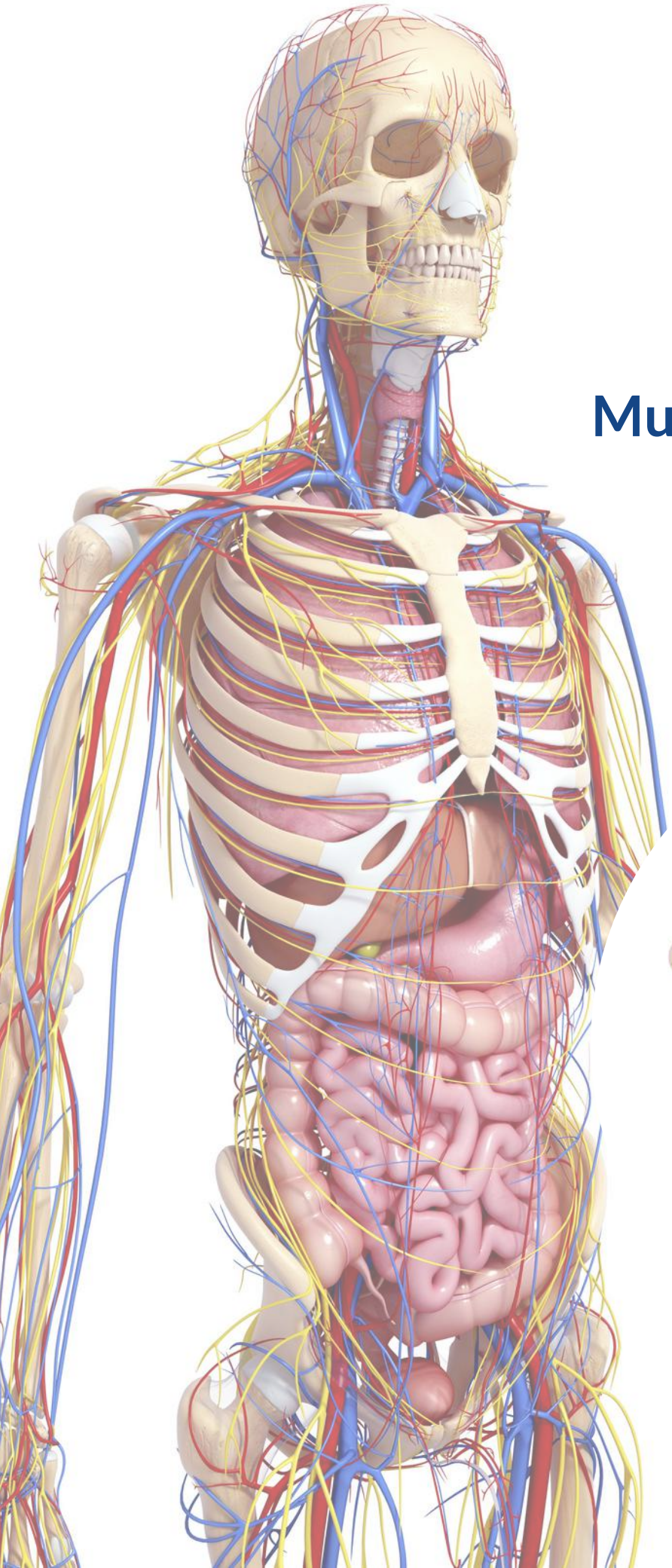

Musculoskeletal System Lesson Plan

Grade 12

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The following unit plan was created in accordance with the Canadian Council on Animal Care's recommendations to replace any present procedures involving the use of animals in teaching, testing and research.

The Three Rs principle of Replacement states, if you can meet your scientific or educational goals without the use of animals, it is your ethical obligation to use non-animal methods. Grade 12 anatomy content is often taught using fetal pigs - here we offer an effective and humane alternative.

This is in alignment with the public's concern for animal welfare and a cultural respect for animals passed down from the Aboriginal perspectives of the First Peoples.

Elisabeth Ormandy created this unit plan and series of lesson plans for your use in teaching life science content to Grades 12 based on the BC Science Curriculum.

These Humane Science Education materials were developed to provide equivalent or greater standards in education for Canadian youth, without the use of animals.

Curriculum Alignment

This lesson plan can be used to create classes for Grades 12 based on the BC Science Curriculum. Specific **Big Ideas** covered in this lesson plan include:

Grade 12 - Organ systems have complex interrelationships to maintain homeostasis.

ORGAN SYSTEMS:

- Structure and function
- Structural and functional interdependence
- Maintenance of homeostasis

We have recommended specific virtual anatomy tools to use to get the most out of the unit plan. You'll find links to those on pages 5 & 6.

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Lesson Plan Overview

Subject: Science

Unit Overview: Anatomy and Physiology

Unit Duration: ~90 minutes

Grade: 12

Big Idea: Organ systems have complex interrelationships to maintain homeostasis

Curricular Competencies

- *Analyze cause-and-effect relationships*
- *Construct, analyze, and interpret graphs, models, and/or diagrams*
- *Consider the changes in knowledge over time as tools and technologies have developed*

Content

- By the end of this lesson, students are expected to demonstrate understanding of the following:
  - *Musculoskeletal system:*
    - *structure and function*
    - *structural and functional interdependence*
    - *maintenance of homeostasis*

Recommended Education Tools

Hardware & Workbooks:

This inventory is for a regular in-person class - use x1 iPad/tablet per student for responsible physical distancing. If teaching online, teachers can screen share their iPad/tablet or desktop.

- 6 (or more) iPads or other tablets
- 6 (or more) 3D Anatomica workbooks

Recommended Software:

- 3D Anatomica: https://3danatomica.com
- 3D4Medical Complete Anatomy: https://3d4medical.com

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Lesson Plan Overview

Topic: Organ systems have complex interrelationships to maintain homeostasis. Homeostasis is maintained through physiological processes.

Content: The human musculoskeletal system: organs, structure and function

Goals	Students will be able to: • Describe the function of the musculoskeletal system and its major components. • Describe the relationships between the different components of the musculoskeletal system. • Explain how the musculoskeletal system is interdependent with the nervous system. • Explain how the musculoskeletal system maintains homeostasis in the body.
Objectives	After this lesson students will state the structure and function of each tissue in the musculoskeletal system and explain how the musculoskeletal system is interdependent with other body systems.
Materials	• 3DAnatomica • 3D4Medical
Introduction	Using the 3DAnatomica and/or 3D4Medical app(s), the teacher will introduce the topic of the musculoskeletal system.
Development	Questions to support inquiry-based learning: • What is the advantage of having specialized tissues in the musculoskeletal system? • How does the musculoskeletal system help the body maintain internal balance during exercise? • What are the impacts of external stimulants (e.g. alcohol, caffeine) on the musculoskeletal system? • What lifestyle decisions would you make to improve your musculoskeletal health? • How does the musculoskeletal system respond to infection by a pathogen?
Practice	Students will work independently or in pairs to navigate 3DAnatomica and/or 3D4Medical to learn about the structure and function of the musculoskeletal system.

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Lesson Plan Approach

If teaching regular in-person classes:

- Split students into **6 groups**.
- Give each group a **3D Anatomica workbook** to refer to, and one (or more) iPad(s) or tablet(s) with the **3D Anatomica app**, and **3D4Medical Complete Anatomy app** loaded and ready to use.
- Your **introduction** should include discussion of the function of the musculoskeletal system, identifying its major components, and the vocabulary you would like students to learn (~ 15 mins). **Define homeostasis**. Have the students follow along using the 3D4Medical Complete Anatomy app.
- Have students **label "Major Structures"** diagram using 3D4 Medical
- **Discuss the function** each major structure in the musculoskeletal system. Have students use the 3D Anatomica and 3D4Medical Complete Anatomy app to fill their 3D Anatomica workbook and/or handouts provided. This can be student or teacher led. (30 mins)
- Go through bone and muscle anatomy and function as a group, following along using the **models in the apps,** then ask students to summarize each stage .
- Ask students to brainstorm **ways the musculoskeletal system interacts with other systems,** and go over the specific examples provided
- Discuss different ways the musculoskeletal system helps maintain homeostasis using examples provided, then ask students to provide their own examples using what they've learned.
- **Close the class with a 20-minute recap** of what the students have learned, discuss how the parts of the musculoskeletal system work together, and check for understanding. Begin a **conversation on ethics** of animals in science using the questions provided.

If teaching a physically-distanced class:

- Use x1 iPad for each student and proceed as per the directions above.

If teaching online:

- Lead the students through the musculoskeletal system by screen sharing your own iPad/tablet or desktop with the 3D4Medical Complete Anatomy app installed, filling out the tables, and labeling the models as you go
- Proceed as per the directions above

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Detailed Lesson Plan & Teaching Notes

Introduction to the Lesson

Include a First Nations land acknowledgement and ask students to reflect on what respect for animals means to them. Provide an introduction to the apps and models that will be used in class. Provide an overview of how to access student anatomy workbooks if teaching remotely.

What is Homeostasis? Discuss with Students

In biology, **homeostasis** refers to the body's ability to maintain a stable internal environment despite changes in external conditions.

Introduction to the Topic

Students will use the **3D4Medical Complete Anatomy** app to explore the musculoskeletal system at large. If you are teaching remotely (i.e. online), you can use this time to do a Kahoot quiz! We recommend covering the function of the musculoskeletal system, identifying the major components of the system, and discussing the vocabulary you would like the students to learn early in the lesson.

THE MUSCULOSKELETAL SYSTEM AT-A-GLANCE

Function	The musculoskeletal system enables movement (with the muscle system), and helps to maintain body temperature.
Components	Bones, muscles (skeletal, smooth, cardiac), tendons, ligaments, fascia
Important vocabulary	bone, long bone, short bone, flat bone, irregular bone, hinge joint, ball and socket joint, gliding joint, pivot joint, fixed joint, condyloid joint, osteogenic cells, osteoblasts, osteocytes, osteoclasts, flexion, extension, agonist, antagonist, ligament, tendon, cartilage, sprain

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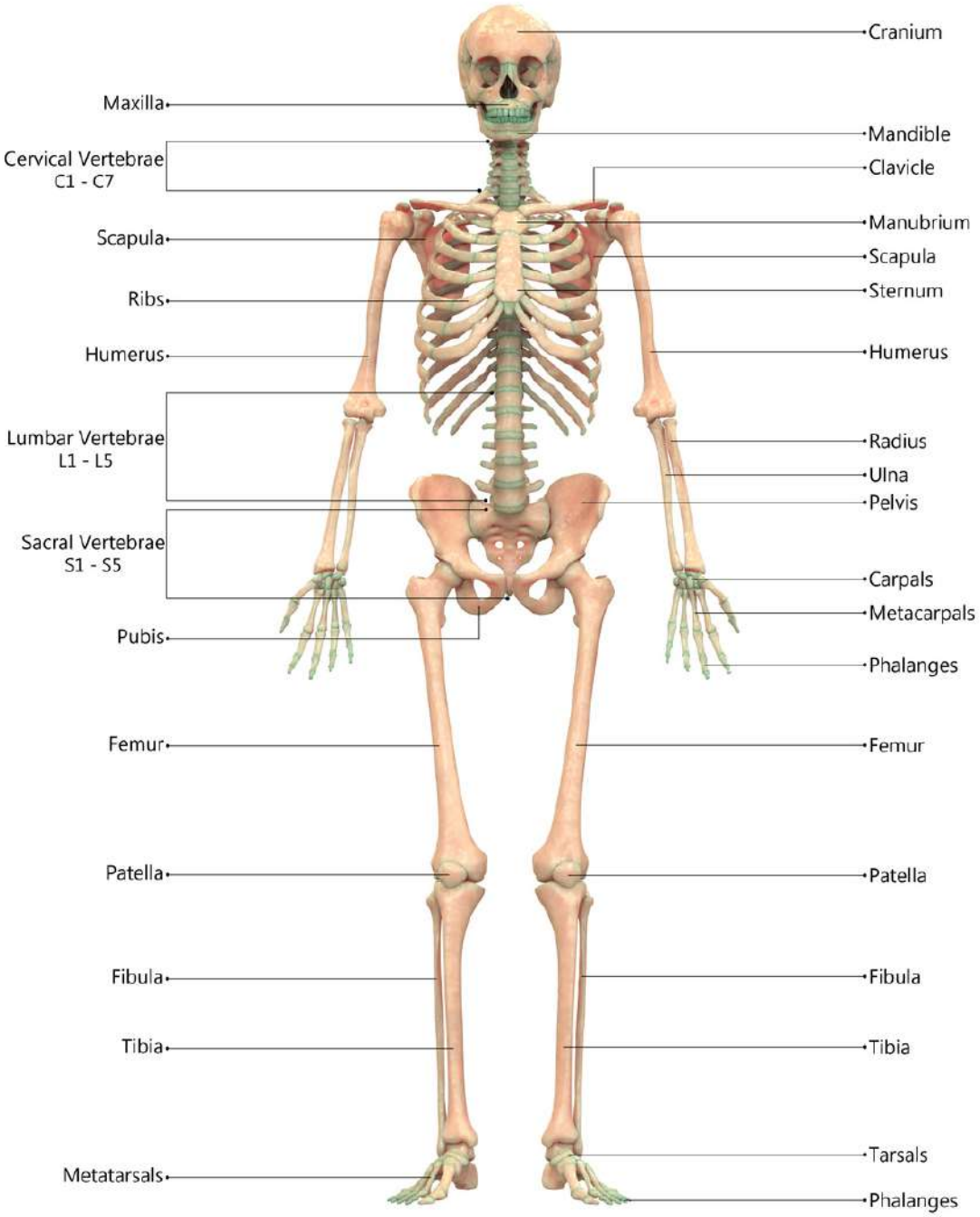
Components in Detail:

Human skeleton (teacher copy)



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Human skeleton (student activity)

Label as many bones as you can on this diagram of the human skeleton

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Components in Detail:

Bone Types & Function

Bones come in different shapes and sizes, and are based on their functions. For example, short, slender bones in your fingers allow your fingers to move and grasp things.

Types of bones:

- **Long bones** - found in the legs and arms
- **Short bones** - found in the fingers and toes
- **Flat bones** - found in the skull and pelvis
- **Irregular bones** - found in the spine and ears

Joint Types & Function

The amount of bone movement at a joint varies. For example, joints in the skull are not movable, while joints in the shoulder allow a wide range of motion. Joints are classified by the type of movement they allow and the shapes of their parts:

- **Ball-and-socket joints**, found in the shoulders and hips, allow for movement in almost all directions.
- **Hinge joints**, found in elbows and knees, allow for movement in one direction.
- **Gliding joints**, found in wrists and ankles, allow limited movement in many directions.
- **Pivot joints**, found between vertebrae in the spine, mainly allow rotating movement from side to side.
- **Fixed joints**, found in the skull, hold the bones of the skull together and do not allow for any movement.
- **Condyloid joints** allow movement similar to ball-and-socket joint without rotation. Found in the wrist.

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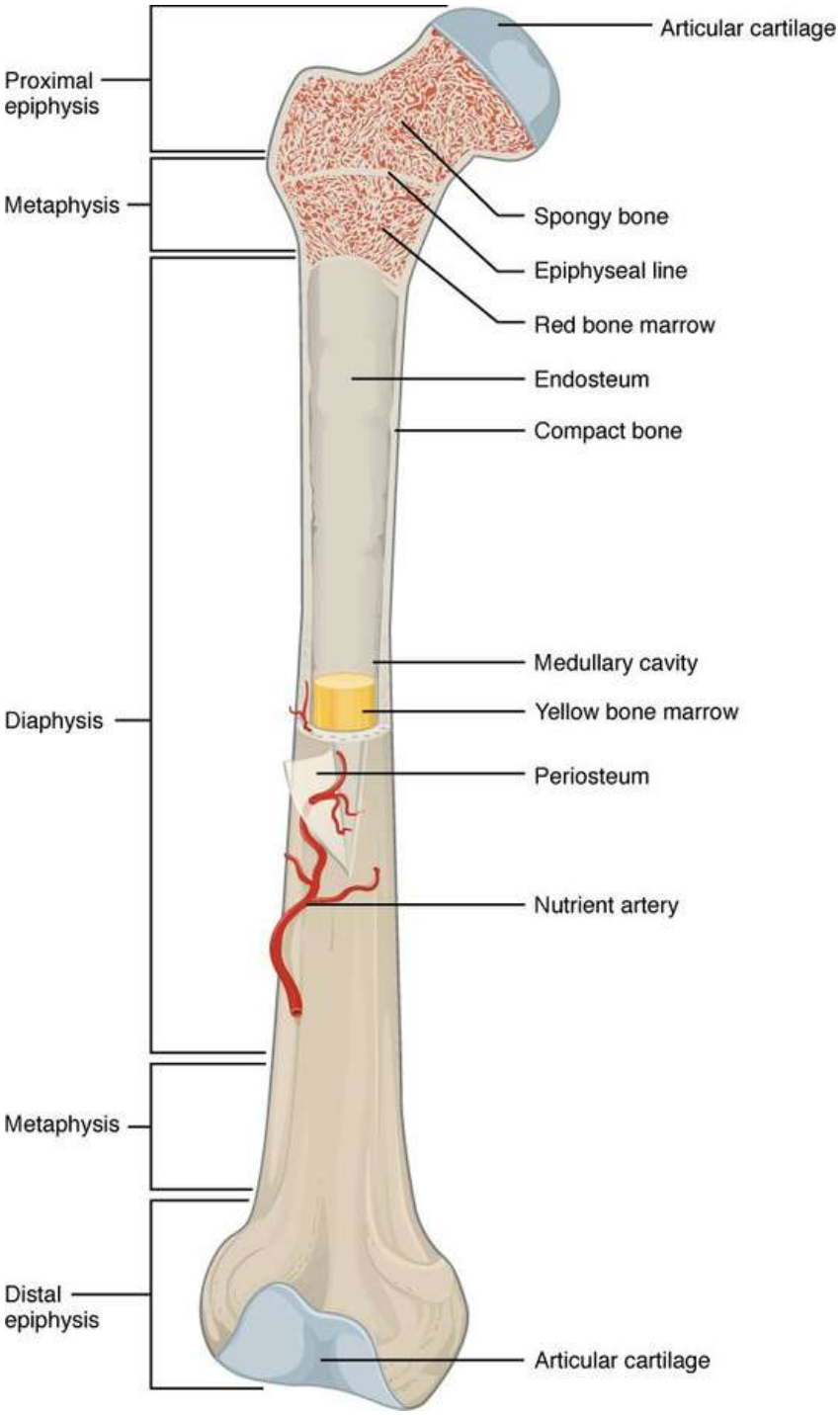
Components in Detail:
Bone Anatomy (teacher copy)

Ask the students to label the major components of long bones - they can either do this as a learning exercise or as a post-learning evaluation. There's a blank diagram on the next page to print and use.



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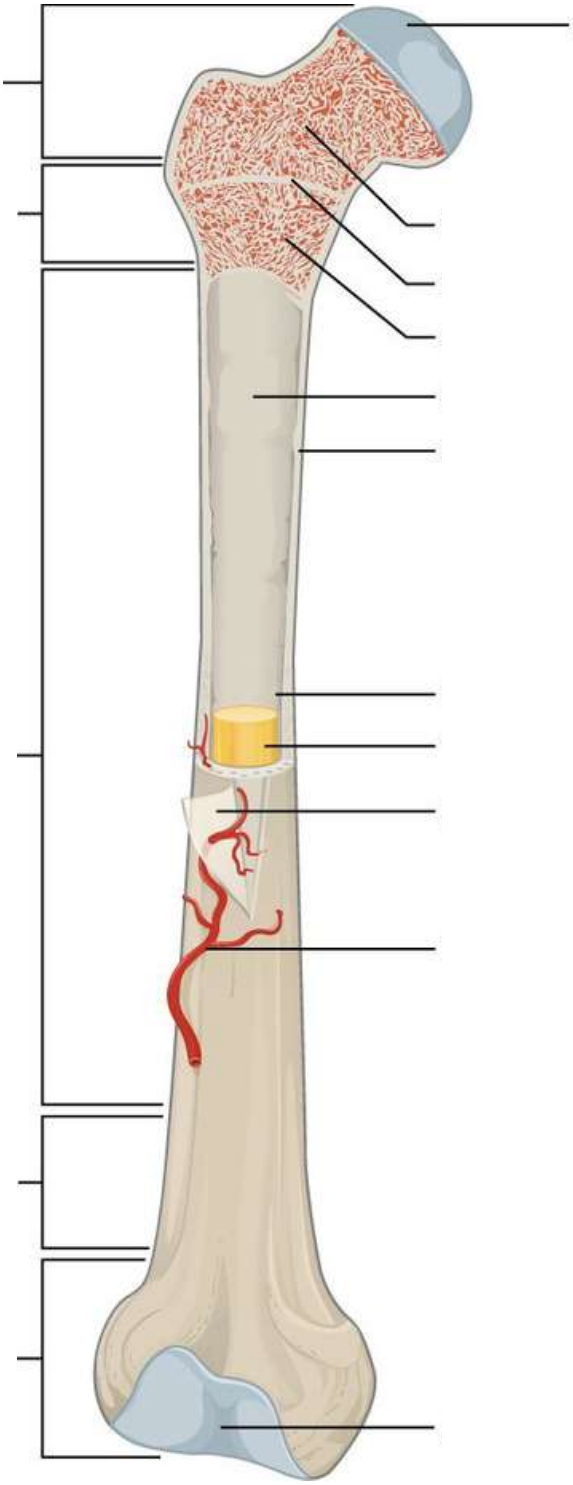
Long Bone Anatomy (student activity)

Label the major components of a long bone on the diagram below



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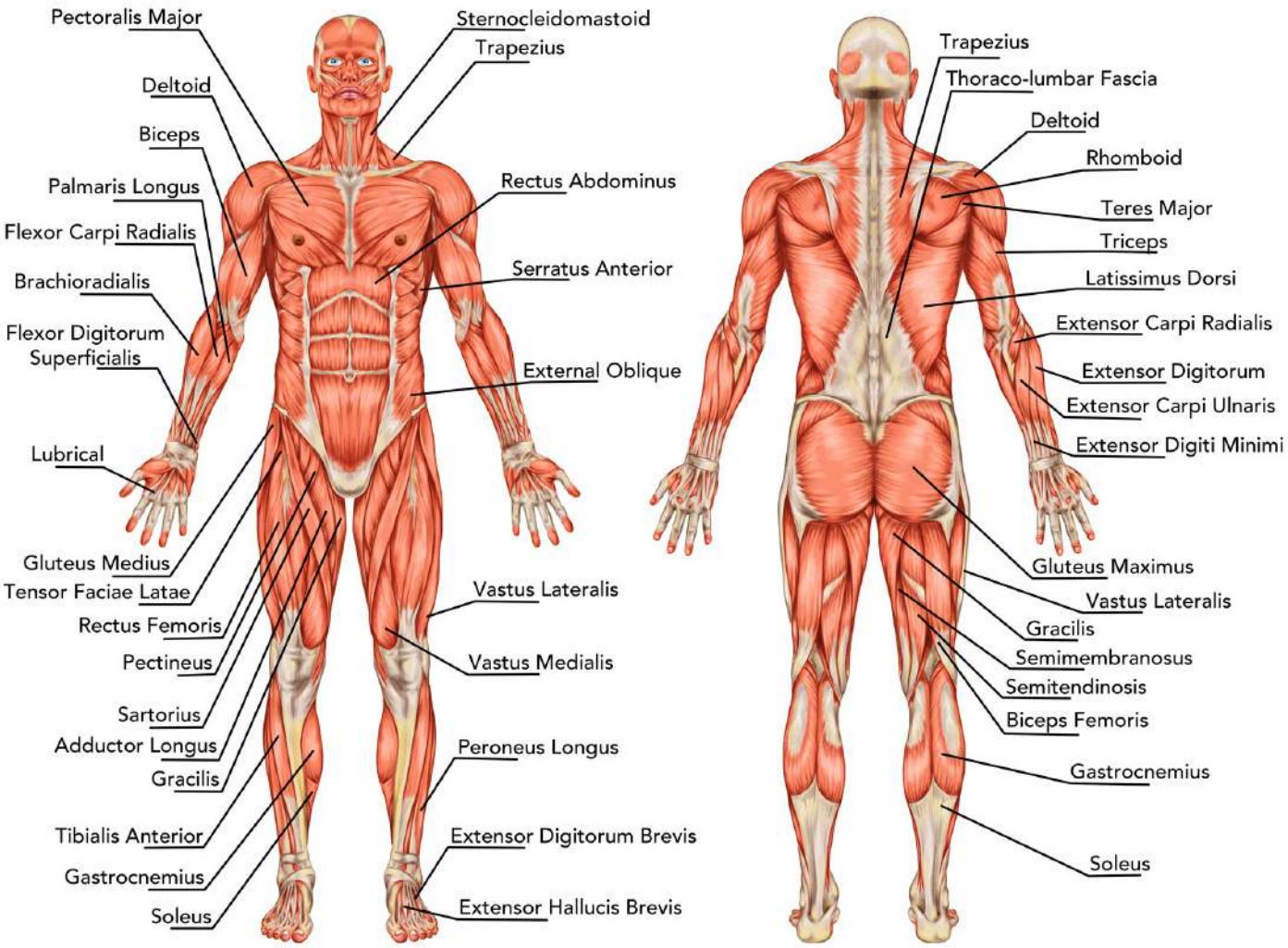
Components in Detail:

Human Musculature (teacher copy)



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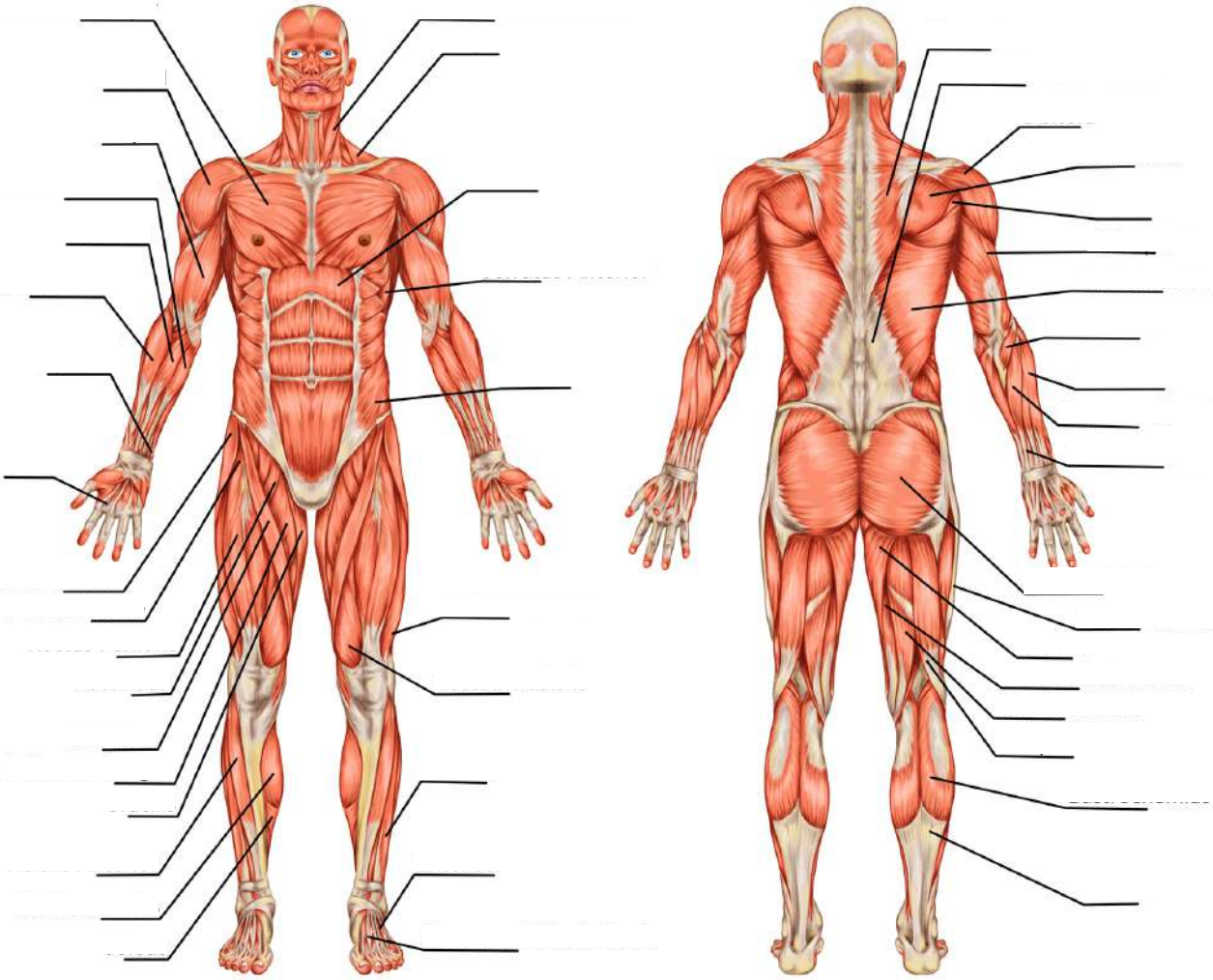
Human Musculature (student activity)

Label the major muscles of the human body on the diagram below



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Components in Detail:
Muscle Types & Function

Types of muscle:

- **Skeletal muscle** - Skeletal muscle, **attached to bones**, is responsible for skeletal movements. The peripheral portion of the central nervous system (CNS) controls the skeletal muscles. Thus, these muscles are under conscious, or **voluntary**, control. The basic unit is the muscle fibre with many nuclei. These muscle fibres are striated (having transverse streaks) and each acts independently of neighbouring muscle fibres.

- **Smooth muscle** - Smooth muscle, found in the walls of the hollow internal **organs** such as blood vessels, the gastrointestinal tract, bladder, and uterus, is under control of the **autonomic nervous system**. Smooth muscle cannot be controlled consciously and thus acts involuntarily. The non-striated (smooth) muscle cell is spindle-shaped and has one central nucleus. Smooth muscle contracts slowly and rhythmically.

- **Cardiac muscle** - Cardiac muscle, found in the walls of the **heart**, is also under control of the **autonomic nervous system**. The cardiac muscle cell has one central nucleus, like smooth muscle, but it also is striated, like skeletal muscle. The cardiac muscle cell is rectangular in shape. The contraction of cardiac muscle is involuntary, strong, and rhythmical.

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Components in Detail:
Muscle Fibres & Function

Two criteria to consider when classifying the types of muscle fibres are how fast some fibres contract relative to others, and how fibres produce adenosine triphosphate (ATP). Using these criteria, there are **three main types of skeletal muscle fibres:**

- **Slow oxidative (SO) fibres** contract relatively **slowly** and use **aerobic** respiration (oxygen and glucose) to produce ATP.
- **Fast oxidative (FO) fibres** have **fast** contractions and primarily use **aerobic** respiration, but because they may **switch to anaerobic** respiration (glycolysis), can fatigue more quickly than SO fibres.
- **Fast glycolytic (FG) fibres** have **fast** contractions and primarily use **anaerobic** glycolysis. The FG fibres fatigue more quickly than the others. Most skeletal muscles in a human contain(s) all three types, although in varying proportions.

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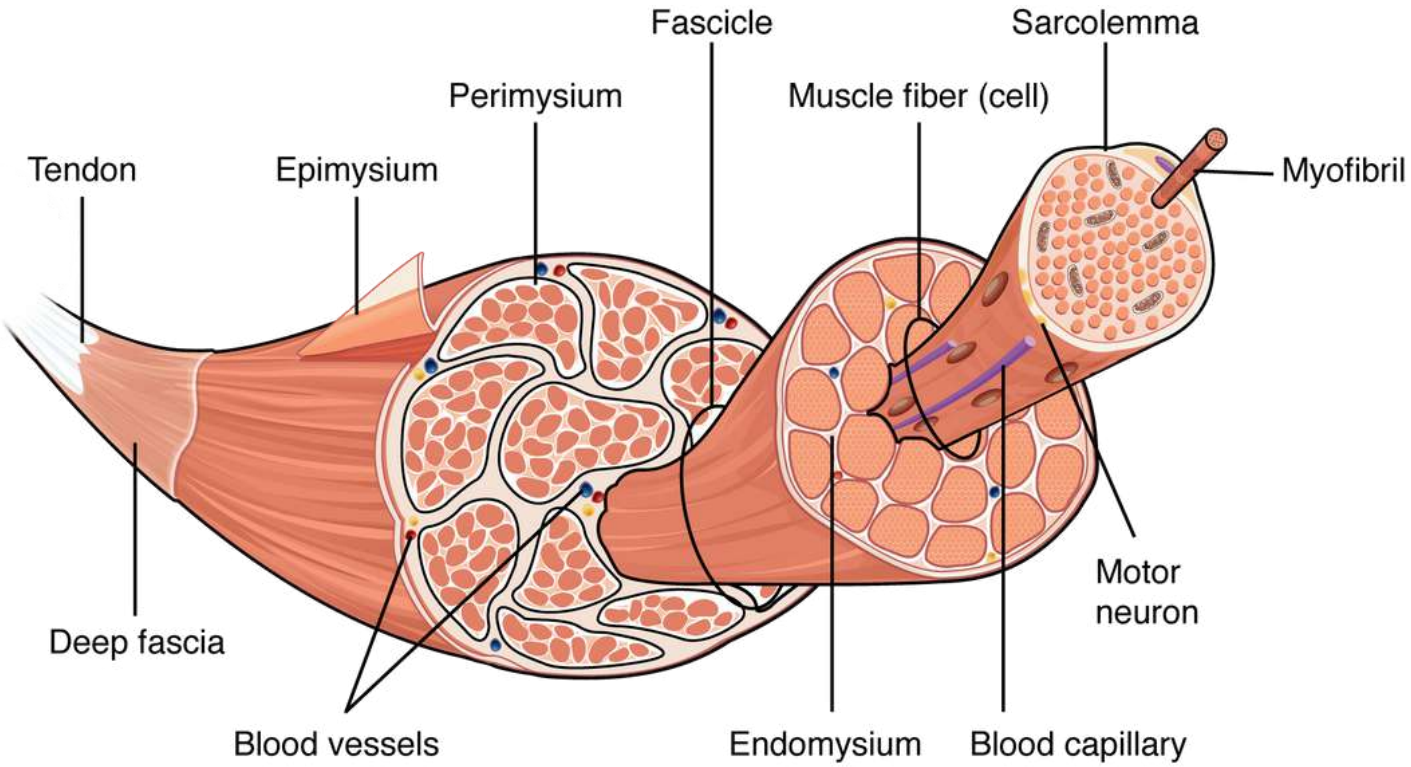
Components in Detail:

Skeletal Muscle Anatomy (teacher copy)



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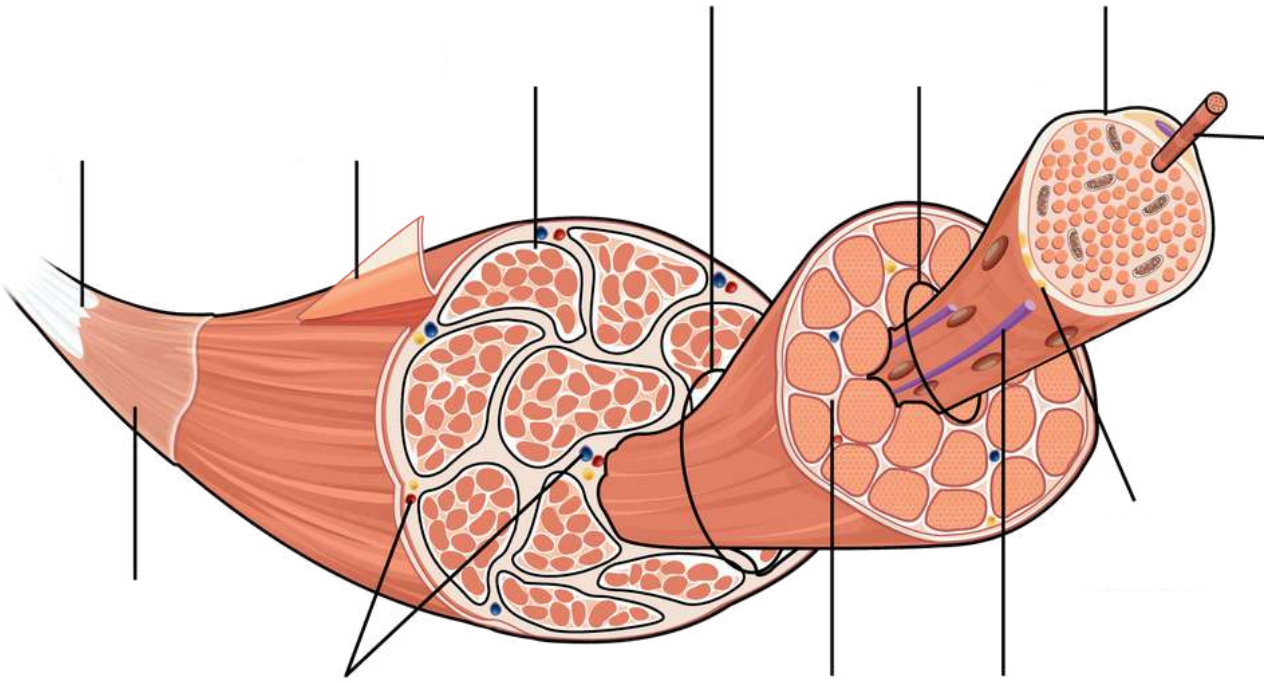
Skeletal Muscle Anatomy (student activity)



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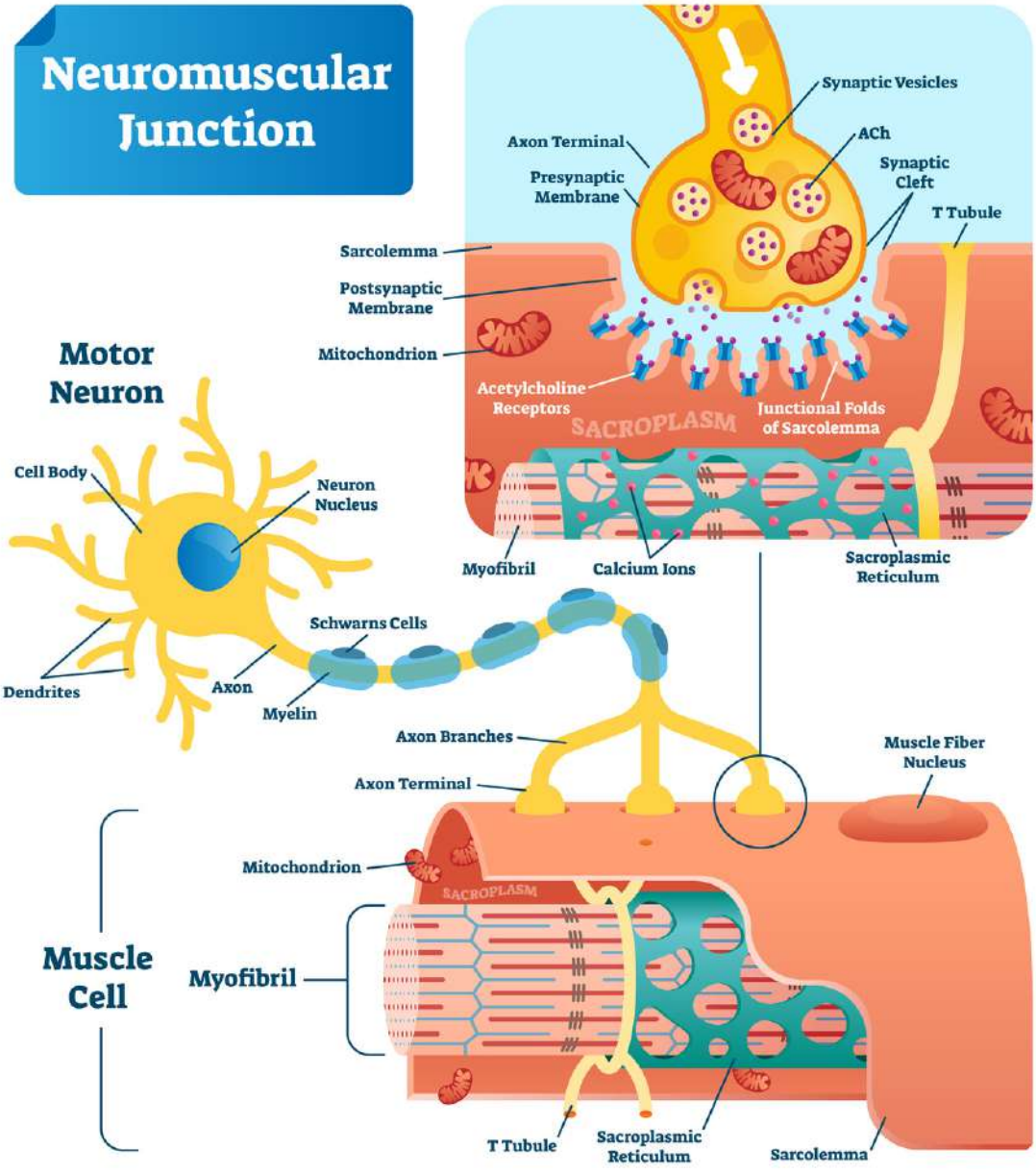
How Does the Musculoskeletal System Work Together With Other Organ Systems?

Nervous System - The musculoskeletal system works with the nervous system. Receptors in muscles provide the brain with information about body position and movement. **The brain controls the contraction of skeletal muscle.** The nervous system regulates the speed at which food moves through the digestive tract (smooth muscle). Nerve impulses stimulate muscle contractions at special junctions between nerves and muscles called **neuromuscular junctions**. A neuromuscular junction is a chemical synapse between a **motor neuron** and a **muscle fibre**. It allows the motor neuron to transmit a signal to the muscle fibre, causing **muscle contraction**. Muscles require innervation to function—and even just to maintain muscle tone, avoiding atrophy.



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How Does the Musculoskeletal System Help Maintain Homeostasis?

Homeostasis in the Muscular System

Skeletal muscles contribute to maintaining **temperature homeostasis** in the body by generating heat. Muscle contraction requires energy and produces heat as a byproduct of **metabolism**. All types of muscle produce heat, but because of the large amount of skeletal muscle present in the body, skeletal muscle contributes most greatly to heat production. This is very noticeable during **exercise**, when sustained muscle movement causes body temperature to rise. In cases of extreme cold, **shivering** produces random skeletal muscle contractions to generate heat as part of the negative feedback mechanism of maintaining body temperature.

Our body can use skeletal muscle contractions to maintain body temperature when we are cold, but excessive contractions can lead to the body overheating to the point that the body's metabolic reactions are interrupted. This can occur in a condition called malignant hyperthermia, which develops in genetically susceptible individuals who are administered a specific combination of anesthetic agents during surgery. In these individuals, a drastic increase in skeletal muscle calcium leads to sustained contractions and heat generation. Because the individuals are anesthetized, they have little ability to cool themselves. If proper interventions are not administered, they will die due to a greatly increased body temperature. Because this condition is genetic, patients are asked prior to surgery if there is a family history of such problems occurring.

Muscle Homeostasis and Growth

Physical training alters the appearance of skeletal muscles and can produce changes in muscle performance. Conversely, a lack of use can result in decreased performance and muscle appearance. Mature muscle cells grow from hypertrophy, not cell division. The loss of structural proteins and muscle mass occurs during atrophy. Cellular components of muscles can also undergo changes in response to changes in muscle use.

Although atrophy due to disuse can often be reversed with exercise, muscle atrophy that comes with age is irreversible. This is why even highly trained athletes succumb to declining performance with age, although extensive training may slow the decline. This is especially noticeable in sports that require an explosion of strength and power over a very short period of time. Examples of these kinds of sports include sprinting, competitive weight lifting, gymnastics and diving. The effects of age are less noticeable in endurance sports such as marathon running or long-distance cycling. Age-related muscle atrophy is called **sarcopenia**. As muscles age, muscle fibres die, and they are replaced by connective tissue and adipose tissue. Because those tissues cannot contract as muscle can, muscles lose the ability to produce powerful contractions.

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Closing Check-In and Discussion

During the check closing in:

Recap with the students the musculoskeletal system and the structure and function of bones, muscles and connective tissues. Go over ways the musculoskeletal system interacts with other body systems, as well as how it helps maintain homeostasis. Ask the following questions:

- **How might virtual dissections and models compare with using real specimens?**
- **Were you able to successfully learn the structure and function of individual parts of the respiratory system?**

Closing - Discussion on Ethics

The knowledge to create these accurate virtual models of the musculoskeletal system had to initially come from real humans and or animals. However, now that we have such a plentiful resources for accurate models of these structures, as well as the ability to perform dissections virtually, do you think we need to continue using animals? Why or Why not?

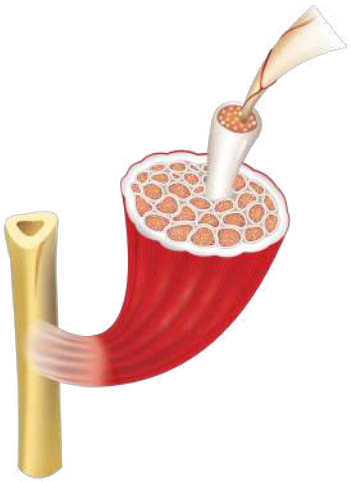
Think

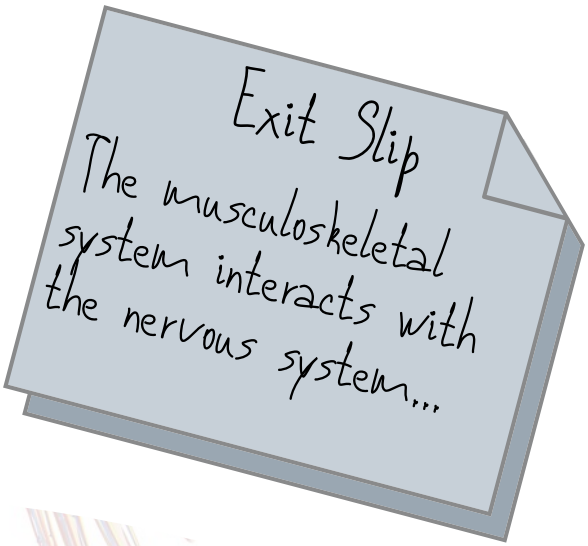
Ask the students to think about where they stand on the subject of animal dissections and the use of animals in science. They don't need to answer right away, rather, this is to get them to start forming their own ethical opinions.

Formative Assessment

The formative assessment can be in the form of an exit slip. This involves asking each student at the end of the class to answer 2-3 questions on a sheet of paper and hand it in, with their names on it, to ensure understanding of the main concepts covered. Examples of questions to include:

- **What is one way the musculoskeletal system maintains homeostasis within the body?**
- **What is one way the musculoskeletal system interacts with other body systems?**
- **Name three major bones and three major muscles in the musculoskeletal system.**





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Thank you for choosing these materials to support your class adventures!

These Humane Science Education materials were developed by Elisabeth Ormandy for the Canadian Society for Humane Science (2015-2022) working to achieve better science without animals. By choosing these unit plans, you have joined a growing family of Humane Science Educators!

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