293 Movement About Joints

Key idea: A joint is the junction where two or more bones meet. All movements of the skeleton occur at joints.

Bones are too rigid to bend. To allow movement, the human skeletal system consists of bones held together at joints by flexible connective tissues called **ligaments**. **Joints** are points of contact between bones or between cartilage and bones. Joints may be classified structurally as fibrous, cartilaginous, or synovial (below). Each of these joint types allows a certain degree of movement. Bones are made to move about a joint by the force of muscles acting upon them.

Cartilaginous Joints

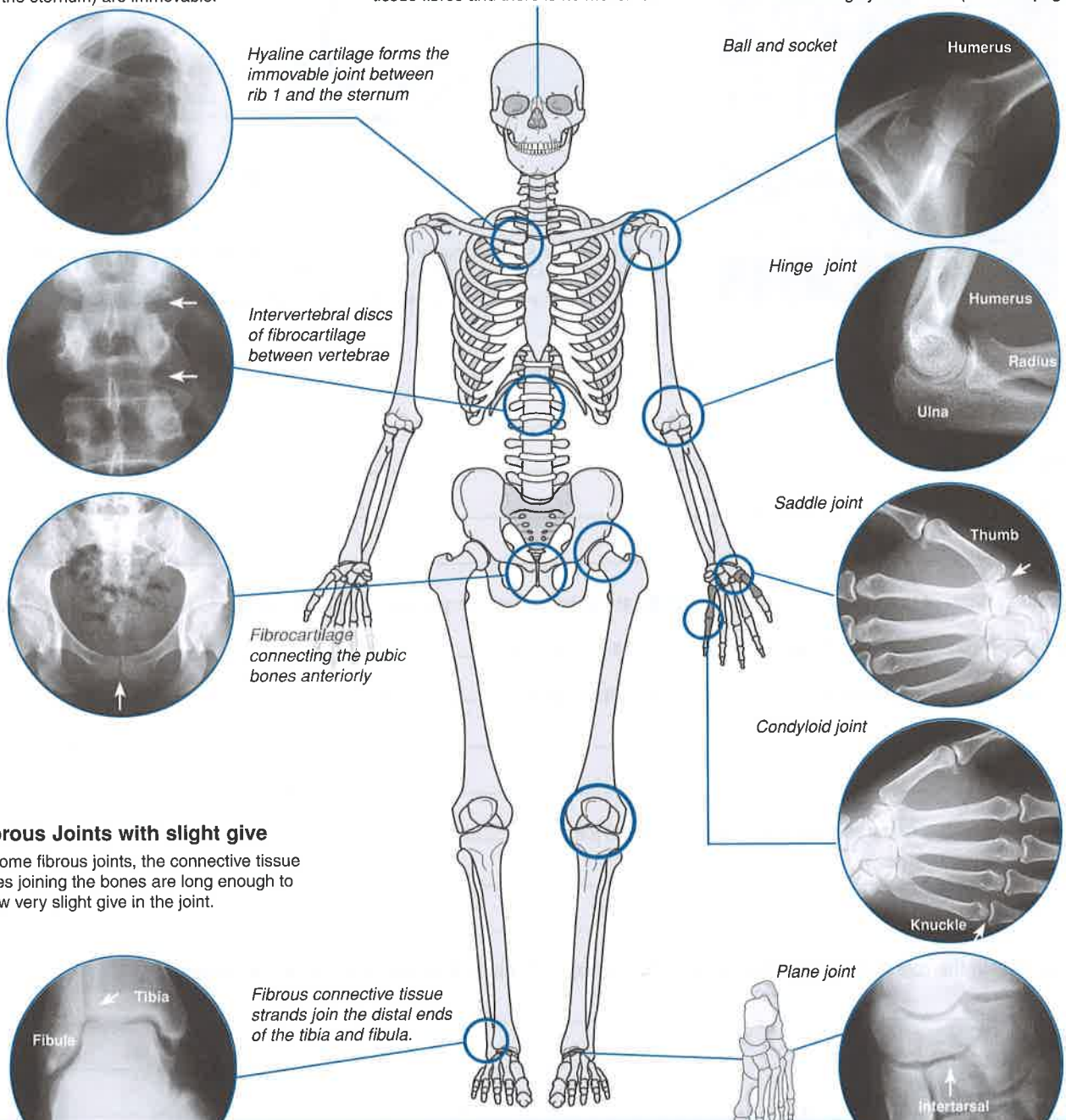
Here, the bone ends are connected by cartilage. Most allow limited movement although some (e.g. between the first ribs and the sternum) are immovable.

Immovable Fibrous Joints

The bones are connected by fibrous tissue. In some (e.g. sutures of the skull), the bones are tightly bound by connective tissue fibres and there is no movement.

Synovial Joints

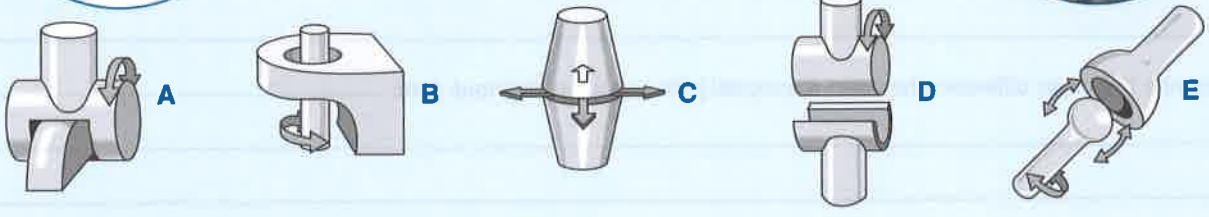
These allow free movement in one or more planes. The articulating bone ends are separated by a joint cavity containing lubricating synovial fluid (see next page).



Fibrous Joints with slight give

In some fibrous joints, the connective tissue fibres joining the bones are long enough to allow very slight give in the joint.

Movement Around Synovial Joints



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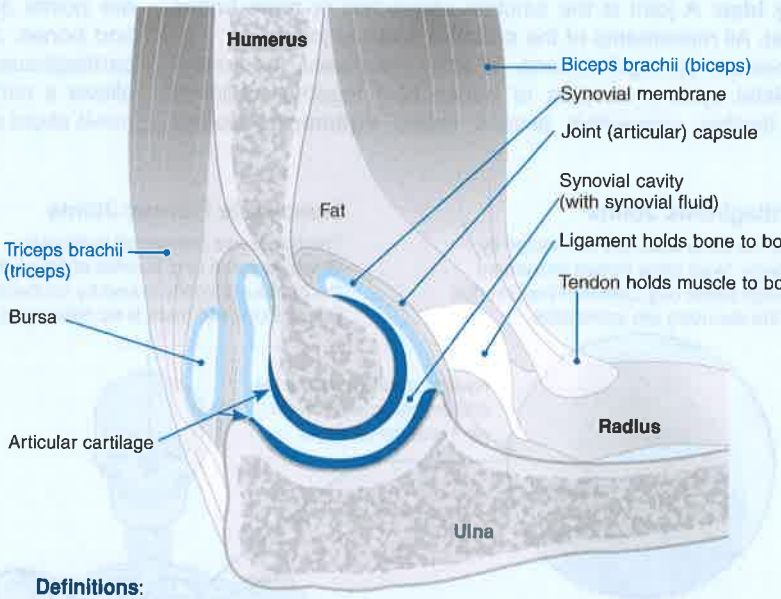
Structure of a Synovial Joint

Synovial joints (right and below) allow free movement of body parts in varying directions (one, two or three planes). The elbow joint is a hinge joint and typical of a synovial joint. Like most synovial joints, it is reinforced by ligaments (not all shown). The joint capsule encloses synovial fluid, which reduces friction and absorbs shocks. In the diagram, the brachialis muscle, which inserts into the ulna and is the prime mover for flexion of the elbow, has been omitted to show the joint structure. Muscles are labelled blue and bones are bolded.



Definitions:

A **bursa** is a fluid filled cavity lined with synovial membrane. It acts as a cushion, e.g. between tendon and bone, or between bones.

Cartilage is a flexible connective tissue. It protects a joint surface against wear.

1. Define the following terms and state the role of each in movement:

   (a) Joint: _____

   (b) Ligament: _____

   (c) Muscle: _____

   (d) Tendon: _____

2. Classify each of the synovial joint models (**A-E**) at the bottom of the previous page, according to the descriptors below:

   (a) Pivot: _____ (b) Hinge: _____ (c) Ball-and-socket: _____ (d) Saddle: _____ (e) Gliding: _____

3. Compare the movements of the hip joint and the elbow joint: _____

   _____

   _____

4. (a) Describe the features common to most synovial joints: _____

   _____

   _____

   (b) Explain the role that synovial fluid and cartilage play in the structure and function of a synovial joint:

   _____

   _____

   _____

   _____

   _____

5. Describe the major difference between a synovial joint and a cartilaginous joint: _____

   _____

   _____

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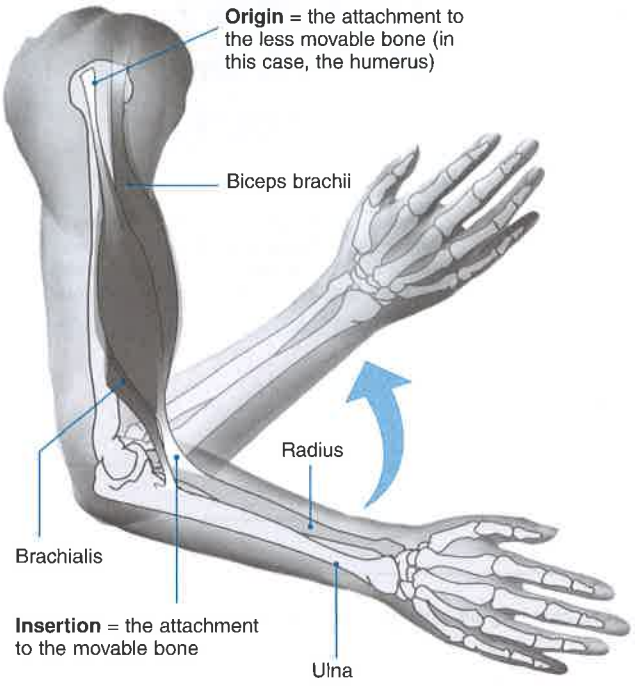
294 Antagonistic Muscles

Key idea: Antagonistic muscles are muscle pairs that have opposite actions to each other. Together, their opposing actions bring about movement of body parts.

In both vertebrates and invertebrates, muscle provide the contractile force to move body parts. Muscles create movement of body parts when they contract across joints. Because muscles can only pull and not push, most body movements are achieved through the action of opposing sets of muscles called **antagonistic muscles**. Antagonistic muscles function by producing opposite movements, as one muscle contracts (shortens), the other relaxes (lengthens). Skeletal muscles are attached to the skeleton by tough connective tissue structures (**tendons** in vertebrates or attachment fibres in insects). They always have at least two attachments: an origin and an insertion. Body parts move when a muscle contracts across a joint. The type and degree of movement depends on how much movement the joint allows and where the muscle is located in relation to the joint.

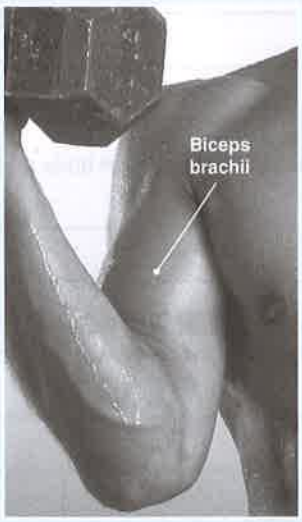


Two muscles are involved in flexing the forearm. The **brachialis**, which underlies the biceps brachii and has an origin half way up the humerus, is the **prime mover**. The more obvious **biceps brachii**, which is a two headed muscle with two origins and a common insertion near the elbow joint, acts as the synergist. During contraction, the insertion moves towards the origin.

Opposing Movements Require Opposing Muscles

The skeleton works as a system of levers. The joint acts as a **fulcrum** (or pivot), the muscles exert the **force**, and the weight of the bone being moved represents the **load**. The flexion (bending) and extension (unbending) of limbs is caused by the action of **antagonistic muscles**. Antagonistic muscles work in pairs and their actions oppose each other. During movement of a limb, muscles other than those primarily responsible for the movement may be involved to fine tune the movement.

Every coordinated movement in the body requires the application of muscle force. This is accomplished by the action of agonists, antagonists, and synergists. The opposing action of agonists and antagonists (working constantly at a low level) also produces muscle tone. Note that either muscle in an antagonistic pair can act as the agonist or **prime mover**, depending on the particular movement (for example, flexion or extension).



Agonists or prime movers: muscles that are primarily responsible for the movement and produce most of the force required.

Antagonists: muscles that oppose the prime mover. They may also play a protective role by preventing over-stretching of the prime mover.

Synergists: muscles that assist the prime movers and may be involved in fine-tuning the direction of the movement.

During flexion of the forearm (left) the **brachialis** muscle acts as the prime mover and the **biceps brachii** is the synergist. The antagonist, the **triceps brachii** at the back of the arm, is relaxed. During extension, their roles are reversed.

Movement of the upper leg is achieved through the action of several large groups of muscles, collectively called the **quadriceps** and the **hamstrings**.

The hamstrings are actually a collection of three muscles, which act together to flex the leg.

The quadriceps at the front of the thigh (a collection of four large muscles) opposes the motion of the hamstrings and extends the leg.

When the prime mover contracts forcefully, the antagonist also contracts very slightly. This stops over-stretching and allows greater control over thigh movement.

Movement at Joints

The synovial joints of the skeleton allow free movement in one or more planes. The articulating bone ends are separated by a joint cavity containing lubricating synovial fluid. Two types of synovial joint, the shoulder ball and socket joint and the hinge joint of the elbow, are illustrated below.

Ball and socket

Hinge joint

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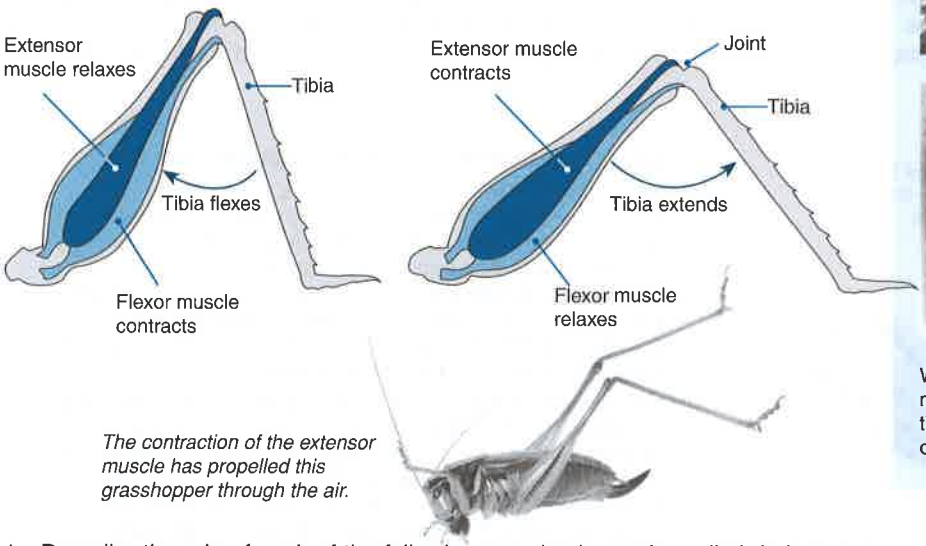
Antagonistic Muscle Pairs in an Insect Leg

Antagonist muscle pairs in insect legs work together to move the legs. The two main muscles are the extensor tibiae muscle (often just called the **extensor**) which causes the leg to extend, and the flexor tibiae muscle (**flexor**) which causes the leg to flex (bend).

The muscles are attached to the tibia via attachment fibres to the cuticle on either side of the joint. When one of the muscles contracts, it pulls on its attachment and moves the tibia one way. When the other muscle in the pair contracts, it moves the tibia the other way (below).



The contraction of the extensor muscle has propelled this grasshopper through the air.

Walking (top) involves contraction of leg muscles. Modification of insect limbs and their muscles enables insects to move in other ways, e.g. jump (left) or swim (above).

1. Describe the role of each of the following muscles in moving a limb in humans:

   (a) Prime mover: _____

   (b) Antagonist: _____

   (c) Synergist: _____

2. Explain why the muscles that cause movement of body parts tend to operate as antagonistic pairs: _____

   _____

   _____

3. Describe the relationship between muscles and joints in a human. Using appropriate terminology, explain how antagonistic muscles act together to raise and lower a limb:

   _____

   _____

   _____

4. (a) Identify the insertion for the biceps brachii during flexion of the forearm: _____

   (b) Identify the insertion of the brachialis muscle during flexion of the forearm: _____

   (c) Identify the antagonist during flexion of the forearm: _____

   (d) Given its insertion, describe the forearm movement during which the biceps brachialis is the prime mover: _____

   _____

5. (a) Identify the fulcrum for forearm movement in humans: _____

   (b) Identify the structures that represent the load: _____

   (c) Identify the structures that represent the force: _____

6. How do antagonistic muscle pairs in insects bring about movement of the legs? _____

   _____

   _____

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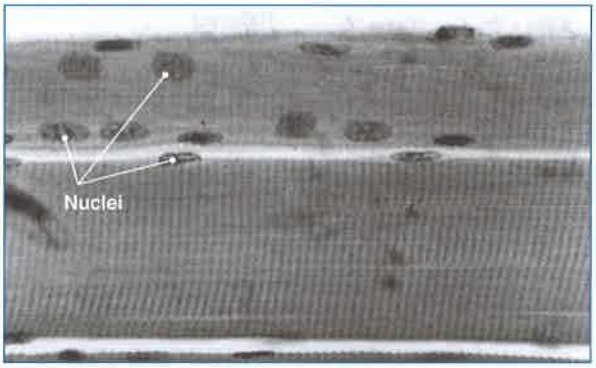
295 Skeletal Muscle Structure and Function

Key idea: Skeletal muscle is organized into bundles of muscle cells or fibres. The muscle fibres are made up of repeating contractile units called sarcomeres.

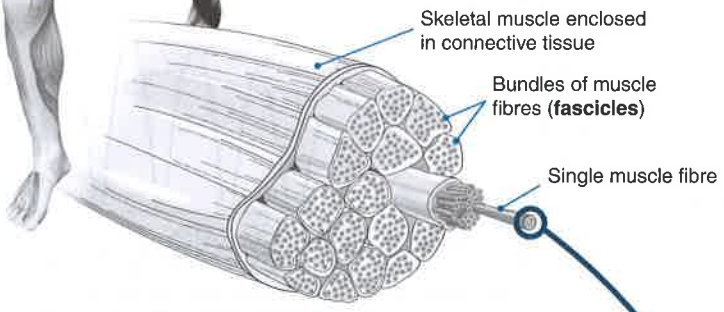
Skeletal muscle is organized into bundles of muscle cells or fibres. Each **fibre** is a single cell with many nuclei and each fibre is itself a bundle of smaller **myofibrils** arranged lengthwise. Each myofibril is in turn composed of two kinds of **myofilaments** (thick and thin), which overlap to form light and dark bands. It is the alternation of these light and dark bands which gives skeletal muscle its striated or striped appearance. The **sarcomere**, bounded by the dark Z lines, forms one complete contractile unit.

When viewed under a microscope (right), skeletal muscle has a banded appearance. The cells are large with many nuclei (multinucleate).



Skeletal muscles require a conscious action to control them. Physical actions, such as running, writing, and speaking require the contraction of skeletal muscles to occur.

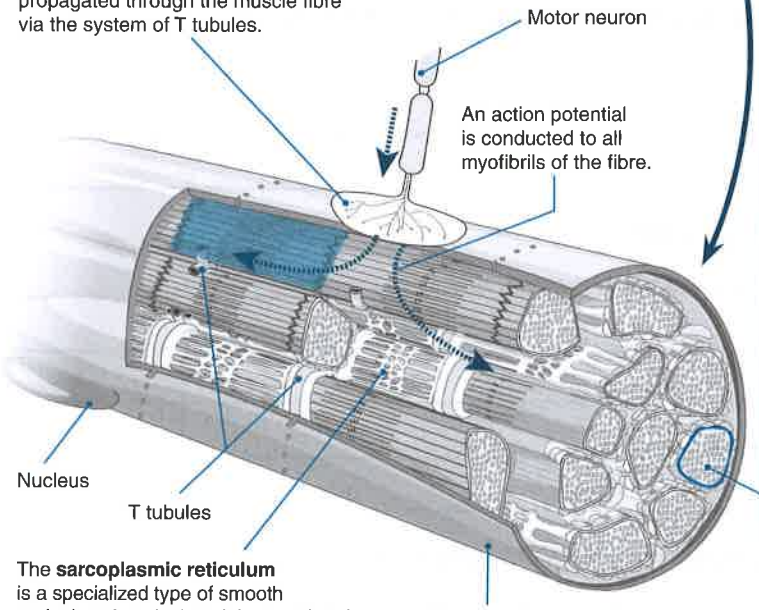
Structure of Muscle



The relationship between muscle, fascicles, and muscle fibres (cells)

Structure of a Muscle Fibre (Cell)

When a nerve impulse arrives at the neuromuscular junction, acetylcholine is released. This stimulates an action potential in the sarcolemma, which is propagated through the muscle fibre via the system of T tubules.

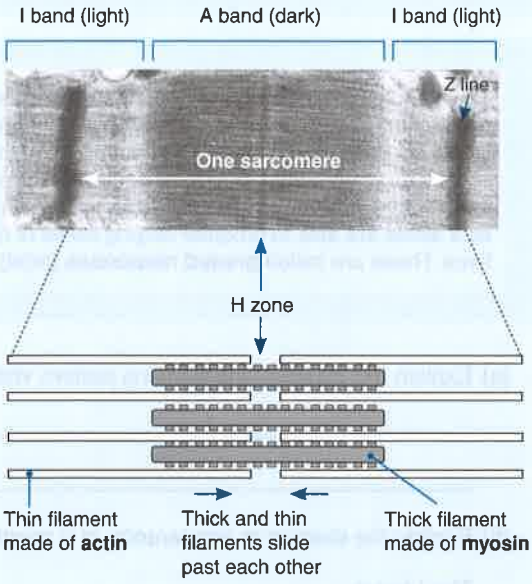


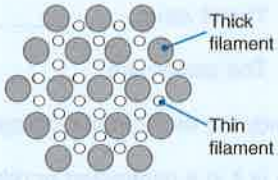
The **sarcoplasmic reticulum** is a specialized type of smooth endoplasmic reticulum. It is associated with the T tubules and forms a network containing a store of calcium ions.

The **sarcolemma** is the plasma membrane of the muscle cell and encloses the sarcoplasm (cytoplasm).

A myofibril (blue outline) with myofilaments in cross section.

Longitudinal Section of a Sarcomere





Cross section through a region of overlap between thick and thin filaments.

The photograph of a sarcomere (above) shows the banding pattern arising as a result of the highly organized arrangement of thin and thick filaments. It is represented schematically in longitudinal section and cross section. A single sarcomere is shown left as the highlighted translucent blue section.

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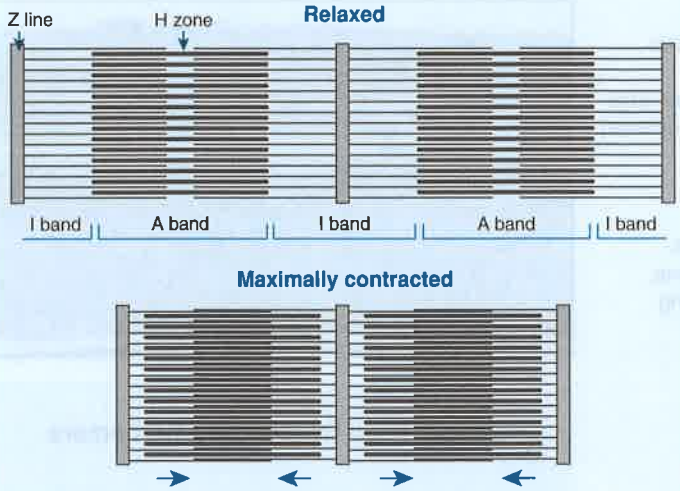
The Banding Pattern of Myofibrils

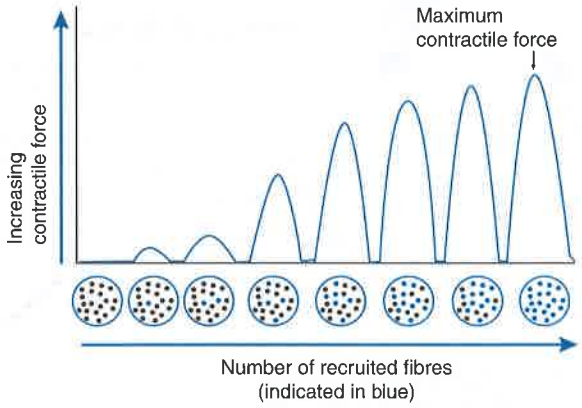
Within a myofibril, the thin filaments, held together by the **Z lines**, project in both directions. The arrival of an action potential sets in motion a series of events that cause the thick and thin filaments to slide past each other. This is called **contraction** and it results in shortening of the muscle fibre and is accompanied by a visible change in the appearance of the myofibril: the I band and the sarcomere shorten and H zone shortens or disappears (below).



The response of a single muscle fibre to stimulation is to contract maximally or not at all; its response is referred to as the **all-or-none law** of muscle contraction. If the stimulus is not strong enough to produce an action potential, the muscle fibre will not respond. However skeletal muscles as a whole are able to produce varying levels of contractile force. These are called **graded responses** (right).

Muscles have Graded Responses

Muscle fibres respond to an action potential by contracting maximally, yet skeletal muscles as a whole can produce **contractions of varying force**. This is achieved by changing the frequency of stimulation (more rapid arrival of action potentials) and by changing the number of fibres active at any one time. A stronger muscle contraction is produced when a large number of muscle fibres are recruited (below left), whereas less strenuous movements, such as picking up a pen, require fewer active fibres (below right).



1. (a) Explain the cause of the banding pattern visible in striated muscle: _____

   _____

   _____

   (b) Explain the change in appearance of a myofibril during contraction with reference to the following:

   The I band: _____

   The H zone: _____

   The sarcomere: _____

2. Study the electron micrograph of the sarcomere (previous page).

   (a) Is it in a contracted or relaxed state (use the diagram, top left to help you decide): _____

   (b) Explain your answer: _____

   _____

3. What is meant by the all-or-none response of a muscle fibre? _____

   _____

4. Name two ways in which a muscle as a whole can produce contractions of varying force: _____

   _____

   _____

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