# Muscle SpikerBox Pre-Assessment Answer Key

1. What are muscles, and what do they do?
Muscles are soft tissues in our bodies composed of cells that contract and relax, enabling movement, posture maintenance, and the function of vital organs. Muscles are specialized tissues that contract to create movement, maintain posture, stabilize joints, and generate heat. Muscles help the heart beat, the chest rise and fall during breathing, and the blood vessels regulate the pressure and flow of blood. When we smile and talk, muscles help us communicate, and when we exercise, they help us stay physically fit and healthy. They also help the body do such things as chew food and then move it through the digestive system. Even when we sit perfectly still, muscles throughout the body are constantly moving. Muscles pull on the joints, allowing us to move. Muscles can pull bones, but they cannot push them back to their original position. So, they work in pairs of flexors and extensors. In other words, muscles move body parts by contracting and then relaxing.

There are three main types:
- Skeletal muscles: Enable voluntary movements (e.g., walking, writing).
- Cardiac muscles: Found in the heart and enable involuntary rhythmic contractions pump blood.
- Smooth muscles: Control involuntary actions in internal organs (e.g., digestion).

2. Describe how we activate muscles in our body.
The movements your muscles make are coordinated and controlled by the brain and nervous system. When you decide to move, the motor cortex sends an electrical signal through the spinal cord and peripheral nerves to the muscles, causing them to contract. The motor cortex on the right side of the brain controls the muscles on the left side of the body, and vice versa. Muscles are activated when motor neurons from the spinal cord transmit electrical signals (action potentials) to muscle fibers, triggering contraction via neurotransmitter release (acetylcholine) at neuromuscular junctions. Muscle activation involves signals from the brain (central nervous system, CNS). The process is:
    1. Decision made in the brain (motor cortex) to perform an action.
    2. Signals travel via neurons down the spinal cord.
    3. Motor neurons carry signals from the spinal cord to the muscle.
    4. At the neuromuscular junction, neurons release neurotransmitters (acetylcholine).
    5. Neurotransmitters bind to muscle fibers, causing contraction and resulting in movement.

Sensors in the muscles and joints send messages back through peripheral nerves to tell the cerebellum and other parts of the brain where and how the arm or leg is moving and what position it is in. This feedback results in smooth, coordinated motion. If you want to lift your arm, your brain sends a message to the muscles in your arm and you move it. When you run, the messages to the brain are more involved, because many muscles must work in rhythm.

3. How are wrist muscles different from finger muscles?
Forearm muscles provide power and control for both wrist and finger movements. Wrist muscles (extrinsic muscles) are typically larger and stronger, controlling broader motions of the hand, including flexion, extension, and deviation, while finger muscles are smaller, more precise, and allow fine motor control.

Small muscles are located within the wrist and hand and are responsible for fine motor movements of the fingers. Muscles within the wrist and hand are referred to as intrinsic muscles. Finger muscles that

originate in the forearm are referred to as extrinsic muscles, controlling finger movement through tendons.

4. Can you sketch the diagram/flowchart (e.g., neuronal circuit) that starts with the input (decision to move in the brain) to the output (motion of your finger)? The circuit should have components for decision making, implementation of decision making, transmission of the decision, and then having the transmitted signal control the muscle to implement motion (end effector).

| Flowchart for neuronal circuit | | | | |
|---|---|---|---|---|
| **Stage** | **Component** | **Signal type** | **Firing Rate / Signal Strength** | **Transmission velocity** |
| 1 | Decision Making | Prefrontal Cortex | ~20 Hz | n/a (local computation) |
| 2 | Implementation | Motor Cortex (primary motor area) | ~50 Hz | n/a |
| 3 | Signal Transmission | Corticospinal Tract (axon bundles) | ~40–60 Hz (spiking activity) | ~50–100 m/s |
| 4 | Muscle Activation | Motor Neuron | ~80–120 Hz (intense activity) | ~50–120 m/s (myelinated) |
| 5 | Muscle Contraction | Neuromuscular Junction | ~80–100 Hz (acetylcholine release rate) | Chemical synaptic delay due to diffusion (~1 ms) |
| 6 | Motion | Muscle Fiber Contraction | - Weak contraction ≈ 5-15 Hz<br>- Moderate contraction ≈ 15-30 Hz<br>- Strong contraction ≈ 30-60+ Hz (sustained strong force) | n/a (muscle fiber contraction) |

**Explanation of Flowchart Components:**
- Decision Making: Prefrontal cortex and associative areas make voluntary decisions about movements.
- Implementation of Decision: Motor planning areas such as the motor cortex prepare movement patterns based on the intended motor action. The primary motor cortex generates specific motor commands for muscle activation.
- Transmission of Decision: Motor commands are transmitted down the corticospinal tract from the brain to the spinal cord. The signal reaches the spinal cord at the relevant motor neuron pool in the anterior horn, which modulates and relays it to peripheral nerves. Peripheral nerves deliver signals to specific wrist muscles.
- Neuromuscular Junction: At the neuromuscular junction, nerve impulses are converted into chemical signals (acetylcholine release), initiating muscle fiber contraction.
- Muscle Contraction: Wrist muscles (e.g., flexors/extensors) contract in response to nerve signals.
- Output Motion: Finally, the muscle contraction produces the desired wrist movement (end-effector motion).

5. For the circuit you sketched, can you think and sketch or put rough numbers for the firing rates (spikes/second) of neurons (indicates strength of signal), transmission velocity, and firing rate of muscle (how strong is the contraction)?
See the answer above.

6. What do you think happens to our muscles when we age?
Aging leads to decreased muscle mass, strength, and flexibility, a condition called sarcopenia. The changes that affect muscle structure, strength, and functional capacity include:
   • Loss of muscle mass and strength (sarcopenia).
   • Reduced muscle fiber size and number.
   • Slower reaction times and reduced fine motor control.
   • Increased fatigue and decreased endurance.
   • Changes in neuromuscular communication, affecting muscle responsiveness.

7. Do you think engineers need to know about muscles? Why?
Yes, engineers designing prosthetics, robots, and medical devices must understand muscle mechanics, structure, and control to create functional and realistic devices that effectively interact with the human body. Engineers apply knowledge about muscles and biomechanics to develop safer, more effective products and equipment. Knowledge of muscles helps engineers design actuators that mimic natural muscle strength, responsiveness, and precision. Engineers use software and computational models to simulate and predict muscle forces, joint movements, and energy efficiency, improving treatment and device designs. Understanding muscle activation patterns helps optimize designs for artificial limbs or exoskeletons.

8. How do robots use ideas of muscles?
Robots often take inspiration from muscles to achieve more efficient, precise, and adaptable movements. This practice is called biomimicry and incorporates biological principles into robotic design. Muscle biomimicry provides significant innovation opportunities, driving robotics toward greater sophistication, human compatibility, and real-world applicability. Robots often mimic muscles with:
   1. Actuators: Motors, pneumatics, hydraulics, and artificial muscles that contract and expand.
   2. Tendons and pulleys: Mimic muscle-tendon interaction for smooth and precise motion.
   3. Feedback sensors: Mimic neural feedback, adjusting strength, position, and force.

9. What are some applications of such robot experiments?
Humanoid robots or prosthetics often use pairs of pneumatic muscles or actuators arranged like the human biceps and triceps. Also, certain surgical robots help surgeons perform muscle-related procedures accurately (e.g., tendon repairs).

10. How do you think gender plays a role in muscle? Are male muscles different than female muscles, for example?
Males have about 10-20 times higher testosterone levels than females, directly contributing to greater muscle size, growth potential, and strength. Estrogen and progesterone levels, which are higher in females, affect muscle growth and recovery differently, sometimes protective against muscle damage. Female fiber composition also contributes to enhanced muscle endurance and recovery, fatigue resistance, and sustained aerobic performance.

11. Elaborate on a topic you are curious about. Topics can include experimental (microcontroller), engineering (robotics), computer science (programming), neuroscience (biology), etc.
Answers will vary.

Neuromorphic computing, inspired by the human brain, and neurofeedback, a technique using real-time brainwave feedback, are intertwined fields with potential for advancements in brain-computer interfaces and neurorehabilitation. Research questions include determining how robotic systems can precisely replicate complex human neuromuscular feedback mechanisms. Specifically, how can we enhance prosthetic or robotic control using microcontrollers (e.g., Arduino) combined with neural data or artificial intelligence to achieve naturalistic and responsive motions?