diameter*, *slow-twitch fibers* that contract more slowly and less forcefully, but can maintain extended periods of contraction
- Requires the continual oxidative generation of large quantities of ATP, so their metabolism is primarily oxidative and they have large quantities of myoglobin, many mitochondria, and a well-developed blood supply.
- The high myoglobin content of type I muscle fibers makes them red, and so sometimes called “red muscle”

Classes of Skeletal Muscle Fibers

- **Type II fibers** - fast twitch fibers, often larger in diameter, contract more rapidly than type I, but they are quickly fatigued.
- Rely primarily on glycolytic energy sources, and they have less myoglobin, fewer mitochondria, and less extensive blood supply.
- Due to low myoglobin content, lighter in color and sometimes called “white muscle”

Classes of Skeletal Muscle Fibers

- **Type II fibers** (continued):
  - There are three subtypes:
    - **IIa** (**fast oxidative-glycolytic** or **FOG**)
    - **IIx** (**fast oxidative** or **FO**)
    - **IIb** (**fast glycolytic** or **FG**) – produce extremely fast, powerful twitches
    - These subtypes have progressively faster, stronger twitches and rely increasingly on glycolytic energy sources

Classes of Skeletal Muscle Fibers

- Most muscles contain <u>all</u> fiber classes (**Figure 10.24**), each of which is stimulated under *different conditions*
  - A baseball player sitting in the dugout uses primarily *type I fibers* in the back and abdomen to *remain sitting upright*
  - When the player gets up and *jogs to the plate* to bat, primarily *type IIa fibers* in the legs are used
  - When the player *hits the ball*, the bat is swung using *type IIx and IIb fibers* in the arms

Classes of Skeletal Muscle Fibers

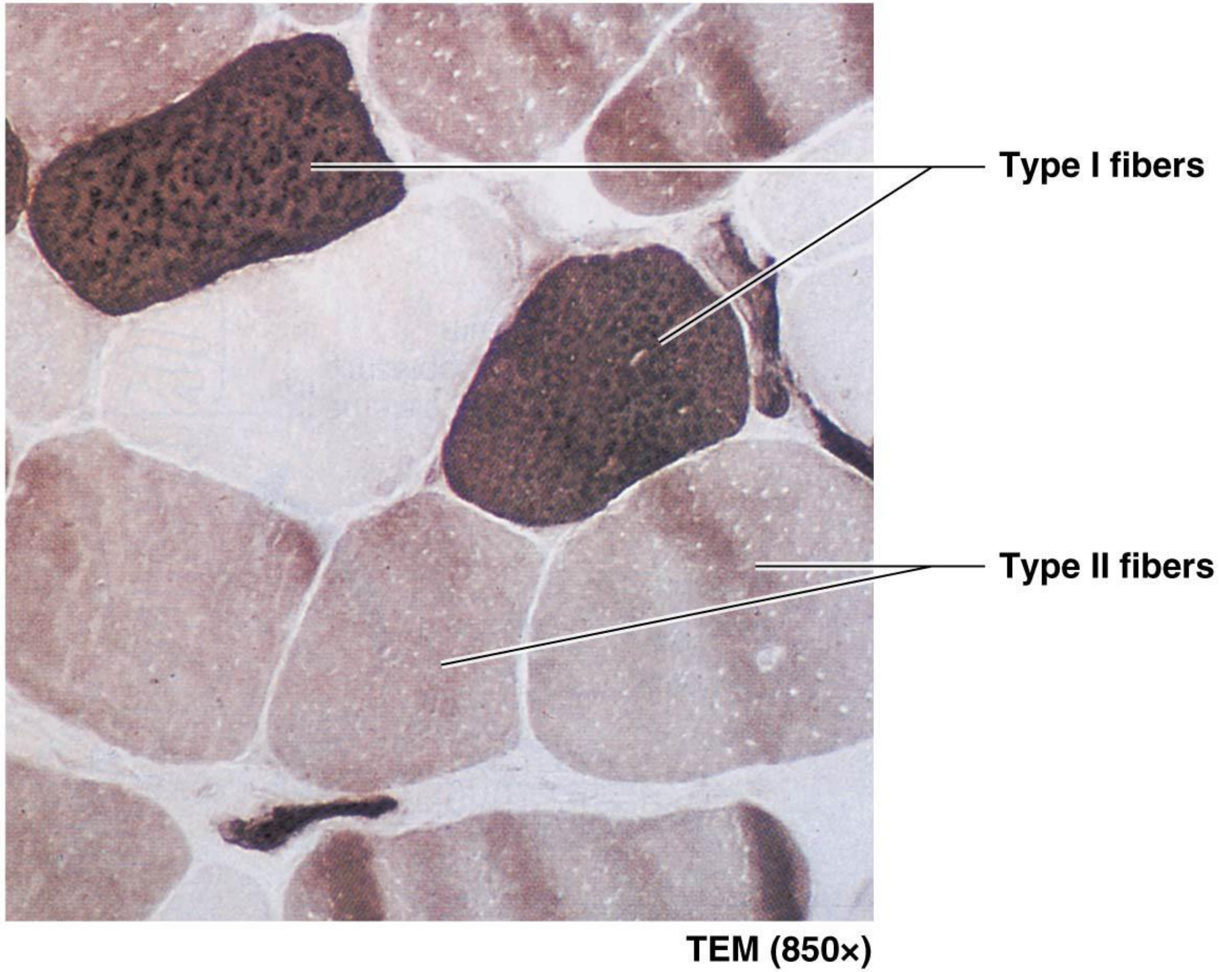


Figure 10.24 Comparison of Type I and type II muscle fibers.

Module 10.7 Muscle Tension at the Organ Level

Motor Units

A single motor neuron and all the muscle fibers that it innervates is called a **motor unit** (**Figure 10.25**)

- Motor units contain one class of muscle fiber, those with type I fibers are called **slow motor units**, and those with type II are **fast motor units.**
- When the motor neuron fires an action potential, all of the muscle fibers within its motor unit respond and produce about the same amount of tension; this applies only to a motor unit, not *entire muscle*

Motor Units

- An average motor unit consists of about 150 muscle fibers, but this number can vary widely with the degree of motor control needed for the muscle.
  - Muscles requiring fine *control* will have multiple small motor units, as in the larynx and fingers
  - Large, powerful muscles, like postural muscles of the back, can have 2000 to 3000 muscle fibers in each motor unit.

Motor Units

- **Recruitment-** An increase in the number of motor units of a skeletal muscle that are stimulated in order to produce a contraction with greater tension.
- Slow motor units are typically activated **first**, followed by fast motor units if additional tension is needed.

Motor Units

- **Muscle tone** –the small amount of tension produced by a muscle at rest due to the involuntary activation of motor units by the brain and spinal cord.
  - The nervous system *alternates* which motor units it activates, so that some can *rest* while others *contract*
  - Serves important functions, including maintaining erect posture, stabilizing joints, generating heat, and ensuring the muscle is ready to respond if movement is initiated.

Motor Units

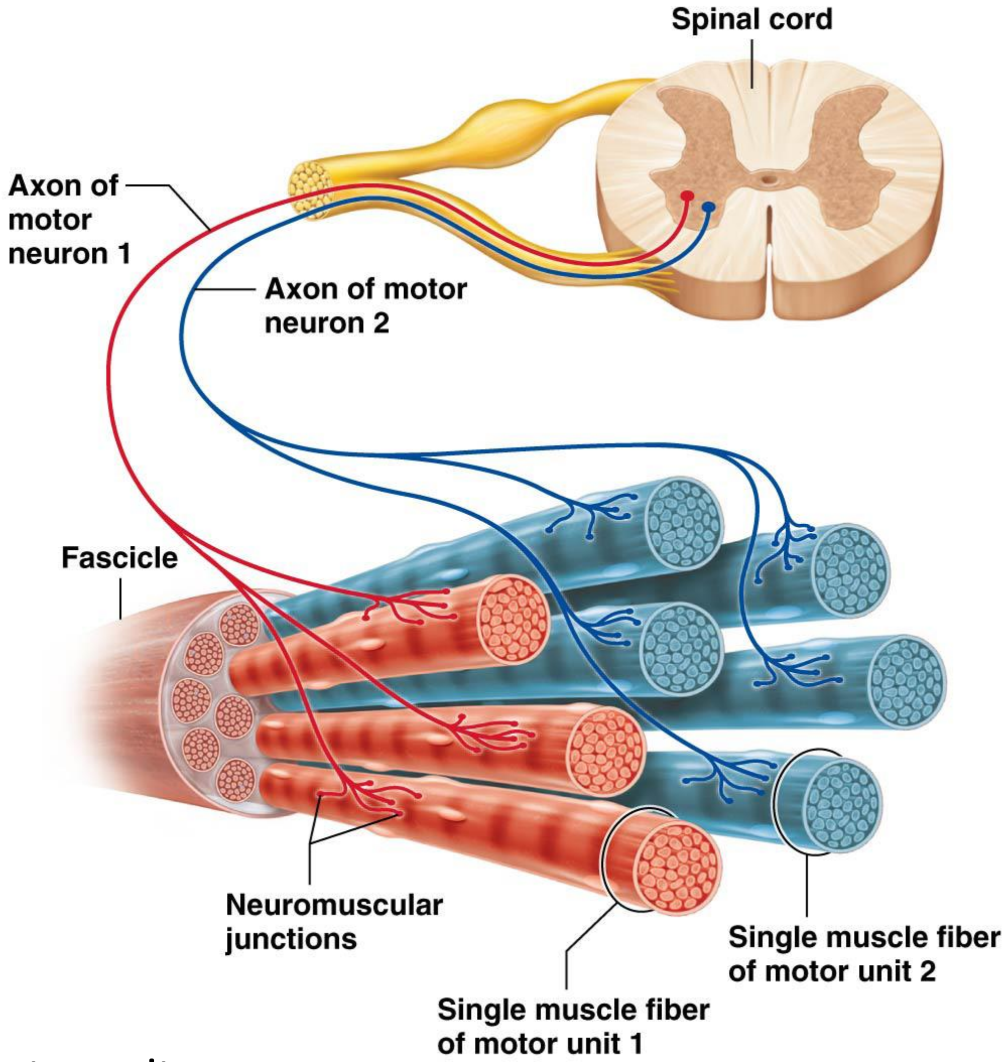


Figure 10.25 The motor unit.

Types of Muscle Contractions

- **Isotonic contractions** (*iso*= "same", *tono*= "tension") produces enough tension to initially move a load, such as a weight, and then maintains that same level of tension throughout the contraction. SAME TENSION but CHANGING length
- **Isotonic concentric contraction** –the tension generated is greater than that of the external load, and so the muscle cell shortens with the contraction.
- **Isotonic eccentric contraction-** The tension generated is less than that of the external load, and so the muscle cell lengthens with the contractions.
- **Isometric contractions** (*-metr*= "measure") results when the external load is equal to the force generated by the muscle. SAME length but CHANGING tension

Types of Muscle Contractions

- A muscle is able to *lengthen* while it is contracting because the elastic filaments in its myofibrils allow it to *stretch* considerably

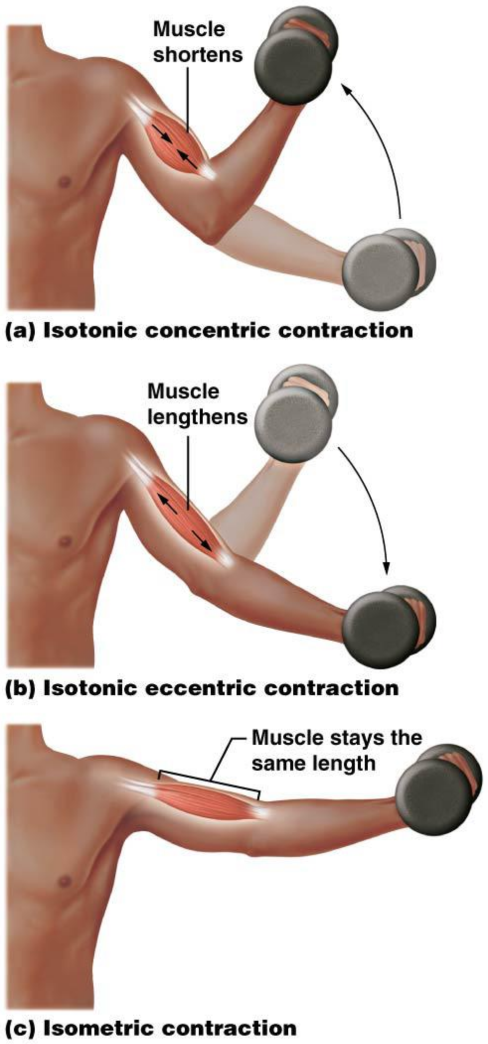


Figure 10.26 The three types of muscle contraction.

Delayed-Onset Muscle Soreness

- The phenomenon of *muscle soreness* following exercise was thought to be due to the *lactic acid* produced during glycolysis
- However, research over the past 10 years suggests instead that it is more likely due to *minor structural damage*, in particular, that caused by *isotonic eccentric muscle contractions*
- Pain may also be due to remodeling of the myofibrils
- The most effective treatment for DOMS is more *exercise*; however, the effectiveness of exercise in treating DOMS, is temporary, once the exercise has ceased, the pain returns until the muscle is sufficiently conditioned through training.
- Other treatment modalities such as massage, topical therapies, acupuncture, and oral medications have shown *little benefit*

Module 10.8 Skeletal Muscle Performance

Changes Caused By Physical Training

- The **principle of myoplasticity** – a muscle will alter its structure to follow its function.

- The majority of mature skeletal muscle fiber nuclei are **amitotic**, meaning that they generally do not undergo *mitosis, therefore the changes are within the muscle fibers themselves, not in the number of muscle fibers.*
  - **Satellite cells** (a small population of unspecialized cells) do retain mitotic ability, can help *repair* injured skeletal muscle
  - The precise structural and biochemical changes depend on the type of training chosen, **endurance** or **resistance training**

Changes Caused By Physical Training

- **Endurance training** is defined as training with a <u>large</u> increase in the *frequency* of motor unit activation and a <u>moderate</u> increase in *force production*—in other words, *more repetitions with lighter weight*
- It leads to the following primarily *biochemical* changes most dramatically in type I fibers, but even in type II (**Figure 10.27a**):
  - <u>Increased</u> *oxidative enzymes*, and *mitochondria* (and associated proteins)
  - More <u>efficient</u> use of fatty acids and *other fuels* for ATP production
  - <u>Increased</u> *fatigue* resistance
  - <u>Increases</u> in the *blood vessel network* supplying the muscle

Changes Caused By Physical Training

- **Resistance**, or **strength**, **training** involves a <u>moderate</u> increase in the *frequency* of motor unit activation and a <u>large</u> increase in *force production*—in other words, *fewer repetitions with heavier weight*
  - It causes primarily *anatomical changes*; both the *number* of myofibrils and the *diameter* of the muscle fibers <u>increase</u>, a change called **hypertrophy** (**Figure 10.27b**)

Changes Caused By Physical Training

- With hypertrophy comes a decreased proportion of mitochondrial proteins and blood supply to the muscle, because of *fiber enlargement*, and not because mitochondria or vessels are actually *lost*
- This can decrease *endurance*, so a balanced program combining both types of training is recommended for most people

Changes Caused By Physical Training

- In response to physical inactivity, the diameter of the muscle fiber decreases due to loss of myofibrils, a condition called **atrophy**.
- The amount of oxidative enzymes decreases
- The fiber has a lower capacity for oxidative catabolism
- The result is a decline in both strength and endurance.
- Muscle atrophy is a particular problem for people who are bedridden or have lost the use of their limbs.

Changes Caused By Physical Training

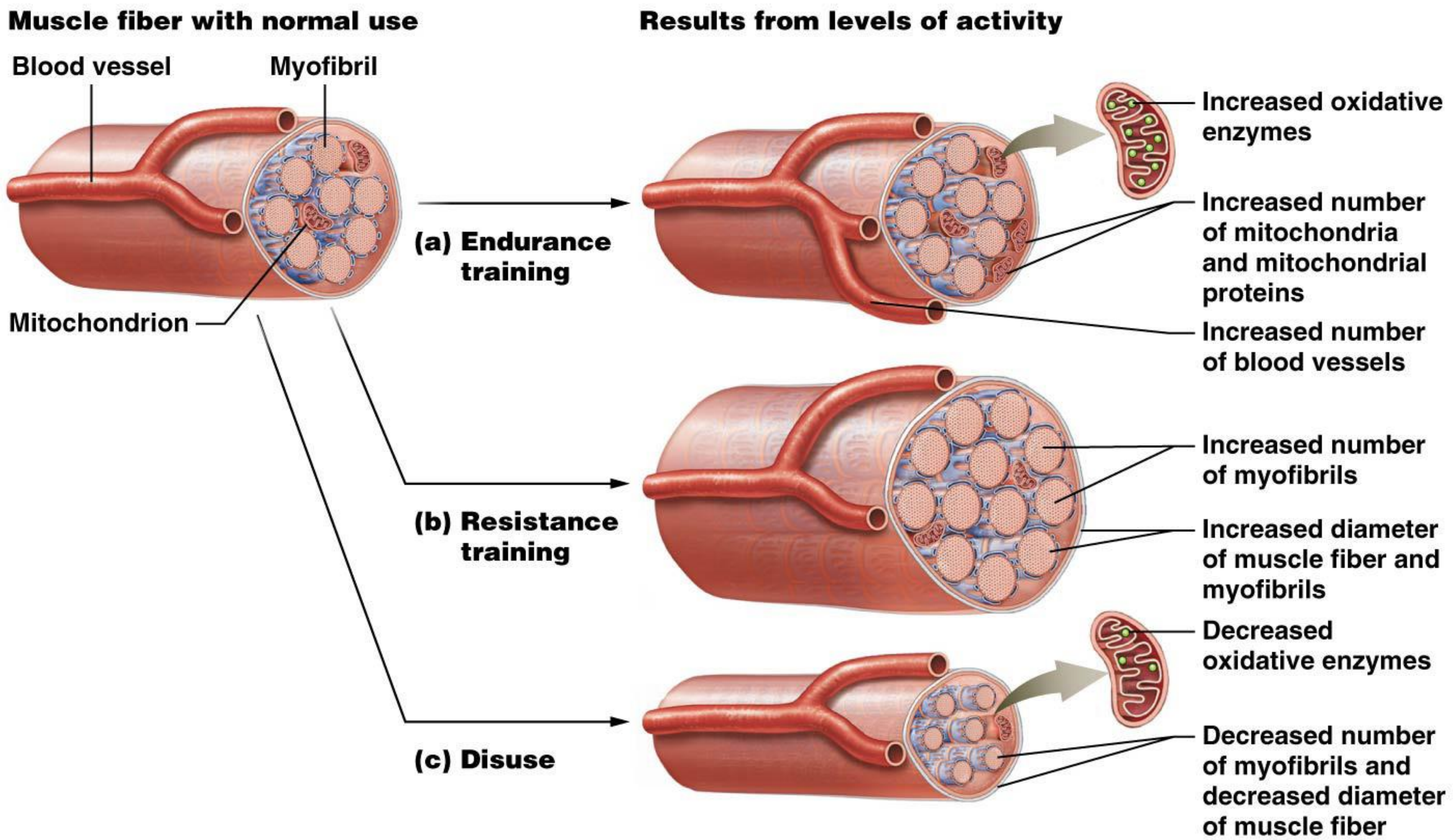


Figure 10.27 Adaptive changes of muscle fibers due to training and disuse.

Muscular Fatigue

- **Fatigue** is the inability to maintain a given level of *intensity* during activity
- Fatigue is a result of *multiple factors*:
  - **The depletion of *key metabolites*** (creatine phosphate, glycogen, and glucose) involved in ATP production
  - **Decreased availability of *oxygen* to muscle fibers** –exercise increases the oxygen requirement of muscle fibers because of the need for more ATP. The amount of oxygen bound to myoglobin may also be depleted by intense exercise, and the amount of oxygen taken in by the lungs may be inadequate to replace it. The muscle fiber must then rely more heavily on the less efficient process of glycolysis to generate ATP.
  - **The accumulation of certain chemicals**
  - **Environmental conditions**,

Excess Postexercise Oxygen Consumption and the Recovery Period

- **Recovery period-** the period of time after exercise that is required to return internal conditions to the pre-exercise state
- The persisting increased *rate of breathing* is called the **excess postexercise oxygen consumption** (**EPOC**)
- EPOC was formerly called oxygen debt or oxygen deficit, but these terms are misnomers, as there is no debt or deficit of oxygen that must be "repaid".
- Physiologists now think that EPOC results from the responses necessary to correct the disturbances to homeostasis that were brought on by exercise.
- To return to homeostasis the body must accomplish several goals: dissipating heat, restoring ion concentrations, and correcting blood pH

Module 10.9 Smooth and Cardiac Muscle

Smooth Muscle

- **Smooth muscle** is widely distributed in the body, typically lining hollow organs, it is also present elsewhere such as in the arrector pili muscle in the dermis and the muscles in the iris of the eye.
- Has the following **functions**:
  - *Propels materials* through hollow organs, a process called **peristalsis**
  - Forms **sphincters** (in the digestive and urinary systems) that control the *passage of materials* by opening and closing
  - ***Regulates flow*** controls the flow of materials through certain hollow organs by changing the diameter of the tubes (such as blood vessels, the respiratory tract, and the gastrointestinal tract),

Smooth Muscle

Smooth muscle cells contain myosin and actin filaments arranged differently than in skeletal and cardiac muscle; there are no *sarcomeres* and no *striations*

- Actin filaments are arranged *obliquely* in the sarcoplasm and are *anchored* to proteins called **dense bodies**
  - Some dense bodies are associated with the sarcolemma, where they attach to the dense bodies of other smooth muscle cells and transmit tension from one cell to the next.
  - Other dense bodies are found in the sarcoplasm, where they are bound to scaffold-like intermediate filaments that connect the dense bodies to one another.

Smooth Muscle

- Several thin filaments radiate from each dense body to surround a *single* thick filament; the *ratio of thin to thick filaments* is <u>higher</u> than in skeletal muscle
  - Both thick and thin filaments are *longer than those in skeletal muscle* and the thin filaments <u>lack</u> troponin
  - The myosin heads have opposite-facing hinges
  - A thick filament contains myosin heads along its entire length

Smooth Muscle

- Smooth muscle cells are structurally different from skeletal muscle fiber in three ways:
- *lack* motor end plates
- the SR is much *less* extensive
- there are *no* T-tubules

Smooth Muscle

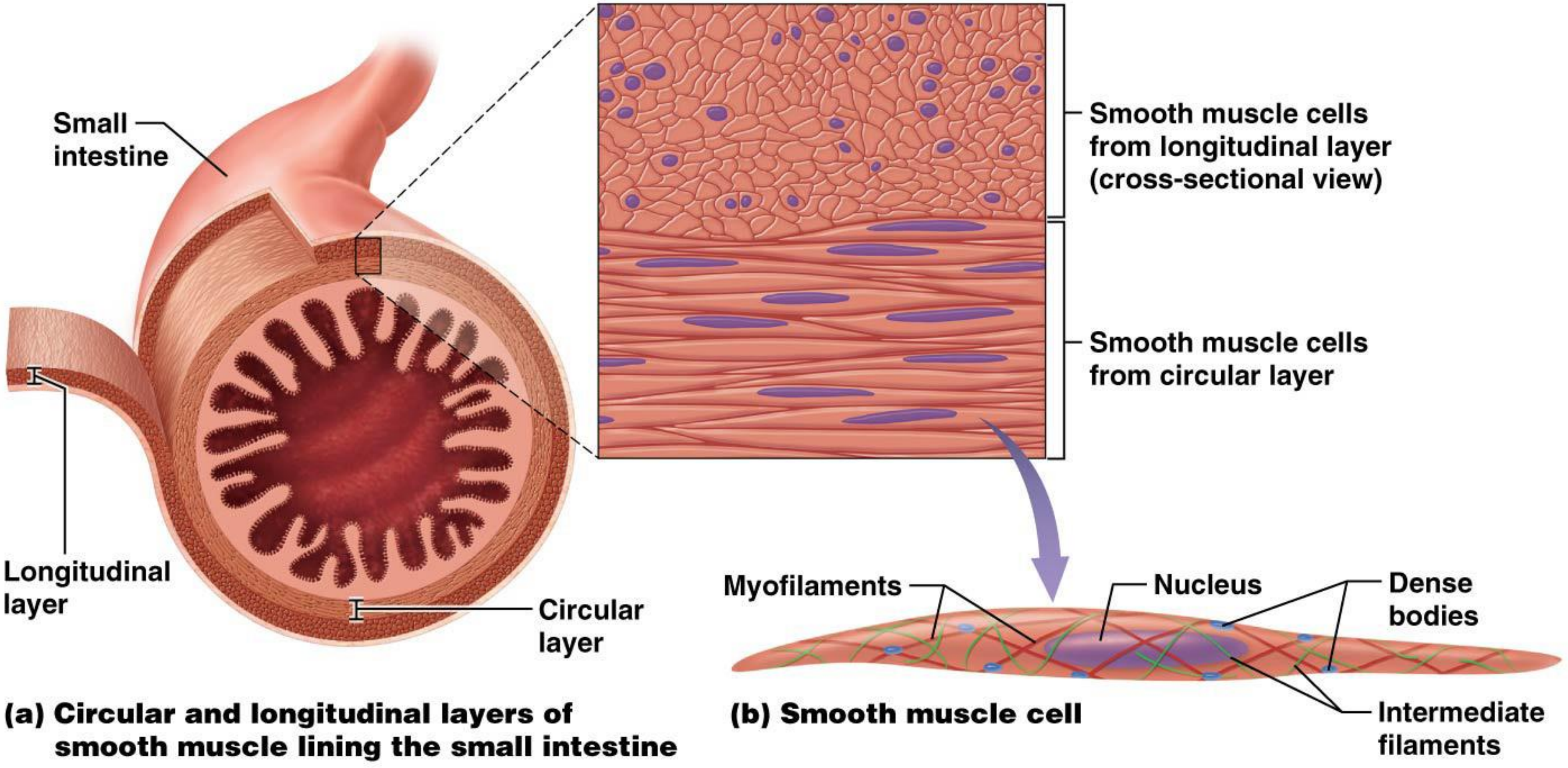


Figure 10.28 Structure of smooth muscle tissue and cells.

Smooth Muscle

Smooth Muscle Contraction and Relaxation (**Figure 10.29**)

- Contraction of smooth muscle involves a different cascade of events:
  1. Calcium ions bind to a protein in the sarcoplasm called **calmodulin (Cam)**
  2. The calcium ion-Cam complex activates and enzyme associated with myosin, called **myosin light chain kinase** (**MLCK**)
  3. MLCK causes activation of myosin ATPase
  4. The crossbridge cycle then begins

Smooth Muscle

Smooth Muscle Contraction and Relaxation (continued):

- As the crossbridge cycles repeat, the crossbridges pull actin along the length of the myosin, and the muscle cell changes shape from long and thin to fat and globular
- Smooth muscles can contract up to *80% of their resting length*, whereas skeletal muscle can only contract a maximum of 30–40% of their resting length
- Most smooth muscle cell contractions consume as little as 1/100 the amount of ATP used by skeletal muscle fibers.

Smooth Muscle

Smooth Muscle Contraction and Relaxation (continued):

- Relaxation begins with removal of Ca^{++} from the cytosol, as this concentration declines, calcium ions dissociate from calmodulin, and MLCK is inactivated.
- At this point, the muscle cell either relaxes or enters the the **latch state,** during this state, the muscle cell maintains tension while consuming very little ATP. The latch state is very important in terms of the ability of smooth muscle to maintain a state of energy-efficient sustained contraction, as is found in **sphincters**, which must stay contracted to remain closed.

Smooth Muscle

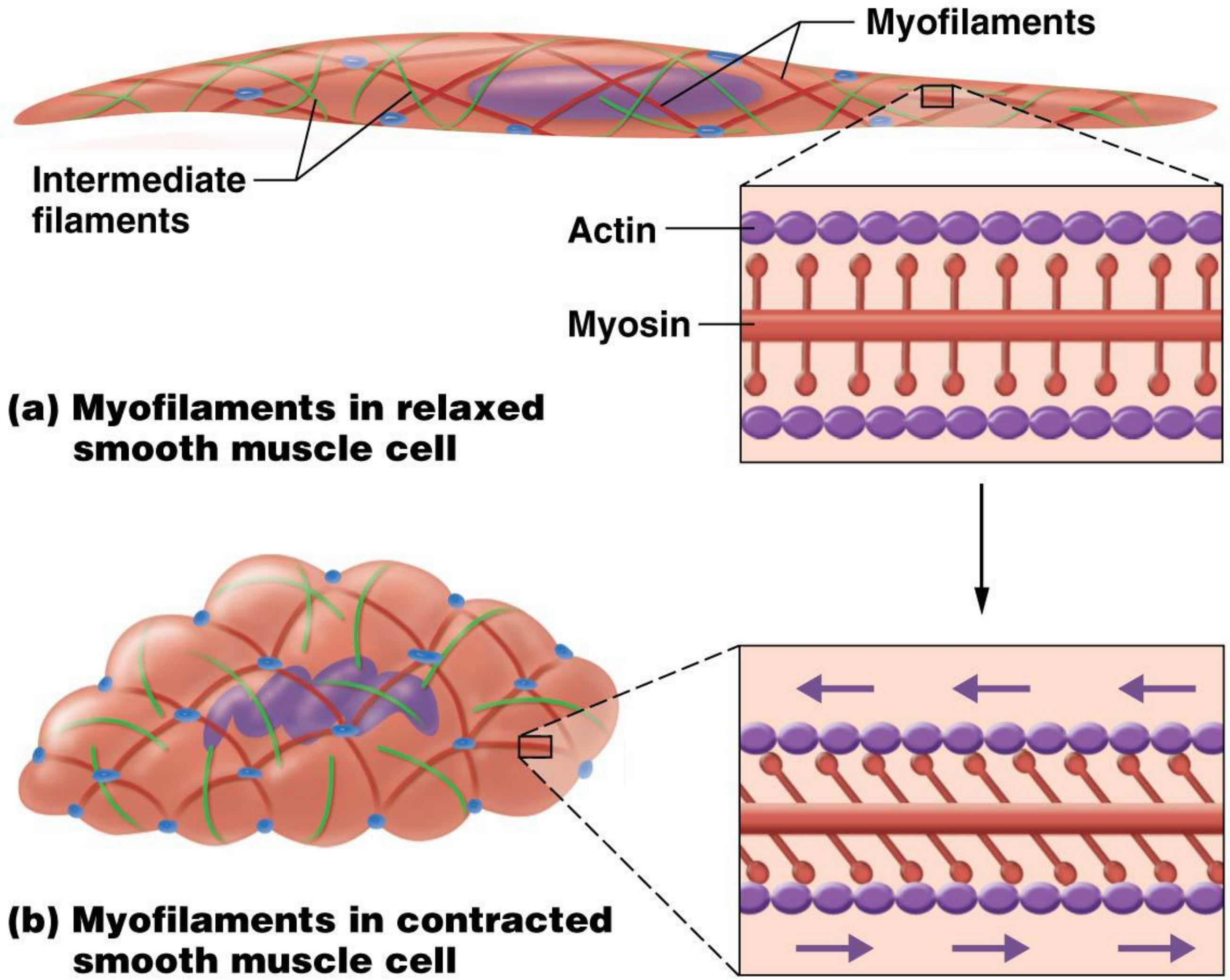


Figure 10.29 Contraction of smooth muscle cells.

Smooth Muscle

Two general types of smooth muscle:

- **Single unit (or unitary) smooth muscle**
  - AKA visceral smooth muscle
  - The *predominant type* in the body
  - Found in nearly all hollow organs
  - Consists of hundreds to thousands of muscle cells whose plasma membranes are linked electrically via gap junction.
  - Action potentials spread rapidly though the cells via the gap junctions, causing the muscle cells to contract in a coordinated wave as a single unit.
  - Able to respond to multiple types of stimulation

Smooth Muscle

Types of Smooth Muscle (continued):

- **Multi-unit smooth muscle**:
  - <u>Less</u> common than single-unit smooth muscle
  - Found in the uterus, eye muscles, and dermis (arrector pili muscles)
  - Made up of <u>individual</u> muscle cells (not joined by gap junctions) that contract *independently* to allow for precision
  - The amount of tension produced by this type of smooth muscle varies with the *number of cells activated* (as in skeletal muscle)
  - Responds primarily to *nerve stimulation*

Cardiac Muscle

- Cardiac muscle cells more closely resemble skeletal muscle: both are striated and consist of sarcomeres, have T-tubules and extensive networks of SR
- *Differences*:
  - Shorter, branched cells with one or two nuclei and abundant myoglobin
  - Mitochondria account for 30% of the cytoplasmic volume
  - **Intercalated discs** link cells together, contain **gap junctions** and **desmosomes**, join cardiac muscle cells *electrically and physically*, permitting the heart to contract as a *coordinated unit*

Cardiac Muscle

- Unlike skeletal muscle fibers, cardiac fibers do <u>not</u> require stimulation from the nervous system to generate action potentials; their electrical activity is coordinated by a small population of **pacemaker cells**
- Cardiac pacemaker cells rhythmically and spontaneously generate action potentials that trigger the remaining cardiac muscle cells to have action potentials as well.
- This allows cardiac muscle tissue to be **autorhythmic**, it sets its own rhythm.

REMEMBER…….
Cell Junctions

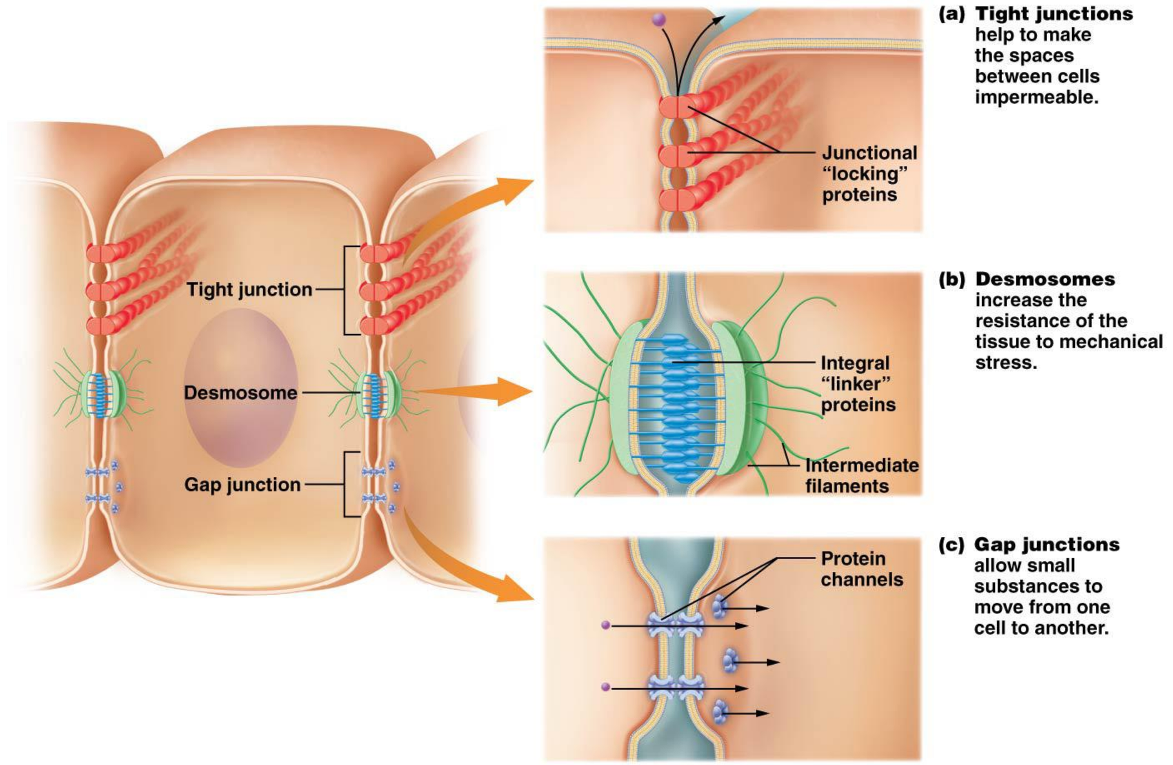


Figure 4.2 Cell junctions.

FLASHBACK………

- ___________ – anything that has *mass* and *occupies space*; can exist in *three states*: **solid**, **liquid**, or **gas**
- ___________ – study of matter and its interactions

- **Matter** – anything that has *mass* and *occupies space*; can exist in *three states*: **solid**, **liquid**, or **gas**
- **Chemistry** – study of matter and its interactions

- _____________– found in central core of atom (atomic nucleus); *positively* charged
- _________– found in atomic nucleus; slightly larger than protons; *no charge*.
- __________– found outside atomic nucleus; *negatively* charged

- **Protons** (**p^+**) – found in central core of atom (atomic nucleus); *positively* charged
- **Neutrons** (**n^0**) – found in atomic nucleus; slightly larger than protons; *no charge*.
- **Electrons** (**e^-**) – found outside atomic nucleus; *negatively* charged

- ________ _________– *regions* surrounding atomic nucleus where *electrons exist*; each can hold a certain number of electrons:
    - **1st shell** (closest to nucleus) can hold ___ *electrons*
    - **2nd shell** can hold ____ *electrons*
    - **3rd shell** can hold 18 electrons but “satisfied” with ____
- Some atoms may have <u>more</u> than 3 shells

- **Electron shells** – *regions* surrounding atomic nucleus where *electrons exist*; each can hold a certain number of electrons:
    - **1st shell** (closest to nucleus) can hold ***2*** *electrons*
    - **2nd shell** can hold ***8*** *electrons*
    - **3rd shell** can hold 18 electrons but "satisfied" with **8**
- Some atoms may have <u>more</u> than 3 shells

- The human body is made up of *four major* elements:
  - **Hydrogen**
  - **_________**
  - **Carbon**
  - **_________**

- The human body is made up of *four major* elements:
  - **Hydrogen**
  - **<u>Oxygen</u>**
  - **Carbon**
  - **<u>Nitrogen</u>**

- There are 3 basic types of mixtures: _________, ________, and _____________ .

- There are 3 basic types of mixtures: **suspensions**, **colloids**, and **solutions**