The body in motion

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CHAPTER 4
Body systems and movement

OUTCOMES
On completion of this chapter, you will be able to:
• explain how body systems influence the way the body moves (P7)
• utilise a range of sources to draw conclusions about health and physical activity concepts (P16)
• analyse factors influencing movement and patterns of participation (P17)
• value the technical and aesthetic qualities of and participation in physical activity. (V&A)

OVERVIEW

SKELETAL SYSTEM
Major bones involved in movement
Structure and function of synovial joints
Joint actions

MUSCULAR SYSTEM
Major muscles involved in movement
Muscle relationship
Types of muscle contraction

RESPIRATORY SYSTEM
Structure and function
Lung function
The exchange of gases
Effect of physical activity on respiration

CIRCULATORY SYSTEM
Components of blood
Structure and function of the heart, arteries, veins and capillaries
Pulmonary and systemic circulation
Blood pressure
The human skeleton has 206 bones.

The arrangement of these bones enables five main functions including:

- support for the body, giving it shape, form and posture
- protection of vital organs and soft tissue
- assistance in body movement by providing the attachment for muscles and being able to serve as levers
- manufacture of blood cells in the marrow cavities
- provision of a storehouse for essential minerals such as calcium and phosphorus.

Bones range in shape and size, a feature that allows them to perform specialised functions. The main types are **long bones**, **short bones** and **flat bones**. Long and short bones function as levers or to transfer forces. Flat bones usually provide protection for vital organs.

The outer part of bone consists of dense, strong compact bone tissue and forms the actual shaft of long bones. At the extremities or ends of long bones, there is a criss-cross network of spongy bone tissue called **cancellous bone** which is strong but light and able to withstand stress (See figure 4.1). This is the area that flares out to articulate (meet) with adjacent bones, forming joints. The centre cavity of the bone and the spaces of the spongy bone are filled with **bone marrow** which contains blood vessels, fat and blood-forming tissue.

On the articular surface (the area where bones meet) of the compact bone is a softer but highly resilient material called **articular cartilage**. This prevents jarring and allows the bones to move freely on each other.

**Figure 4.1:** The structure of a long bone

The major bones of the human body are shown in figure 4.2. Not all the bones identified in this figure are involved in movement. For example, the skull comprises many bones, but their role is to protect vital brain tissue rather than assist movement. Our focus in this chapter is on the bones that comprise and surround joints, establishing connecting structures that enable movement.

Bones provide structure to the body in the same way that a frame gives structure to a house. Bones move only because muscles pull them, often rapidly, through specific positions, enabling activities such as throwing, kicking, running and swimming. During movement, large long bones move considerably while others move marginally or not at all as they anchor joint structures. It is still important to be familiar with all bones that surround a joint so you fully understand how that structure functions during movement.
An anatomical reference system called *directional terms* is used to identify the location of bones. The starting point assumes that the body is in the anatomical position; that is, a reference position where the subject is standing erect, facing front on and with palms facing forward (see figure 4.3(a)). From here, we can locate a bone by saying where it is relative to another part of the body. For example, in anatomical terms, superior means ‘towards the head’. For location purposes we might say that the chest is superior to the hips or the knee is superior to the foot. Anatomical terms as they apply to locating body parts are shown in figure 4.3.

1. **Superior** — towards the head; for example, the chest is superior to the hips
2. **Inferior** — towards the feet; for example, the foot is inferior to the leg
3. **Anterior** — towards the front; for example, the breast is on the anterior chest wall (see figure 4.3(b))

**Figure 4.2:** Major bones in the human body
4. **Posterior** — towards the back; for example, the backbone is posterior to the heart (see figure 4.3(b))

5. **Medial** — towards the midline of the body; for example, the big toe is on the medial side of the foot

6. **Lateral** — towards the side of the body; for example, the little toe is on the lateral side of the foot

7. **Proximal** — towards the body’s mass; for example, the shoulder is proximal to the elbow

8. **Distal** — away from the body’s mass; for example, the elbow is distal to the shoulder.

**Major bones involved in movement**

The major bones involved in movement are as follows.

- **Clavicle (collar bone)**. This is a long bone that provides attachment between the shoulder girdle and the vertebral column. It gives greater mobility to the shoulder joint when movement is taking place, such as throwing a softball.

- **Scapula (shoulder blade)**. This is a large, triangular flat bone. The scapula/clavicle structure allows the arm to attach to the trunk portion of the skeleton. Many muscles involved in movement attach to this bone.

- **Humerus**. This is the major long bone in the upper arm joining the shoulder to the elbow. It can move in most directions and even rotate within the shoulder joint, as might be required for bowling in cricket.

- **Radius**. This long bone is found on the thumb side of the forearm. It works with the ulna in providing structure to the forearm and allowing it to rotate on the elbow joint. Muscles work on and around the radius and ulna.
rotating the palm of the hand, as might be required during freestyle swimming or providing topspin to a table tennis ball.

- **Ulna.** This is the longer bone of the forearm, found on the little finger side.

- **Carpals, metacarpals and phalanges.** These are the bones of the wrist and fingers. Carpals are short bones; metacarpals and phalanges are long. Collectively they provide structure to the hand allowing it to perform important fine motor movements such as catching, holding a bat, flicking as part of a throw, spinning a ball and squeezing.

- **Pelvic girdle.** The pelvis comprises a number of bones and provides the base of support necessary for the weight of the upper body. While not directly contributing to movements such as kicking, it is important because it also allows for the attachment of the lower limbs and muscles of the leg and lower back. The pelvic girdle allows less movement than the shoulder girdle because the supporting ligaments are short and strong. The hip joint where the femur (thigh bone) attaches is deep, adding to the stability of the structure.

- **Femur** (thighbone). The femur is the longest and strongest bone in the body, having the capability to support up to 30 times the weight of an adult. The bone is covered by large muscles that extend from the pelvic girdle to the shin, enabling many movements such as running and kicking.

- **Patella** (kneecap) is a small, flat triangular bone whose main role is to provide protection to the knee.

- **Tibia** or shinbone is the larger of two long bones that form the lower leg. It bears most of the body weight and of course is involved in all movements of the lower body, such as running, kicking and swimming.

- **Fibula** is a slender long bone that lies parallel with and on the lateral side of the tibia. It works with the tibia in providing support and stability to the lower leg, while allowing slight rotation from the knee joint.

- **Tarsals, metatarsals and phalanges** comprise the bones of the foot. Tarsals are short bones; metatarsals and phalanges are long. They work as a unit providing a structure that enables leg movements including walking, running, balancing, hopping and kicking.

### The skeletal system and its role in movement

**Equipment**

- Textbook, diagram of a skeleton, an anatomical model of the skeleton, a skeletal chart, blank labels

**Procedure**

1. Refer to the text about the major bones of the body and to figure 4.2. Using a diagram of the skeleton, label the major bones involved in movement.

2. Work in pairs, rotating the role of performer and analyst during the following activities. As one student slowly performs each action, the other should identify the bones involved in the movement and establish the role played by each bone; for example, support, transfer of load.

   - (a) Throwing a javelin
   - (b) Kicking a football
   - (c) Paddling a canoe
   - (d) Shooting in netball
   - (e) Bowling in cricket
   - (f) Swinging a golf club
Structure and function of synovial joints

A joint is a junction of two or more bones and is commonly referred to as an articulation. There are three types of joint — immovable or fibrous, slightly movable or cartilaginous, and freely movable or synovial.

An immovable or fibrous joint is a joint where no movement is possible. Examples of this type of joint include the bones of the cranium, which are fused in lines called sutures.

A slightly movable or cartilaginous joint is a joint that permits limited movement. Examples of this joint exist in the vertebral column, where fibrous cartilage between discs allows a limited range of movement.

A freely movable or synovial joint is one that allows maximum movement. Most joints in the body are synovial joints; for example, the hip joint.

The knee joint is a typical synovial joint. Although its structure is complex, its features are typical of that of synovial joints throughout the body. The most important structures in synovial joints are tendons, ligaments, cartilage and synovial fluid.
Ligaments

Ligaments are well-defined, fibrous bands that connect the articulating bones. They are designed to assist the joint capsule to maintain stability in the joint by restraining excessive movement, but can also control the degree and direction of movement that occurs.

Ligaments are relatively inelastic structures that may become permanently lengthened when stretched excessively. This can occur in injury to the joint and may lead to some joint instability.

Tendons

Tendons are tough, inelastic cords of tissue that attach muscle to bone. Joints are further strengthened by muscle tendons that extend across the joint and assist ligaments to hold the joint closed.

Synovial fluid

Synovial fluid acts as a lubricant, keeping the joint well oiled and the moving surfaces apart. As no two joint surfaces fit together perfectly, synovial fluid forms a fluid cushion between them. It also provides nutrition for the cartilage and carries away waste products.

The amount of synovial fluid produced depends on the amount and type of physical activity of the joint. When the articular cartilage is under pressure — that is, during movement — fluid is ‘pumped’ into the joint space. The viscosity (stickiness) of the fluid can also vary, with the synovial fluid becoming more viscous with decreases in temperature. This may be the reason for joint stiffness in cold weather.

Hyaline cartilage

While synovial fluid acts as a cushion between the articulating surfaces of the bones, they are also covered with a layer of smooth, shiny cartilage that allows the bones to move freely over each other. Hyaline cartilage has a limited blood supply but receives nourishment via the synovial fluid. This cartilage is thicker in the leg joints, where there is greater weight bearing.

APPLICATION

Observing synovial joints in action

Equipment

Textbook and model of skeletal system

1. In pairs, observe the anatomical model, giving particular attention to the joints.
   If possible, gently manipulate major joints while noting the structure of bones that articulate at the joint.

2. Copy and complete the table at the top of the next page.

3. Use the information you have gathered to discuss the relationship between the types of bone (long, short, flat) and movement allowable at each joint.
The role of joints in movement

1. What do you think would be the effect of a ruptured medial ligament on movement? Use the Medial ligaments weblink in your eBookPLUS to help you answer this question.

2. What would be the effect of missing menisci on movement?

3. The human skeletal system is remarkable in that it allows us to perform a very wide range of movements. Discuss how the various joint structures allow us to run quickly, throw a shot-put and perform a somersault in gymnastics.

Joint actions

The numerous joints of the body, together with the muscles around these joints, allow us to perform a remarkable range of twisting, turning and rotating movements. Physiologists use specific terminology to describe those movements, which are called joint actions. An example is flexion which refers to the action of two bones coming closer together, as happens when we bend the elbow. In this action, the radius and ulna are drawn closer to the humerus. The types of joint actions are summarised in table 4.1.

<table>
<thead>
<tr>
<th>Joint action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>A movement that decreases the angle between the bones at the joint; for example, bending the leg at the knee or the arm at the elbow</td>
</tr>
<tr>
<td>Extension</td>
<td>A movement that increases the angle between the bones at the joint; for example, straightening the leg at the knee</td>
</tr>
<tr>
<td>Abduction</td>
<td>The movement of a body part away from the midline of the body; for example, raising the leg or arm to the side</td>
</tr>
<tr>
<td>Joint action</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Adduction</td>
<td>The movement of a body part towards the midline of the body; for example, lowering the arm or leg towards the midline</td>
</tr>
<tr>
<td>Inversion</td>
<td>Rotation of the foot to make the sole of the foot face inwards</td>
</tr>
<tr>
<td>Eversion</td>
<td>Rotation of the foot to make the sole of the foot face outwards</td>
</tr>
<tr>
<td>Rotation</td>
<td>Moving a body part such as the head or trunk around on its long axis</td>
</tr>
<tr>
<td>Circumduction</td>
<td>The circular movement of a body part; for example, making a large movement with the arm that describes a cone in space</td>
</tr>
<tr>
<td>Pronation</td>
<td>The rotation of the hand and forearm that causes the hand to face palm downwards</td>
</tr>
<tr>
<td>Supination</td>
<td>The rotation of the hand and forearm that causes the hand to face palm upwards</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>This is flexion of the ankle. It is a movement that pulls the top of the foot towards the tibia.</td>
</tr>
<tr>
<td>Plantar flexion</td>
<td>This is extension of the ankle. It is a movement that moves the top of the foot from the tibia; that is, pointing the toes.</td>
</tr>
</tbody>
</table>

**INQUIRY**

Identifying joint action

Closely examine the illustrations in table 4.2 (pages 146–7). Indicate the type of movement taking place at the specified joint.
### Table 4.2: Joints involved in movements

<table>
<thead>
<tr>
<th>Movement</th>
<th>Joint</th>
</tr>
</thead>
</table>
| 1.       | Knees (points 4–6)  
          | Knees (9–10)  
          | Hips (4–6)  
          | Hips (9–10)  
          | Neck (3–6) |
| 2.       | Neck (2–4)  
          | Elbows (2–4)  
          | Feet at point 1  
          | Feet at 3 |
| 3.       | Hips (5–7)  
          | Arms (1–2)  
          | Feet (6–7) |
| 4.       | Hips (5–7)  
          | Arms (1–2) |
**Joint actions**

Work in pairs. One person names a specific joint action and the other person performs an example of the movement. Continue until all joint actions have been explored, then change roles.

**Joint actions in a sport or activity**

Identify each of the joint actions in a particular sport or activity. Suggest how knowledge of joint structures could improve efficiency of movement and lessen the risk of injury.

**MUSCULAR SYSTEM**

There are more than 600 muscles in the body and they are all attached to bones. The role of muscles is to contract. When they contract, we move. Muscles are unable to push to enable movement. Instead they shorten, causing joint movement, then relax as opposing muscles pull the joint back into position. The major muscles of the body are shown in figure 4.12.
To locate muscles, it is important to establish the **origin** and **insertion** of the muscle. The origin of the muscle is usually attached directly or indirectly to the bone via a tendon. The attachment of the muscle is usually by a tendon at the movable end, which tends to be away from the body’s main mass. When the muscle contracts it causes movement. This is called muscle **action**.

**Figure 4.12:** Muscles of the human body

The muscle’s point of attachment to the more stationary bone is called its **origin**. In most cases, this point is nearer the trunk.

The **insertion** of a muscle is the point of attachment at the movable end. This end tends to be away from the body’s main mass.

The muscle **action** refers to movement made at the joint when the muscle contracts.

**Figure 4.13:** The origin, insertion and action of the biceps brachii
**Major muscles involved in movement**

The identification and location of the major muscle groups is summarised in table 4.3.

Palpation is a term that means feeling a muscle or muscle group. Most of the muscles shown in table 4.3 are superficial muscles because they are just underneath the skin surface and can be palpated. It is often easier to palpate a muscle if we move it a little.

**Table 4.3: Location of major muscles and their actions**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin, insertion, action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper limb</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Deltoid      | Origin: scapula, clavicle  
Insertion: humerus  
Action: abduction of arm                       |
| Biceps brachii | Origin: humerus, scapula  
Insertion: radius  
Action: flexion of arm and forearm, supination of forearm |
| Triceps      | Origin: scapula, humerus  
Insertion: ulna (proximal end)  
Action: extension of arm and forearm          |
| **Trunk**    |                                                                                          |
| Latissimus dorsi | Origin: spine: T6–L5 vertebrae, iliac crest  
Insertion: humerus (proximal end)  
Action: adduction, extension and rotation of arm |
| Trapezius    | Origin: base of skull, C7–T5 vertebrae  
Insertion: scapula (upper surface), clavicle  
Action: adduction of scapula, elevation of shoulders |
| Pectorals    | Origin: sternum, clavicle  
Insertion: head of humerus  
Action: flexion and adduction of arm           |

(continued)
Table 4.3: (continued)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin, insertion, action</th>
<th>Muscle</th>
<th>Origin, insertion, action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus abdominis</td>
<td>Origin: crest of pubis, insertion: ribs 5, 6, 7, Action: flexion of trunk</td>
<td>Quadriceps</td>
<td>Origin: iliac crest, femur, insertion: tibia (proximal end), patella, Action: flexion of hip, extension of lower leg</td>
</tr>
<tr>
<td>Muscle</td>
<td>Origin, insertion, action</td>
<td>Muscle</td>
<td>Origin, insertion, action</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------------------------------</td>
<td>---------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Origin: femur (distal end)&lt;br&gt;Insertion: heel bone (posterior)&lt;br&gt;Action: knee flexion, plantar flexion of foot</td>
<td>Tibialis anterior</td>
<td>Origin: tibia&lt;br&gt;Insertion: ankle, tarsal, metatarsal&lt;br&gt;Action: dorsiflexion and inversion of foot</td>
</tr>
<tr>
<td>Soleus</td>
<td>Origin: tibia and fibula&lt;br&gt;Insertion: heel bone (posterior)&lt;br&gt;Action: plantar flexion of foot</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Palpating muscles

Working in pairs, palpate as many muscles as convenient. Try to identify place of origin, belly (main part) of the muscle and point of insertion. Change roles after each muscle palpation.

Muscle palpation and identification

1. Which five muscles were easiest to palpate?
2. Which muscles were most difficult to palpate?
3. Why is palpation difficult with some muscles?
4. Examine the action of each muscle that you were able to palpate. Identify how that muscle influences the way we move by describing a movement caused by the contraction of the muscle.
5. Discuss the importance of the strength of tendons in 'collecting' muscle fibres and joining them to a bone.

Muscle relationship

In producing a particular movement, a muscle performs one of three roles. It can act as an agonist, antagonist or stabiliser (or fixator).

Agonist

An agonist or prime mover is the muscle causing the major action. There are agonists for all movable joints and usually more than one is involved in a particular joint movement.

Antagonist

An antagonist is a muscle that must relax and lengthen to allow the agonist to contract, thus helping to control an action. The agonist works as a pair with the antagonist muscle. The two roles are interchangeable depending on the direction of the movement.

Antagonists cause an opposite action to that caused by the agonist. For example, figure 4.14 shows that:

- in bending the elbow, the flexor (biceps) is the agonist while the extensor (triceps) is the antagonist, relaxing for flexion to occur
- in straightening the elbow, the extensor (triceps) is the agonist while the flexor (biceps) is the antagonist.

Similarly, abductors and adductors are generally antagonistic to each other.

Stabiliser

Stabiliser or fixator muscles act at a joint to stabilise it, giving the muscles a fixed base. The muscle shortens very little during its contraction, causing minimal movement. This permits the action to be carried out correctly and allows other joints to work more effectively. For example, in a dynamic movement such as throwing, while some shoulder muscles serve to propel the object, others act as stabilisers to allow the efficient working of the elbow joint and to reduce the possibility of damage to the joints.

**Figure 4.14:** The changing roles of muscles — bending and straightening the arm
Types of muscle contraction

When a muscle is stimulated, it contracts. This may happen in a number of ways. There are three principal types of muscle contraction — **concentric**, **eccentric** and **isometric**. Both concentric and eccentric contractions are isotonic contractions (also called dynamic contractions) because the length of the muscle will change; that is, it will become shorter or longer. In contrast, an isometric contraction is a form of static contraction where length is unchanged despite application of tension.

Examples of concentric contractions are the contraction of the rectus abdominis to raise the trunk during a sit-up, or the biceps contracting to lift a weight, as shown in figure 4.15.

Examples of eccentric contractions are the rectus abdominis extending to gradually lower the trunk during the downward action of a sit-up, or the biceps muscle fibres lengthening as the weight is returned to its original position, as shown in figure 4.16.

A **concentric** contraction is the most common type of muscular contraction. During this contraction, the muscle shortens, causing movement at the joint. An **eccentric** contraction occurs when the muscle lengthens while under tension. The action often happens with the assistance of gravity. An **isometric** contraction occurs when the muscle fibres are activated and develop force, but the muscle length does not change; that is, movement does not occur.

Figure 4.17: Isometric muscle contractions are important in rock climbing and many other physical activities and sports.

Figure 4.18: An example of an isometric contraction. The muscle length does not change when trying to lift a fixed weight.

Figure 4.15: An example of a concentric contraction. The biceps shortens to lift the weight.

Figure 4.16: An example of an eccentric contraction. The biceps lengthens to lower the weight.

Despite effort, there is no change in length of muscle.

Isometric contractions are commonly seen in attempted movements where a resistance cannot be overcome. Examples are a weight-lifter trying to lift a weight that cannot be moved, or a person pushing against a wall. In each case, the effort is being made, but the muscle length does not change because the resistance is too great.
Joints and movement

Following is a list of common sporting movements. Working in pairs, have one person imitate each of the actions:

- arm action while taking a shot in basketball
- wrist action while taking a shot in netball
- arm action during an overarm throw
- knee action during a vertical jump
- foot action during the take-off in a long jump.

Observe each action closely and then copy and complete the following table.

<table>
<thead>
<tr>
<th>Movement</th>
<th>Bones involved</th>
<th>Muscles and their roles</th>
<th>Joint action</th>
<th>Type of contraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm action — basketball shot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist action — netball shot</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm action — overarm throw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee action — vertical jump</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot action — long jump take-off</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Anatomical structures and movement

Copy and complete a mind map similar to figure 4.19, to respond to the question: “How does the body’s musculoskeletal system influence and respond to movement?”

Figure 4.19: Sample mind map
Structure and function

Every cell in our body needs a constant supply of oxygen (O₂) and food to maintain life and to keep the body operating effectively. But how does oxygen get from the atmosphere to the muscles and other body tissues? How is carbon dioxide (CO₂) removed from the body? What causes us to breathe? What is lung capacity and how does it influence our physical performance? These are the types of questions that can arise when we consider the system through which the human body takes up oxygen and removes carbon dioxide in the process known as respiration.

Respiration is a process that occurs in practically all living cells. It uses oxygen as a vital ingredient to free energy from food and can be characterised by the following equation:

\[
\text{Glucose (from food) + Oxygen (O}_2\text{ breathed in) \rightarrow Carbon dioxide (CO}_2\text{ breathed out) + Energy + Water}
\]

This process is made possible through the respiratory system that facilitates the exchange of gases between the air we breathe and our blood. The respiratory system acts to bring about this essential exchange of gases (CO₂ and O₂) through breathing; the movement of air in and out of the lungs. The lungs and the air passages that ventilate them make up the basic system.

The passage of air from the nose to the lungs can be followed in figure 4.20.

1. Air containing oxygen from the atmosphere enters the body either through the nose or the mouth. When entering through the nose it passes through the nasal cavities and is warmed, moistened and filtered of any foreign material.
2. The pharynx or throat serves as a common passage for air to the trachea (windpipe) or food to the oesophagus. It leads from the nasal cavity to the larynx (voice box) located at the beginning of the trachea.
3. The trachea is a hollow tube strengthened and kept open by rings of cartilage. After entering the chest cavity or thorax, the trachea divides into a right and a left bronchus (bronchial tube), which lead to the right and left lungs respectively.
4. The inner lining of the air passages produces mucus that catches and holds dirt and germs. It is also covered with microscopic hairs (cilia) that remove dirt, irritants and mucus through steady, rhythmic movements.
5. The lungs consist of two bag-like organs, one situated on each side of the heart. They are enclosed in the thoracic cavity by the ribs at the sides, the sternum at the front, the vertebral column at the back and the diaphragm (a dome-shaped muscle) at the base. The light, soft, lung tissue is compressed and folded and, like a sponge, is composed of tiny air pockets (see figure 4.21).

**Figure 4.21:** Human lungs are made up of bronchi, bronchioles and alveoli.

The right and left bronchi that deliver air to the lungs divide into a number of branches or bronchioles within each lung. These bronchioles branch many times, eventually terminating in clusters of tiny air sacs called alveoli (singular — alveolus). The walls of the alveoli are extremely thin, with a network of capillaries (tiny vessels carrying blood) surrounding each like a string bag (see figure 4.22). This is where oxygen from the air we breathe is exchanged for carbon dioxide from our bloodstream.

**Figure 4.22:** Air enters the lungs through the bronchi. The air moves into the bronchioles, then enters the microscopic air sacs called alveoli.
Lung function

Breathing is the process by which air is moved in and out of the lungs. It is controlled automatically by the brain and involves two phases: inspiration and expiration.

Inspiration and expiration

During **inspiration**, the diaphragm contracts and flattens as the external intercostal muscles (between the ribs) lift the ribs outwards and upwards (see figure 4.23(a)). This movement increases the volume of the chest cavity and pulls the walls of the lungs outwards, which in turn decreases the air pressure within the lungs. In response to this, air from outside the body rushes into the lungs through the air passages.

During **expiration**, the diaphragm relaxes and moves upwards as the internal intercostal muscles allow the ribs and other structures to return to their resting position (see figure 4.23(b)). The volume of the chest cavity is therefore decreased,

**Inspiration** is air movement from the atmosphere into the lungs; breathing in.

**Expiration** is air movement from the lungs to the atmosphere; breathing out.

**Figure 4.23:** (a) Inspiration and (b) expiration
which increases the air pressure inside the lungs. Air is consequently forced out to make the pressures inside and outside the lungs about equal.

Under normal resting conditions we breathe at a rate of approximately 12 to 18 breaths per minute. This rate can increase with physical activity, excitement or elevated body temperature. It also changes with age, being higher in babies and young children.

\section*{Inspiration and expiration}

Use the Inspiration and expiration weblink in your eBookPLUS to observe a short video of how inspiration and expiration function.

Describe what happens during inspiration and expiration.

\section*{The exchange of gases}

During inspiration, the alveoli are supplied with fresh air that is high in oxygen content and low in carbon dioxide. On the other hand, blood in the capillaries arriving at the alveoli is low in oxygen and high in carbon dioxide content, as shown in table 4.4. The different concentrations of oxygen and carbon dioxide between the blood and the air result in a pressure difference.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
\textbf{Gas} & \textbf{Inhaled air (per cent)} & \textbf{Exhaled air (per cent)} \\
\hline
Oxygen ($O_2$) & 20.93 & 16.4 \\
Carbon dioxide ($CO_2$) & 0.03 & 4.1 \\
Nitrogen (N) and other gases & 79.04 & 79.5 \\
\hline
\end{tabular}
\caption{The composition of inspired and expired air by percentage at rest}
\end{table}

Gases such as oxygen and carbon dioxide move from areas of high concentration or pressure to areas of low concentration or pressure. Oxygen, therefore, moves from the air in the alveoli across the alveolar–capillary wall into the blood, where it attaches itself to haemoglobin in the red blood cells. At the same time, carbon dioxide is unloaded from the blood into the alveoli across the alveolar–capillary wall to be breathed out. This two-way diffusion is known as the exchange of gases (or gaseous exchange) and is diagrammatically represented in figure 4.24.

Exchange of gases, using the same principle, occurs between blood in the capillaries of the arterial system and the cells of the body; for example, the muscle cells. Here, oxygen is unloaded to the cells while carbon dioxide resulting from cell metabolism is given up to the blood. Blood that is high in carbon dioxide content (deoxygenated blood) is carried back to the lungs where it unloads carbon dioxide.

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{figure424}
\caption{As blood goes past an alveolus, the blood gives up carbon dioxide and picks up oxygen. These gases move in and out by diffusion through the thin alveolar walls.}
\end{figure}

\section*{The exchange of gases}

Use the Exchange of gases weblink in your eBookPLUS to observe a short video detailing how the exchange gases in the lungs takes place.

Describe how the exchange of gases takes place in the lungs.
How does smoking affect lung function?

Investigate what happens in gaseous exchange when the person is a smoker. Discuss how this affects physical performance. Carry out your own research or use the Smoking and lung function weblink in your eBookPLUS for this chapter for information.

Effect of physical activity on respiration

During physical activity, the body’s higher demand for oxygen triggers a response from our respiratory system. Increased rates of breathing combine with increased volumes of air moving in and out of the lungs, to deliver more oxygen to the blood and remove wastes. At the same time, blood flow to the lungs has been increased as a result of the circulatory system’s own response to the exercise (discussed on pages 160–70).

Physical activity brings about a number of immediate adjustments in the working of the respiratory system.

1. The rate and depth of breathing often increase moderately, even before the exercise begins, as the body’s nervous activity is increased in anticipation of the exercise. Just the thought of a jog can increase our demand for oxygen!

2. Once exercise starts, the rate and depth of breathing increase rapidly. This is thought to be related to stimulation of the sensory receptors in the body’s joints as a result of the movement. Further increases during the exercise result mainly from increased concentrations of carbon dioxide in the blood, which triggers greater respiratory activity.

3. The increases in the rate (frequency) and depth (tidal volume or TV) of breathing provide greater ventilation and occur, generally, in proportion to increases in the exercise effort (workload on the body). Refer to figure 4.25.

**Figure 4.25:** Changes in ventilation (frequency and TV) during moderate exercise. These changes are due mainly to CO₂ levels in the blood produced during exercise. In maximal exercise, the levelling off doesn’t occur. Ventilation continues to increase until exercise ceases. During the recovery period, CO₂ levels are reduced. (Source: D. K. Mathews and E. L. Fox, The Physiological Basis of Physical Education and Athletics, 3rd edn, W. B. Saunders, Philadelphia, 1981, p. 168. Reprinted with permission W. C. M. Brown.)

CHAPTER 4 BODY SYSTEMS AND MOVEMENT
**APPLICATION**

Lung function and physical activity

Equipment
Stopwatch, recording sheets

This application aims to measure changes in lung function between rest and exercise. Work in pairs, as recorder and subject.

(a) The subject should rest while the recorder counts the subject’s number of breaths per minute and records the information.

(b) The subject should then run 100 metres as quickly as possible. The recorder records the subject’s breathing rate during the minute following the run.

(c) Finally, the subject should run steadily for four to five minutes, then have their breathing rate monitored for one minute.

**INQUIRY**

How does physical activity affect my rate of breathing?

1. Compare the number of breaths recorded for each test in the preceding application and indicate any differences.
2. Did you notice any difference in the depth of breathing between rest and physical activity? If so, suggest why this might occur.
3. Discuss the effects of physical activity on breathing rate. Why do you think this change occurs?
4. Which type of exercise (short burst or longer distance) had the greater effect on breathing rate? Suggest reasons for your answer.
5. Use the internet or a reputable source to explore the effects of asthma on lung function. Suggest how asthma can be improved by certain exercise programs.

**CIRCULATORY SYSTEM**

The continual and fresh supply of oxygen and food that the tissues of the body require is provided by the blood. Blood flows constantly around the body from the heart, to the cells, and then returns to the heart. This is called circulation. The various structures through which the blood flows all belong to the circulatory system, which is also referred to as the cardiovascular system (cardio — relating to the heart; and vascular — relating to the blood vessels). This transport system delivers oxygen and nutrients to all parts of the body and removes carbon dioxide and wastes. It consists of:

- blood
- the heart
- blood vessels — arteries, capillaries and veins.

**Components of blood**

Blood is a complex fluid circulated by the pumping action of the heart. It nourishes every cell of the body. An average sized person contains about five litres of blood. Blood’s main functions include:

- transportation of oxygen and nutrients to the tissues and removal of carbon dioxide and wastes
- protection of the body via the immune system and by clotting to prevent blood loss
The circulatory or cardiovascular system is a network that distributes blood containing oxygen and nutrients and collects wastes. It comprises the heart, arteries, blood and veins.

**Plasma** is a straw-coloured liquid mainly consisting of water (about 90 per cent).

- regulation of the body’s temperature and the fluid content of the body’s tissues.

Blood consists of a liquid component (55 per cent of blood volume) called **plasma** and a solid component (45 per cent of blood volume) made up of red and white blood cells and platelets.

**Plasma**

Substances such as plasma proteins, nutrients, hormones, mineral salts and wastes are dissolved in the plasma and are necessary for the nourishment and functioning of tissues. Much of the carbon dioxide and very small amounts of oxygen are also carried in a dissolved state in plasma.

Water is a significant component of the circulatory system and controls body heat through sweating. When we work hard, the blood transfers excess heat generated by the body to the surface of the skin to be lost. If sweating is extreme, excessive loss of water from plasma and tissues can decrease blood volume, making frequent hydration (replacement of water) necessary.

**Red blood cells**

Red blood cells are formed in bone marrow. Their main role is to carry oxygen and carbon dioxide around the body. They contain iron and a protein called haemoglobin. Haemoglobin readily combines with oxygen and carries it from the lungs to the cells. Red blood cells outnumber white blood cells by about 700 to one.

Red blood cells have a flat disc shape that provides a large surface area for taking up oxygen. About two million red blood cells are destroyed and replaced every second. They live for only about four months.

On average, men have 16 grams of haemoglobin per 100 millilitres of blood (as a percentage of blood volume), while women average 14 grams per 100 millilitres of blood. Women, therefore, have lower levels of haemoglobin and a slightly lessened ability to carry oxygen in the blood.

**Anaemia**

What is anaemia? Use the Anaemia weblink in your eBookPLUS to investigate the symptoms of anaemia. Using the information, discuss how being anaemic could affect physical performance.

**White blood cells**

White blood cells are formed in the bone marrow and lymph nodes. They provide the body with a mobile protection system against disease. These cells can change shape and move against the blood flow to areas of infection or disease.

The two most common types of white blood cells are phagocytes, which engulf foreign material and harmful bacteria, and lymphocytes, which produce antibodies to fight disease. Diseases such as HIV/AIDS, which suppress the activity of the immune system, do so by disrupting the normal functioning of the white blood cells.

**Platelets**

Platelets are fragments of cells found in blood and are responsible for clotting.

**INQUIRY**

What is anaemia? Use the Anaemia weblink in your eBookPLUS to investigate the symptoms of anaemia. Using the information, discuss how being anaemic could affect physical performance.

**Figure 4.27:** Components of blood

**Figure 4.28:** The structure of blood cells and platelets

<table>
<thead>
<tr>
<th>Blood plasma</th>
<th>Blood cells</th>
<th>Platelets</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 per cent</td>
<td>45 per cent</td>
<td>Platelets</td>
</tr>
<tr>
<td>(90 per cent</td>
<td>(red cells, white cells,</td>
<td>are fragments of</td>
</tr>
<tr>
<td>water, 10 per cent</td>
<td>platelets)</td>
<td>cells found in blood and are</td>
</tr>
<tr>
<td>dissolved substances)</td>
<td></td>
<td>responsible for clotting.</td>
</tr>
</tbody>
</table>
Structure and function of the heart, arteries, veins and capillaries

Heart

The heart is a muscular pump that contracts rhythmically, providing the force to keep the blood circulating throughout the body. It is slightly larger than a clenched fist and is the shape of a large pear. The heart lies in the chest cavity between the lungs and above the diaphragm, and is protected by the ribs and sternum.

The heart beats an average of 70 times per minute at rest. This amounts to more than 100 000 beats per day. In one day the heart pumps approximately 12 000 litres of blood, which is enough to fill a small road tanker.

A muscle wall divides the heart into a right and left side. Each side consists of two chambers:
- **atria** — the upper, thin-walled chambers that receive blood coming back to the heart.
- **ventricles** — the lower, thick-walled chambers that pump blood from the heart to the body.

A system of four one-way valves allows blood to flow in only one direction through the heart; that is, from the atria to the ventricles (the atrioventricular valves) and from the ventricles into the main arteries taking blood away from the heart (the arterial valves).

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Figure 4.29: Position of the heart

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Figure 4.30: The heart. The atrioventricular valves consist of flaps that are attached to the sides of the ventricles by tough cords, the heart strings. The arterial valves are like little pockets.
Chapter 4
Body Systems and Movement

**Action of the heart**

The heart is able to receive blood from the veins and pump it to the lungs and the body through a rhythmic contraction and relaxation process called the cardiac cycle. The cardiac cycle consists of:

- **diastole** (relaxation or filling) phase. The muscles of both the atria and ventricles relax. Blood returning from the lungs and all parts of the body flows in to fill both the atria and ventricles in preparation for systole (contraction).

- **systole** (contraction or pumping) phase. The atria contract first to further fill the ventricles. The ventricles then contract and push blood under pressure to the lungs and all parts of the body. As they contract, the rising pressure in the ventricles closes the atrioventricular valves (between the atrium and the ventricle) and opens the valves in the arteries leaving the heart (the aorta and the pulmonary artery).

**Heartbeat**

The heart is made to contract or beat regularly by small impulses of electricity that are initiated and sent out from a natural pacemaker in the wall of the right atrium.

The heartbeat is heard as a two-stage ‘lub-dub’ sound. An initial low pressure sound is caused by the atrioventricular valves closing. This occurs at the beginning of the ventricular contraction (systole) after blood has filled the ventricles. The high pressure sound that follows is caused by the valves closing at the exits to the heart, and occurs after blood has been pushed from the ventricles at the end of the systole phase. Unusual heart sounds can mean that the valves may not be working properly.

Each time the ventricles contract (that is, the heart beats), a wave of blood under pressure travels through the arteries, expanding and contracting the arterial walls. This pressure wave is called a pulse. It reflects the fluctuating pressure of blood in the arteries with each heartbeat. The pulse can be felt at various points where an artery lies near the skin surface, in particular the radial pulse at the base of the thumb and the carotid pulse at the side of the neck.

**Blood supply to the heart**

The heart (cardiac muscle) itself requires a rich supply of blood and oxygen to enable it to contract repeatedly. It receives this through its own system of cardiac blood vessels that branch off the aorta and spread extensively over the heart wall (myocardium). This is called the coronary circulation. The heart muscle has a very high demand for blood (particularly during exercise) and extracts more than 75 per cent of the oxygen delivered to it both at rest and during exercise.

During exercise when the heart’s extra demands for oxygen must be met, coronary circulation accounts for up to approximately 10 per cent of the total
Arteries are blood vessels that carry blood away from the heart.

Blood volume leaving the left ventricle, compared to approximately three per cent at rest.

**Arteries**

Arteries carry blood away from the heart. They have thick, strong, elastic walls containing smooth muscle to withstand the pressure of the blood forced through them.

The blood pumped under pressure from the left ventricle passes through the aorta (the largest artery) and throughout the body. At the same time, blood from the right ventricle passes through the pulmonary artery to the lungs where it collects oxygen and then returns to the heart. These large exit arteries branch into smaller arteries that eventually divide into tiny branches called arterioles. Arterioles in turn divide into microscopic vessels (capillaries).

Capillaries are the smallest of all blood vessels. They function to exchange oxygen and nutrients for waste.

Figure 4.32: An artery has a thick, elastic wall, covering layers of smooth muscle.

Capillaries are a link between the arterioles and the veins. They rejoin to form tiny veins called venules.

In active tissue such as the muscles and brain, the capillary network is particularly dense with much branching of very fine structured vessels. This provides a large surface area for the exchange of materials between the blood and the fluid surrounding the cells (interstitial fluid).

Capillary walls are extremely thin, consisting of a single layer of flattened cells. These walls allow oxygen, nutrients and hormones from the blood to pass easily through to the interstitial fluid, then into the cells of the body’s tissues. The blood pressure (due to the pumping action of the heart) helps to force fluid out of the capillaries.

Meanwhile, carbon dioxide and cell wastes are received back into the capillaries. This diffusion of oxygen and other nutrients from the capillaries into the cells and carbon dioxide and wastes from the cells into the capillaries is known as *capillary exchange* (see figure 4.35).

**Capillaries**

Figure 4.34: A capillary has a very thin wall that allows oxygen and nutrients to pass into the cells and carbon dioxide to move from the cells to the blood.
Veins carry deoxygenated blood from the body tissues back to the right atrium. Pulmonary veins from the lungs differ in that they carry oxygenated blood to the left atrium.

**Veins**

The venules collect deoxygenated (low oxygen content) blood from the capillaries and transfer it to the veins.

As pressure in the veins is low, blood flows mainly against gravity (blood flow in the veins above the heart is, however, assisted by gravity). The walls of veins are thinner than those of arteries, with greater ‘give’ to allow the blood to move more easily. Valves at regular intervals in the veins prevent the backflow of blood during periods when blood pressure changes.

Pressure changes created by the pumping action of the heart stimulate blood flow in the veins and help to draw blood into it during diastole (relaxation phase). The return of blood from the body back to the heart (venous return) is further assisted by rhythmic muscle contractions in nearby active muscles (muscle pump) which compress the veins (see figure 4.37). It is also assisted by surges of pressure in adjacent arteries pushing against the veins.

If we stop exercising suddenly or stand still for long periods, the muscle pump will not work. Blood pooling (sitting) then occurs in the large veins of
the legs because of the effect of gravity. This can result in a drop in blood pressure, insufficient blood flow to the brain and possible fainting. This pooling of blood has implications for the cool down period after strenuous exercise. Rather than stop the exercise immediately, it is recommended that the activity is gradually tapered off with lower intensity exercise and maintained until the heart rate returns to a steady state. This allows blood from the extremities to be returned to the heart and lungs for re-oxygenating. It also promotes the disposal of waste products such as lactic acid.

**Pulmonary and systemic circulation**

Both sides of the heart work together like two pumps with overlapping circuits. The right side receives venous blood that is low in oxygen content (de-oxygenated) from all parts of the body and pumps it to the lungs. The closed circuit of blood to and from the lungs is the **pulmonary circulation**. The left side of the heart receives blood high in oxygen content (oxygenated) from the lungs and pumps it around the body. This circuit to and from the body is called **systemic circulation**.

**INQUIRY**

Investigate factors that contribute to poor circulation. How would an improved circulatory system impact on your health, movement efficiency and athletic performance? Present your findings as a PowerPoint.

To assist in gathering information, use the Circulation weblink in your eBookPLUS for this chapter.
Circulatory system and movement performance

Examine the following image representing the body’s circulatory system. Label the parts indicated by the lines. Now imagine you are a drop of blood. Describe your passage through the entire circulatory system, beginning with entry into the right atrium. Analyse your role in influencing physical performance as you move from one type of blood vessel to the next.

Blood pressure

What is blood pressure?

The term blood pressure refers to the force exerted by blood on the walls of the blood vessels. The flow and pressure of blood in the arteries rises with each contraction of the heart and falls when it relaxes and refills. Blood pressure has two phases — systolic and diastolic.

Blood pressure generally reflects the quantity of blood being pushed out of the heart (cardiac output) and the ease or difficulty that blood encounters in passing through the arteries (resistance to flow). It is determined by:

- cardiac output. Any increase in cardiac output results in an increase in blood pressure.
- volume of blood in circulation. If blood volume increases because of increased water retention, such as when salt intake is high, blood pressure increases. During blood loss, such as during a haemorrhage, blood pressure falls.
- resistance to blood flow. If the viscosity (stickiness) of the blood is increased, such as during dehydration, resistance increases. The diameter of the blood vessels also affects blood flow through the vessels. With narrowing of the vessels (for example, in atherosclerosis), resistance to blood flow is increased. The elasticity of the arterial walls acts to maintain blood flow. As deposits build up on the walls, the arteries become less elastic and harder.
arteriosclerosis), thereby making it more difficult for blood to flow. Any increase in the resistance to blood flow consequently causes elevated blood pressure.

- **venous return.** Since this affects cardiac output, it also affects blood pressure.

Blood pressure can be recorded with a **sphygmomanometer** and is measured in millimetres of mercury (mm.Hg) (see figure 4.40). It is expressed as a fraction that represents systolic pressure over diastolic pressure (for example, \(\frac{120}{80}\)). When blood pressure is recorded in a relaxed healthy person, ‘normal’ systolic pressure is in the range of 100 mm.Hg to 130 mm.Hg, with ‘normal’ diastolic pressure being 60 mm.Hg to 80 mm.Hg (see figure 4.41).

Blood pressure varies in response to posture (lying or standing), breathing, emotion, exercise and sleep. Temporary rises due to excitement, stress or physical exertion are quite natural and blood pressure returns to normal with rest. Under normal conditions, it provides valuable information about how well the circulatory system is operating.

### Measuring blood pressure

When measuring blood pressure with a sphygmomanometer, an inflatable cuff is attached to a gauge that records the pressure in the cuff. The cuff is firmly wrapped around the upper arm above the elbow and is inflated with a hand pump. This squeezes the artery under the cuff until the blood flow stops. The diaphragm of a stethoscope is placed over the artery just below the cuff at the elbow joint (inside of the arm). The cuff pressure is carefully released while watching the slowly falling mercury in the gauge. Two distinct sounds are heard — one representing the peak of blood pressure and the other representing the lowest pressure within the artery.

![Figure 4.40: A sphygmomanometer](image)

**Figure 4.40:** A sphygmomanometer

A sphygmomanometer is an instrument used to measure blood pressure.

![Figure 4.41: (a) A mercury gauge showing normal readings. The pressures above 130–160 systolic and 80–90 diastolic should be judged as being high only after the patient’s age, current treatment and other risk factors have been considered. (b) Blood pressure reading using an electronic blood pressure machine](image)
With each heartbeat, as small amounts of blood return to the artery past the obstruction (the cuff) a thudding sound is heard. The position of the mercury in the gauge is noted as the first sounds are heard. This reading represents the systolic blood pressure.

Air continues to be released from the cuff until there is no obstruction to the blood flow in the artery and the thudding sounds can no longer be heard. The position of the mercury in the gauge is noted when the sounds disappear. This reading represents the diastolic blood pressure.

**Figure 4.42:** Measuring blood pressure with a sphygmomanometer

Air continues to be released from the cuff until there is no obstruction to the blood flow in the artery and the thudding sounds can no longer be heard. The position of the mercury in the gauge is noted when the sounds disappear. This reading represents the diastolic blood pressure.

**APPLICATION**

**Measuring blood pressure**

**Equipment**

Sphygmomanometer

Work in pairs or threes. Using the sphygmomanometer and the procedures outlined in the text, measure the blood pressure of a subject in your group. You will need to inflate the cuff to approximately 160 mm/Hg. Ensure the ear plugs of the stethoscope completely seal the ear passage and prevent outside interference.

**INQUIRY**

**Analysing blood pressure readings**

1. Examine the systolic and diastolic values obtained in the application above. Are they within the normal range? If not, suggest why.
2. Discuss the difficulties that you experienced in taking the measurement. How could these affect the reading?
3. Use the internet to conduct a search on blood pressure. Find the meaning of hypertension and suggest reasons why so many people have this condition. Why is hypertension called a ‘silent killer’ and what can be done about the condition?
Blood pressure changes with exercise

Aim
To observe changes in blood pressure with changes in exercise intensity.

Equipment
Sphygmomanometers, stopwatches, bicycle ergometers

If a bicycle ergometer is not available, a 30–40 centimetre step-up bench can be used. Initially, the subject can step up and down at a moderate rate (about 24 steps per minute) for the duration of one minute. One step consists of four beats (up left, up right, down left, down right). The workload can be increased for step three by stepping up and down rapidly (about 36 steps per minute).

Procedure
Work in groups of two or three.

1. Using the method described on pages 167–9, calculate blood pressure while the subject is sitting in a chair. Allow the subject to sit for several minutes before taking the blood pressure reading.

2. The subject should now work on a bicycle ergometer at a workload of 300 kp.m/min for one minute. Be ready to establish blood pressure 15 seconds before the finish. Pump the cuff up to past 250 mm/Hg. Stop the test. Measure blood pressure and record the reading in the table below.

3. The subject now works at a workload of 900 kp.m/min on the ergometer for one minute. Using the same method as in step two, measure blood pressure immediately the exercise finishes. Record the reading in the table.

4. Wait one minute for recovery. Measure blood pressure again and record the reading.

<table>
<thead>
<tr>
<th>Workload</th>
<th>Systolic pressure</th>
<th>Diastolic pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 kp.m/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>900 kp.m/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Examining changes in blood pressure

1. What does the systolic blood pressure reading represent?
2. What does the diastolic blood pressure reading represent?
3. What was the effect of moderate exercise (300 kp.m/min) on blood pressure?
4. What was the effect of strenuous exercise (900 kp.m/min) on blood pressure? What accounts for this difference?
5. Why do the results for the different workloads vary? Explain with reference to both systolic and diastolic blood pressures.
6. Which blood pressure measurement is nearest to resting levels during recovery? Explain why.
The cardiorespiratory system and movement

Copy and complete a mind map similar to figure 4.44, to respond to the question:

How does the cardiorespiratory system of the body influence and respond to movement?

Summary

- The body has 206 bones of varying shapes and sizes. They provide important functions such as protecting vital organs and enabling movement.
- Bones involved in movement are usually long, meeting at joints such as the knee and elbow joints. Muscles surrounding these joints pull on bones making many different types of movement possible.
- Joints are places where two or more bones meet. Some joints allow more movement than others. Synovial joints allow maximum movement.
- The knee joint is a typical synovial joint. It contains important structures including tendons, ligaments, cartilage and synovial fluid.
- Synovial joint movements can be described in terms of flexion, extension, abduction, adduction, inversion, eversion, rotation, circumduction, pronation, supination, dorsiflexion and plantar flexion.
- Muscles enable us to move. There are more than 600 muscles in the body. The most important muscles that enable us to move include the deltoid, biceps brachii, triceps, latissimus dorsi, trapezius, pectorals, erector spinae (sacrospinalis), gluteus maximus, hamstrings, quadriceps, gastrocnemius, soleus, tibialis anterior, rectus abdominis and external obliques.
- Muscles perform roles according to the movement required. They can act as agonists (prime movers), antagonists (the lengthening muscle on the opposing side), or stabilisers (muscles that fix a joint while other actions are occurring). During movements such as running, the roles are constantly being reversed.
- The types of muscle contraction are concentric, eccentric and isometric. In a concentric contraction, the muscle shortens while under tension; in an eccentric contraction it lengthens while under tension and, in an isometric contraction, there is no change in length despite the muscle being under tension.
The major components of the respiratory system include the bronchi, bronchioles, lungs and alveoli. The alveoli are microscopic sacs surrounded by capillaries. It is here that oxygen is exchanged for carbon dioxide.

Inspiration and expiration are automatic processes controlled by the contraction of the diaphragm and intercostal muscles.

The immediate effect of exercise on the lungs is to increase the rate and depth of breathing. This provides more oxygen to blood that is being moved rapidly around the body.

The role of circulation is to transport oxygen and nutrients to the body’s cells, carry hormones to target sites and collect carbon dioxide and waste.

Blood consists of plasma and formed elements consisting of red and white cells, as well as platelets.

The heart is a pump consisting of four chambers. The right chambers receive blood from the body and pump it to the lungs. The left chambers receive blood from the lungs and pump it to the body.

Arteries and arterioles deliver blood to capillaries where oxygen exchange takes place. Venules and veins return the deoxygenated blood to the heart.

Pulmonary circulation refers to the circulation of blood from the heart to the lungs and back to the heart again. Systemic circulation is circulation from the heart to the body tissues and back to the heart.

Blood pressure refers to the force exerted by the blood on the walls of the blood vessels. Blood pressure is measured using a sphygmomanometer. It indicates peak pressure, when blood is forced into the arteries (systolic pressure) and lowest pressure (diastolic pressure), when the heart is filling.

**QUESTIONS**

**Revision**

1. **Identify** the location and type of the major bones involved in movement. (P7) (3 marks)

2. Using the knee joint as an example, **discuss** the role of ligaments, tendons, cartilage and synovial fluid. How do these structures assist movement? (P7) (5 marks)

3. Using an example, **outline** the difference between each of the following joint actions — flexion and extension, inversion and eversion, pronation and supination, rotation and circumduction, dorsiflexion and plantar flexion, adduction and abduction. (P7) (5 marks)

4. For each of the following movement descriptions, give an example of a sporting movement or activity that **demonstrates** the movement.
   (a) flexion at the knee
   (b) flexion at the elbow
   (c) abduction of the leg
   (d) dorsiflexion of the ankle
   (e) wrist flexion (P7) (5 marks)

5. (a) **Describe** the joint action of each of the following muscles — deltoid, trapezius, biceps brachii, quadriceps, soleus and latissimus dorsi. (6 marks)
   (b) **Describe** a movement from any sport or activity where the action of each of the listed muscles can be observed in the movement. (P7) (6 marks)

6. Using an example, **discuss** the role of agonists and antagonists in movement. (P7) (4 marks)

7. Using exercises from weight-training programs as examples, **outline** the difference between concentric, eccentric and isometric contractions. (P7) (3 marks)

8. Use a diagram to indicate the major components of the lungs. **Briefly state** the function of each component. (P7) (4 marks)

9. **Describe** the process of inspiration and expiration. What is its function in making body movement possible? (P7) (5 marks)

10. Using a diagram, **describe** how the exchange of gases takes place in the lungs. (P7) (5 marks)

(continued)
11. (a) **Identify** and **discuss** the functions of the various components of blood. (4 marks)
   (b) Which component is most important in enabling a person to move? Why? (P7) (2 marks)

12. Use a diagram to **describe** how the heart pumps blood. Indicate the direction of blood flow through the heart. **Discuss** the importance of the heart in transporting blood around the body. (P7) (5 marks)

13. **Outline** the difference between coronary, pulmonary and systemic circulation. How could a narrowing or blockage in any part of these systems affect our health? (P16) (3 marks)

14. Consider the following facts and **propose** a reason for each.
   (a) The wall of the left ventricle is thicker and more muscular than the right ventricle.
   (b) Arteries have thicker and more muscular walls than veins.
   (c) Capillary walls are extremely thin.
   (d) Veins contain valves. (P16) (4 marks)

15. Briefly **describe** how the respiratory and circulatory systems coordinate the supply and transport of oxygen to the cells and removal of carbon dioxide from the blood. **Discuss** the importance of this process to physical performance. (P7) (5 marks)

16. What is blood pressure and how is it measured? (P7) (2 marks)

17. **Discuss** the importance of blood pressure to health. (P16) (3 marks)

18. ‘It is obvious that the higher the blood pressure, the harder the heart must work.’ **Discuss** this statement with particular reference to
   (a) the effect of high blood pressure on the heart itself
   (b) the effect of high blood pressure on the blood vessels. (P16) (4 marks)

**Extension**

1. Locate two pieces of soft wood approximately 2 centimetres × 4 centimetres that are each 20 centimetres long. Join the two pieces at one end using a small hinge. Use your model to **demonstrate** the following movements to the class:
   (a) flexion
   (b) extension
   (c) abduction
   (d) adduction
   (e) dorsiflexion
   (f) plantar flexion.

   Using two drawing pins, attach a thick elastic band to both pieces to simulate a muscle. Use your model to **demonstrate**
   (g) muscle origin
   (h) muscle insertion
   (i) a concentric contraction
   (j) an eccentric contraction
   (k) an isotonic contraction
   (l) an isometric contraction.

   Using more bands and tissue paper, **demonstrate** the role of tendons, ligaments and cartilage in a joint. **Discuss** how forces such as tackles can easily damage the joint. (P7, P16) (10 marks)

2. A spirometer is an instrument commonly used to measure aspects of lung functioning. Use the **Spirometer** weblink in your eBookPLUS to complete the following.
   (a) Learn more about spirometry and how to use it to measure lung function.
   (b) **Predict** your lung function using height, age and gender.
   (c) **Establish** why your values might differ from others in the class. (P7, P16) (6 marks)

**Note:** For an explanation of the key words used in the revision questions above, see Appendix 2, page XXX.

**Digital docs:**
A summary quiz and revision test on this chapter’s content are available in Microsoft Word format in your eBookPLUS.