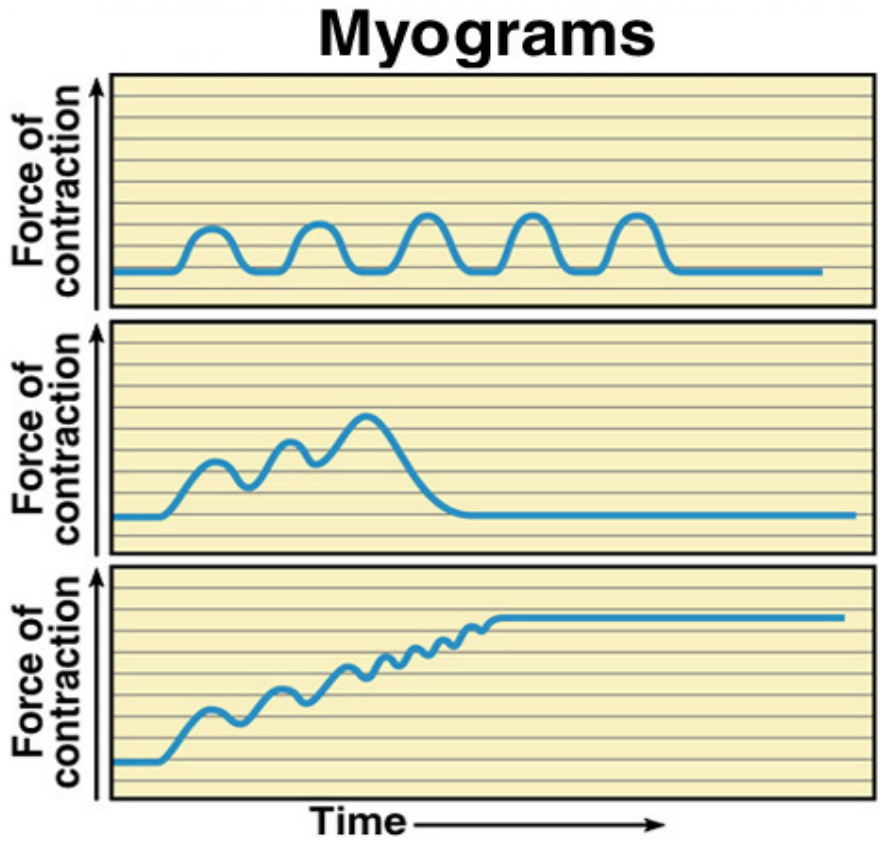
BIO 211:

ANATOMY & PHYSIOLOGY I



CHAPTER 09

MUSCULAR SYSTEM

Part 2 of 2

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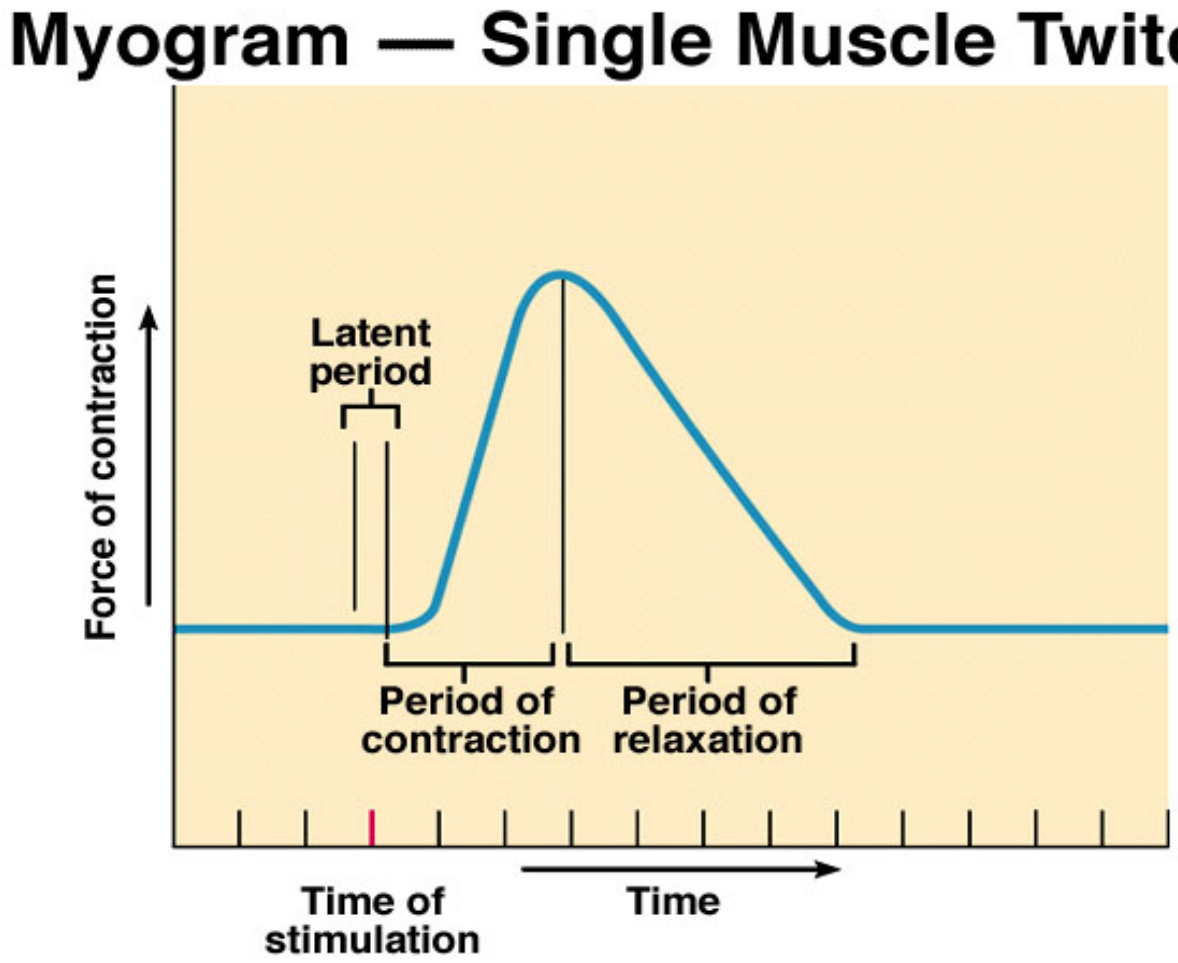
Some illustrations are courtesy of McGraw-Hill.

Naugatuck Valley Community College



LATENT PERIOD

No visible change occurs in the muscle fiber during (and immediately following) the action potential. This period, called the **latent period**, lasts from 3–10 msec.

Behavior of Whole Muscles

A. Threshold, Twitch and Latent Period

See the previous slide !

1. Muscles have a **threshold**, or ***minimal voltage necessary to produce a muscle contraction.***

2. If a muscle is given a **single, brief stimulation**, it will show a **cycle** of contraction and relaxation, called a ***twitch***.
   During the **twitch**, it has a **contraction phase** followed by a **relaxation phase.**

3. **Latent Period:** **No *visible* change in muscle during and slightly after an action potential (3 – 10 msec).**

Behavior of Whole Muscles

B. Graded and "ALL or NONE" response

1. The muscle **fiber** **(not the whole muscle!)** exhibits a **maximum contraction response** **or it exhibits none at all**, a phenomenon called the ***all-or-none law*****.**

2. The **strength** of contraction of a **whole** muscle is **graded** as more ***motor units join in.***

   Recall Motor Unit from Part 1:

   A motor neuron + all the fibers it innervates

Behavior of CARDIAC Muscles

First discovered in Cardiac muscle but ALSO OBSERVED during "warm "up" period of skeletal muscle!

C. TREPPE

Muscle cells exhibit **treppe**, or the ***staircase phenomenon***, in response to a **series of stimuli of the same strength.**

This is probably due to the inability of the muscle cells to fully return calcium to the sarcoplasmic reticulum.

The occurrence of a successive increase in amplitude of the first few contractions of **cardiac muscle** that has received a number of stimuli of the same intensity following a quiescent period. Also called *staircase phenomenon*.

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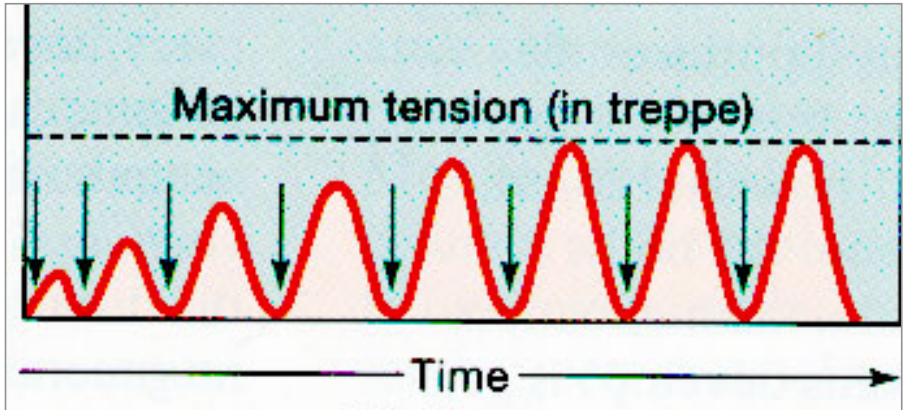
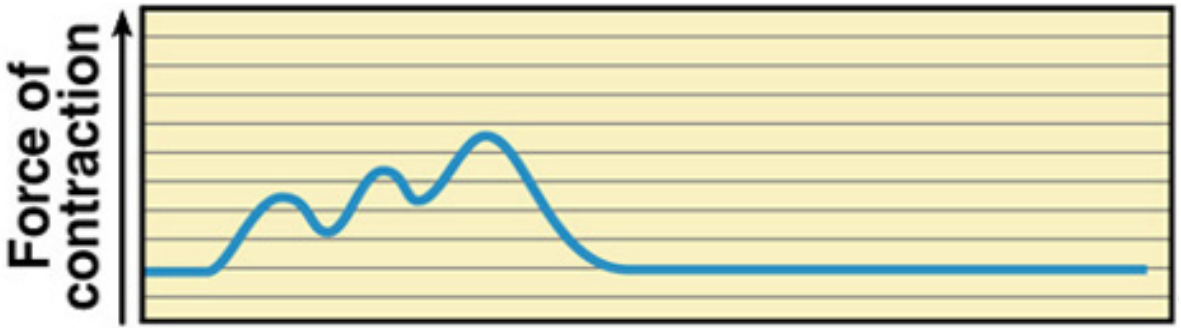


Behavior of Whole Muscles

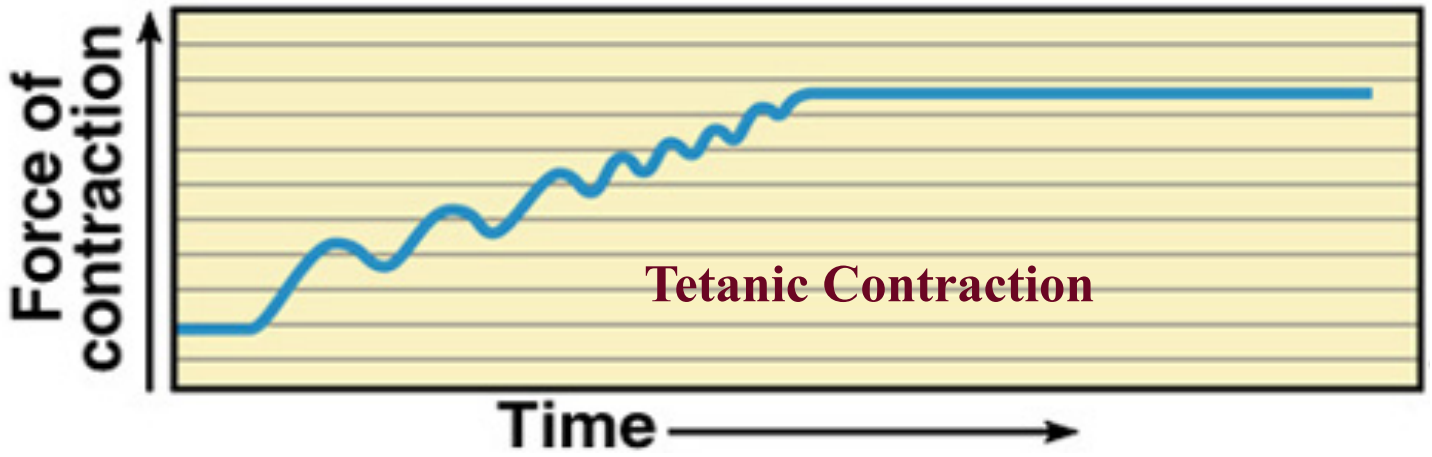
D. Refractory Period *and* Temporal Summation

* Refractory Period: After a twitch, this is the brief (1–2 msec) period needed to restore the resting potential. During this time, the sarcolemma is repolarizing and will not respond to a new stimulus.
* If a second stimulation arrives **before** the complete relaxation of a muscle, the muscle will achieve **temporal summation** (or ***wave summation***) and achieve a ***higher level of tension***.



Behavior of Whole Muscles

E. Tetanus

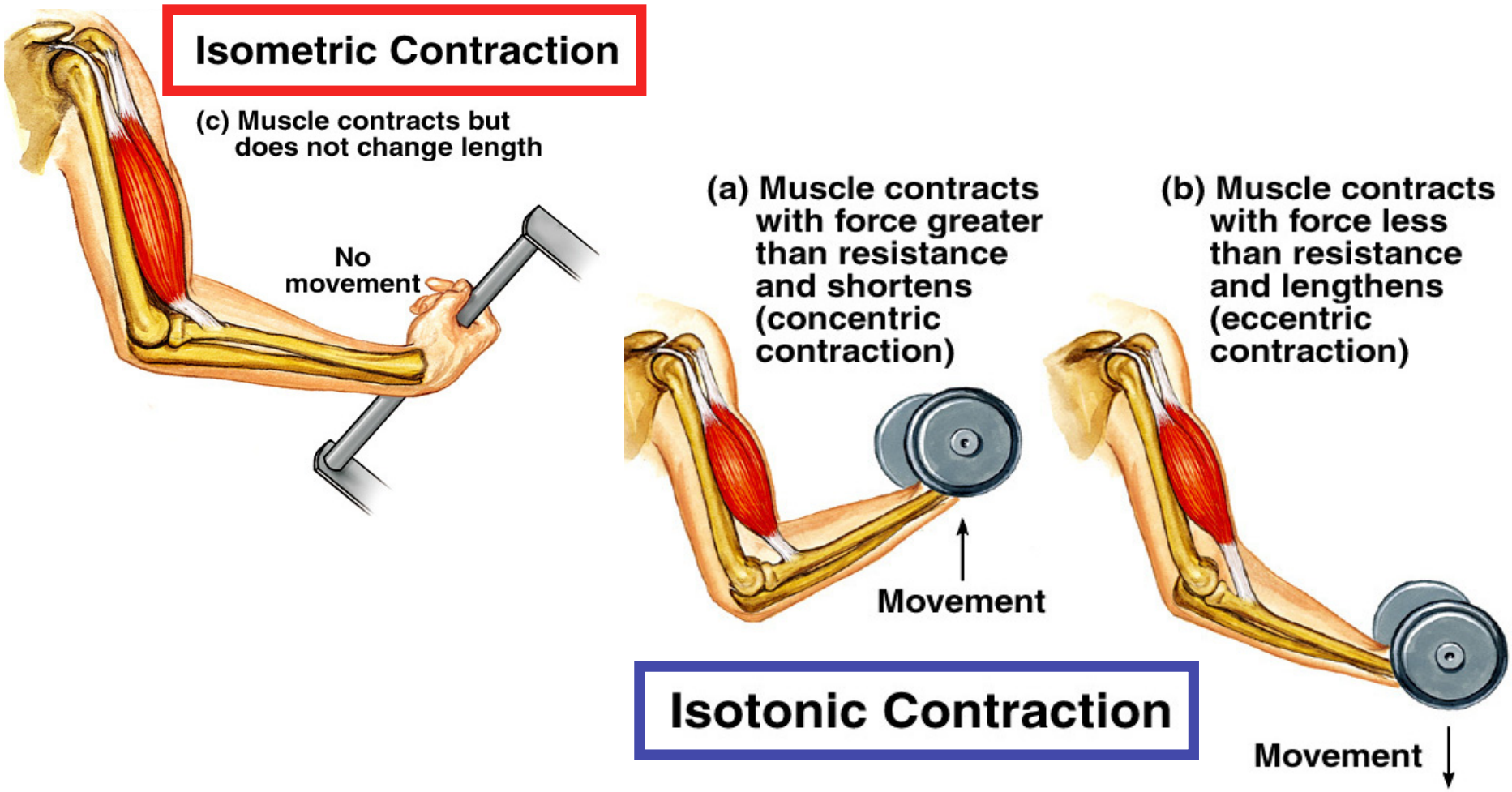


* If the stimuli are **frequent** enough that the muscle **cannot relax completely in between,** a state of ***incomplete*** **tetanus** is reached.

If there is **no time to relax *at all*** between stimuli, ***complete*** **tetanus** is achieved.

Behavior of Whole Muscles

F. Isometric vs. Isotonic Contraction



Muscle Metabolism

A. Energy Transfer

1. During exercise, muscles use energy produced by **aerobic respiration** (when there is an adequate supply of oxygen) and **anaerobic fermentation**, when oxygen is limited, and **lactic acid** accumulates.

2. **Immediate Energy**
   For short, quick spurts of energy, muscle tissue relies on the **phosphagen** system to supply ATP.
   This includes **myokinase** and **creatine kinase** that ***recruit phosphate groups.***

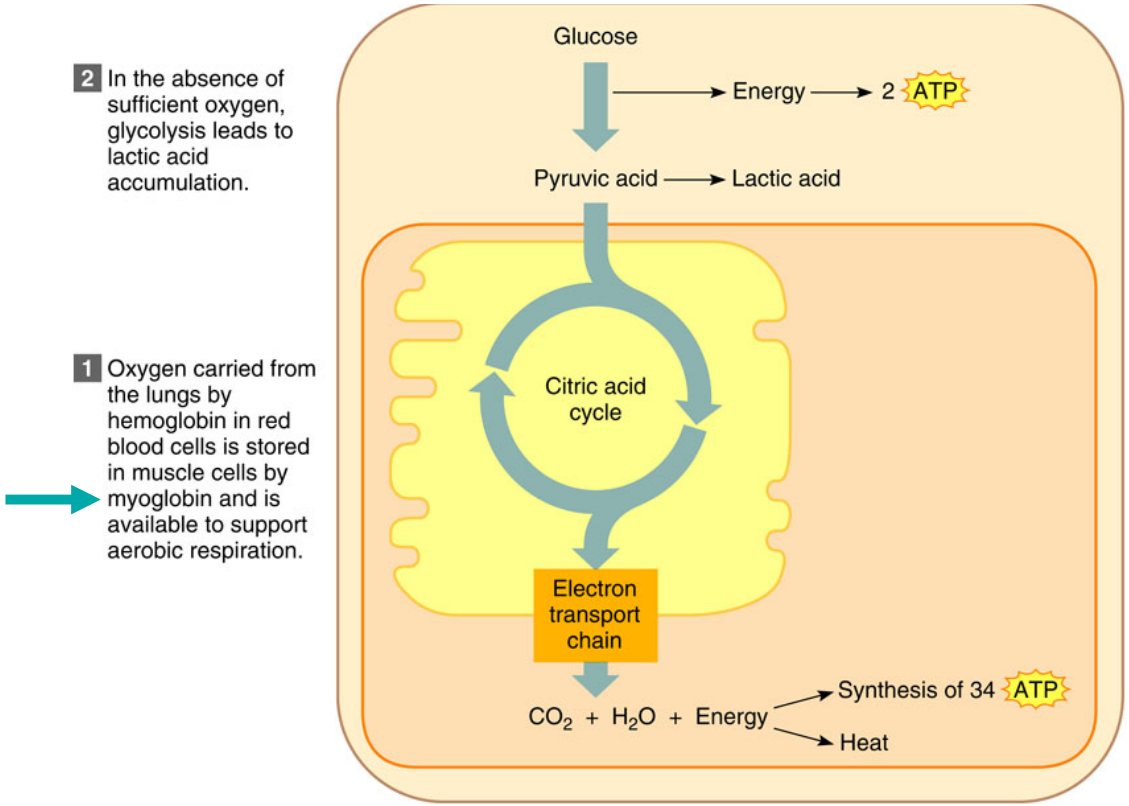
3. **Short-Term Energy**
   After the phosphagen system is exhausted, muscles rely temporarily on the **glycogen-lactic acid pathway** for ATP to supply energy for 30-40 seconds.

Muscle Metabolism

A. Energy Transfer

4. Long-Term Energy

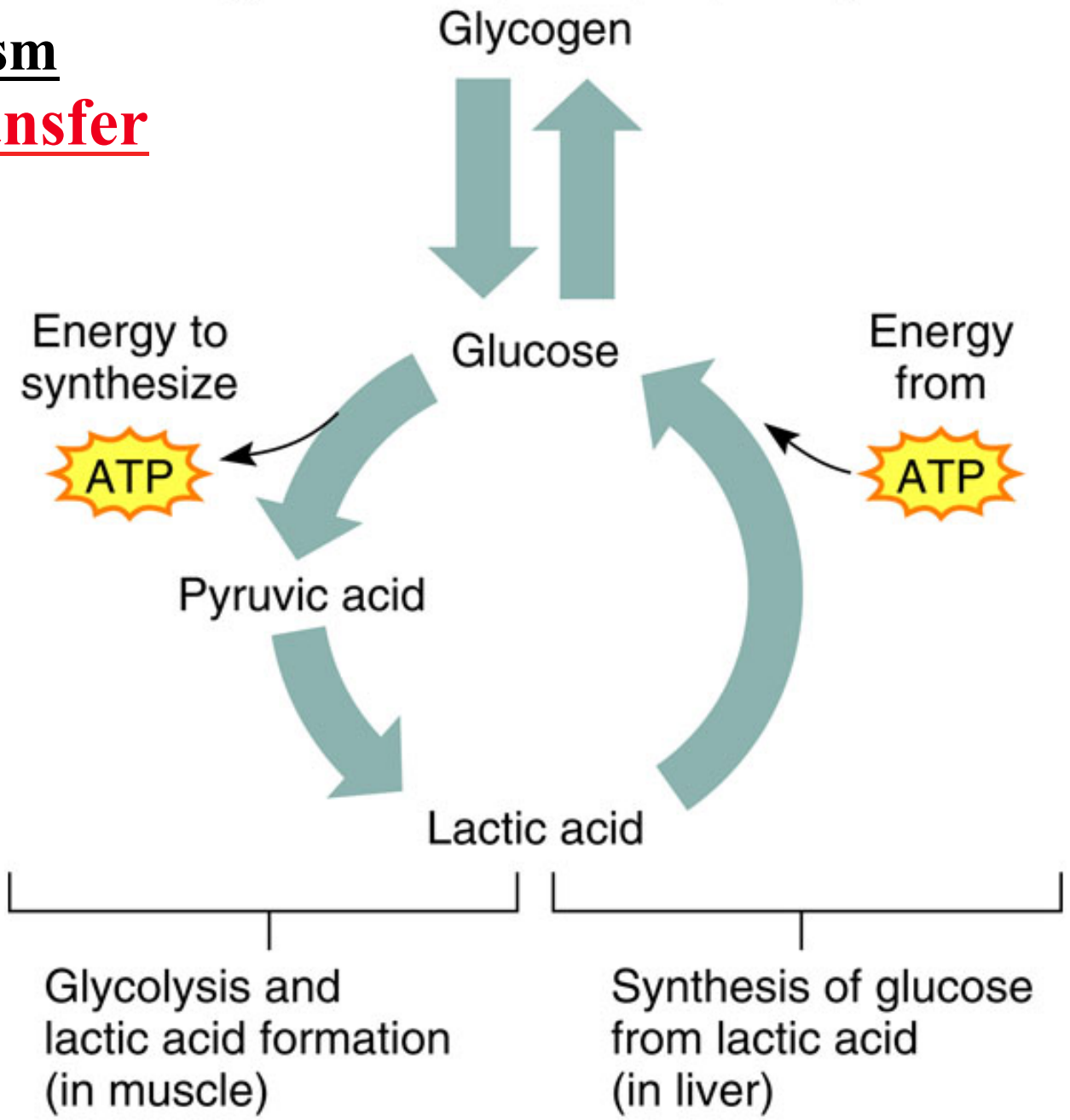
After 40 seconds, the respiratory and cardiovascular systems catch up and deliver enough oxygen to meet the demands of aerobic respiration. **Aerobic respiration** can supply muscle demands for **longer periods** of activity. **(see Myoglobin below)**



Muscle Metabolism

A. Energy Transfer

Conversion of Lactic Acid to Glucose



Muscles: Other Factors and Considerations

A. Fatigue and Endurance

1. **Muscle fatigue, the progressive weakness and loss of contractility, is due to a variety of causes:**

   - **ATP synthesis declines** as glycogen is consumed, the ATP shortage slows down the cell's ability to **maintain** the resting membrane potential **(remember Na^+/K^+ pump??)**

   - **accumulation of potassium ions reduces the membrane potential;**

   - **lactic acid lowers the pH of the sarcoplasm and impairs the action of enzymes;**

   - **motor nerve fibers use up their ACh, and the CNS fatigues for unknown reasons.**

2. Physical endurance depends on the maximum **oxygen uptake** of the athlete & the supply of **organic nutrients**.

Muscles: Other Factors and Considerations

B. Oxygen Debt

1. **Oxygen debt** is the ***difference*** between the **resting state of oxygen consumption** and the **elevated rate following an exercise.**
2. Oxygen inhaled **after exercise** is used to replace the body's oxygen reserves, replenish the phosphagen system, oxidize lactic acid, and serve the now elevated metabolic rate

C. Muscular Strength

Muscle strength depends on:

muscle size
fascicle arrangement
size of active motor units
multiple motor unit summation (recruitment).
temporal summation (wave summation).

Muscles: Other Factors and Considerations

D. Slow- and Fast-Twitch Fibers

1. **Slow-twitch fibers** are small and produce twitches up to 100 msec long.
   They have more mitochondria and capillaries,
   and are **high-endurance fibers**.
   Impart a **red**, or "dark-meat" quality to muscles.

2. **Fast-twitch fibers** are **larger** and produce twitches as short as 7.5 msec. They produce **quick energy** (phosphagen system) for stop-and-go activities.
   These fibers impart a **white** appearance to muscles.

3. **Individuals are born with different ratios of slow to fast-twitch fibers.**
   Athletic conditioning cannot change the genetic component of ability.

Muscles: Other Factors and Considerations

E. Muscular Conditioning and Atrophy

1. **Resistance** exercise (weight lifting) is the contraction of muscles **against a load** that resists movement, and is enough to **stimulate muscle growth.** Growth results mostly from **cellular enlargement, *not cell division.***

2. **Endurance (aerobic)** exercise improves the fatigue-resistance of the muscles. **Slow-twitch fibers acquire a greater density of blood capillaries.**

3. Optimal performance and skeletomuscular health require **cross - training**, which incorporates elements of **both types *(endurance* + *resistance)*.**

Muscles: Other Factors and Considerations

F. Delayed Onset Muscle Soreness

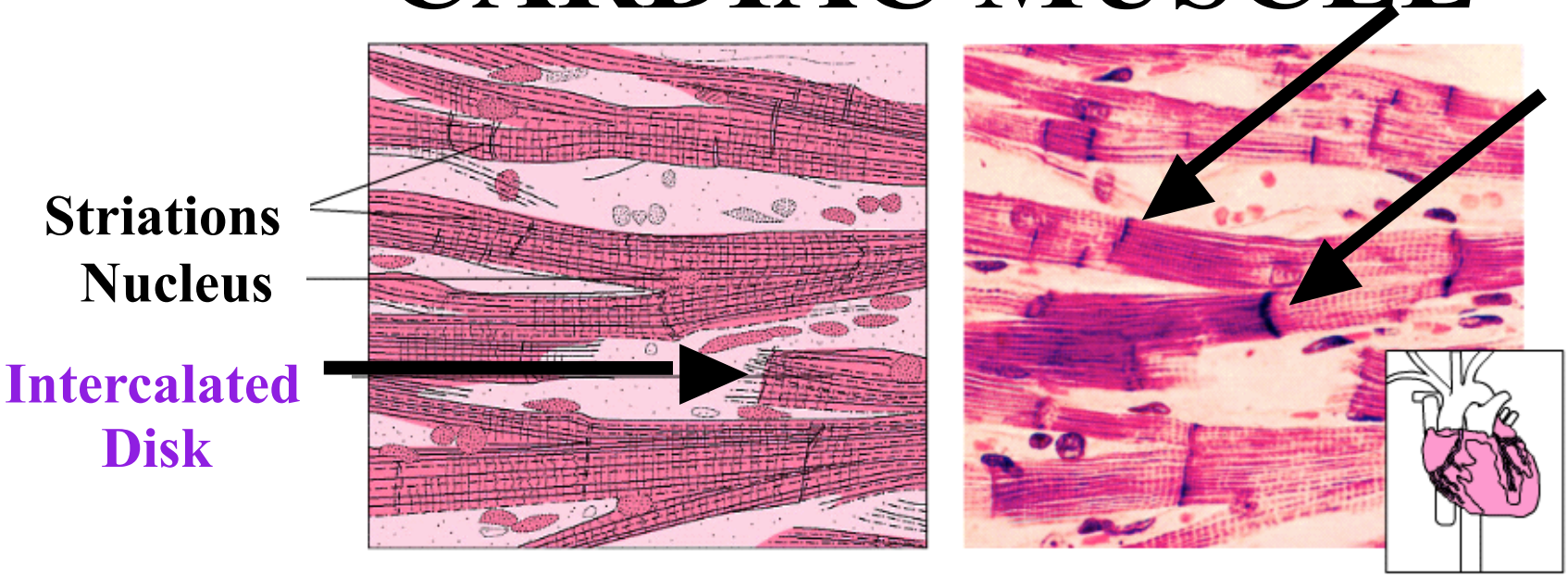
Delayed onset muscle soreness is unusual pain, stiffness, or tenderness that is felt several hours to a day **after** strenuous exercise.
This is due to muscle **microtrauma.**

G. Cramps

The **central nervous system** (Brain + Spinal Cord) occasionally triggers painful, **spasmodic contractions (cramps).** These are initiated by:

extreme cold
heavy exercise
lack of blood flow
electrolyte depletion
dehydration
low blood glucose.

CARDIAC MUSCLE



Cardiac muscle tissue is only in the heart. Its cells, which are striated, are joined end-to-end. The resulting muscle fibers are branched and connected in complex networks. Each cell within a cardiac muscle fiber has a single nucleus. Where it touches another cell is a specialized intercellular junction called an intercalated disk, seen only in cardiac tissue.

Intercalated Disks of Cardiac Muscle

Smooth Muscle

A. Types and Functions

1. **Multiunit smooth muscle** occurs in ***some*** **arteries** and **pulmonary air passages,** in the **arrector pili,** and **iris.** The terminal branch of an **axon synapse with individual muscle cells and form a motor unit.**

2. In **single-unit smooth muscle**, a nerve fiber ***does not synapse with a particular cell*** but rather releases **neurotransmitter at several points** within the tissue.

   Single-unit smooth muscle cells also communicate electrically with each other through **gap junctions**. This type of muscle is also called ***visceral muscle***.

3. Within the digestive tract, an inner circular layer and outer longitudinal layer of visceral muscle produce **peristalsis.**

Smooth Muscle

B. Microscopic Anatomy

1. A smooth muscle cell is **fusiform**, short, and **uninucleate**.
   There are **no visible striations**; Z discs are absent.
   Instead, thin filaments attach to dense bodies.

2. ***There is scanty (little) sarcoplasmic reticulum, and no T tubules.***
   Calcium enters through channels in the sarcolemma.

Smooth Muscle is innervated in an involuntary fashion by the ANS (Autonomic Nervous System).

We will cover that network during our final chapter of BIO 211.

Smooth Muscle

C. Gap Junctions and Pacemakers

1. Single-unit muscle cells can *electrically stimulate each other through their* ***gap junctions***, producing a wavelike contraction in the tissue as a whole.
2. The **first cells to contract** act like ***pacemakers,*** setting off nearby cells.

D. Contraction and Relaxation

1. **Contraction** is triggered by an **influx of calcium ions**; most of it comes in **from extracellular fluid.**
2. There is **no troponin** in smooth muscle; there is **calmodulin** instead to which calcium ions attach.

Smooth muscle has a latch-bridge mechanism that enables the myosin to remain attached to the actin for some time **without** expending more energy from ATP. Smooth muscle is **very resistant to fatigue,** allowing for smooth muscle tone.

Postscript:

Muscular dystrophy is a collective term for a number of hereditary diseases causing muscles to degenerate. The most common form is **Duchenne muscular dystrophy**, caused by a sex-linked recessive gene.

Last Slide