TOPIC 4
Body systems and movement

OVERVIEW
4.1 Skeletal system
4.2 Muscular system
4.3 Respiratory system
4.4 Circulatory system
4.5 Topic review

OUTCOMES
In this topic students will:
• 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)
4.1 Skeletal system

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.

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 topic 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.
FIGURE 4.2 Major skeletal bones from the anterior and posterior of the body

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)).
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.

FIGURE 4.3 The (a) anatomical and (b) anterior and posterior positions

(a) Superior (b) Anterior Posterior

Lateral Proximal Lateral Distal

Inferior
4.1.1 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.

Use the **Skeletal system** weblink in the Resources tab to help you review the skeletal system.

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**Application**

**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) Bowling in cricket
   - (e) Shooting in netball
   - (f) Swinging a golf club

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**Resources**

- **Weblink**: Skeletal system
- **Interactivity**: Major bones of the skeletal system (int-6616)
4.1.2 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, 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 below.
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.

<table>
<thead>
<tr>
<th>Joint name</th>
<th>Joint type</th>
<th>Articulating bones</th>
<th>Movement allowable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 4.11 The knee joint
Inquiry
The role of joints in movement
1. 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.
2. Investigate the effect of osteoarthritis on movement.

Application
Synovial joints
The weblinks joints and synovial joint anatomy in the Resources tab provide videos useful for revising the synovial joint section.

4.1.3 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>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>Decrease in the angle of the joint</td>
<td>Bending the elbow or knee</td>
</tr>
</tbody>
</table>

(Continued)
### TABLE 4.1 Types of joint actions (Continued)

<table>
<thead>
<tr>
<th>Joint action</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension</td>
<td>Increase in the angle of the joint</td>
<td>Straightening the elbow or knee</td>
</tr>
<tr>
<td>Abduction</td>
<td>Movement of a body part away from the midline of the body</td>
<td>Lifting arm out to side (out phase of star jump)</td>
</tr>
<tr>
<td>Adduction</td>
<td>Movement of a body part back towards the midline of the body</td>
<td>Returning arm into body or towards midline of the body</td>
</tr>
<tr>
<td>Circumduction</td>
<td>Movement of the end of the bone in a circular motion</td>
<td>Drawing a circle in the air with straight arm</td>
</tr>
<tr>
<td>Rotation</td>
<td>Movement of a body part around a central axis</td>
<td>Turning head from side to side</td>
</tr>
<tr>
<td>Pronation</td>
<td>Rotation of the hand so that the thumb moves in towards the body</td>
<td>Palm facing down</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Joint action</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supination</td>
<td>Rotation of the hand so that the thumb moves away from the body</td>
<td>Palm facing up</td>
</tr>
<tr>
<td>Eversion</td>
<td>Movement of the sole of the foot away from the midline</td>
<td>Twisting ankle out</td>
</tr>
<tr>
<td>Inversion</td>
<td>Movement of the sole of the foot towards the midline</td>
<td>Twisting ankle in</td>
</tr>
<tr>
<td>Dorsi flexion</td>
<td>Decrease in the angle of the joint between the foot and lower leg</td>
<td>Raising toes upwards</td>
</tr>
<tr>
<td>Plantar flexion</td>
<td>Increase in the angle of the joint between the foot and the lower leg</td>
<td>Pointing toes to the ground</td>
</tr>
<tr>
<td>Elevation</td>
<td>Movement of the shoulders towards the head</td>
<td>Shrugging shoulders</td>
</tr>
<tr>
<td>Depression</td>
<td>Movement of the shoulders away from the head</td>
<td>Returning shoulders to normal position</td>
</tr>
</tbody>
</table>
Inquiry

Identifying joint action

Closely examine the illustrations in table 4.2. 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) |

(Continued)
TABLE 4.2 Joints involved in movements (Continued)

<table>
<thead>
<tr>
<th>Movement</th>
<th>Joint</th>
</tr>
</thead>
</table>
| 5.       | Hips (1–2)  
          | Hips (2–4) |
| 6.       | Hips (1–6)  
          | Left knee (2–6)  
          | Neck (1–4)  
          | Right foot (4–5) |

Application
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.

Inquiry
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. Watch the video Joint movements in the Resources tab to learn more about different types of joint movement.

Resources

eLesson: Joint movements (eles-2578)
4.2 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.

**FIGURE 4.12** Muscles of the human body: (a) anterior view and (b) posterior view
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**.

### 4.2.1 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>
<th>Muscle</th>
<th>Origin, insertion, action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper limb</strong></td>
<td></td>
<td><strong>Trunk</strong></td>
<td></td>
</tr>
<tr>
<td>Deltoid</td>
<td>Origin: scapula, clavicle</td>
<td>Latissimus dorsi</td>
<td>Origin: spine: T6–L5 vertebral, iliac crest</td>
</tr>
<tr>
<td></td>
<td>Insertion: humerus</td>
<td></td>
<td>Insertion: humerus (proximal end)</td>
</tr>
<tr>
<td></td>
<td>Action: abduction of arm</td>
<td></td>
<td>Action: adduction, extension and rotation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>of arm</td>
</tr>
<tr>
<td>Biceps brachii</td>
<td>Origin: humerus, scapula</td>
<td>Trapezius</td>
<td>Origin: base of skull, C7–T5 vertebral</td>
</tr>
<tr>
<td></td>
<td>Insertion: radius</td>
<td></td>
<td>Insertion: scapula (upper surface), clavicle</td>
</tr>
<tr>
<td></td>
<td>Action: flexion of arm and forearm, supination of forearm</td>
<td>Action: adduction of scapula, elevation of shoulders</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 4.3 Location of major muscles and their actions (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>Triceps</td>
<td>Origin: scapula, humerus</td>
<td>Pectorals</td>
<td>Origin: sternum, clavicle</td>
</tr>
<tr>
<td></td>
<td>Insertion: ulna (proximal end)</td>
<td></td>
<td>Insertion: head of humerus</td>
</tr>
<tr>
<td></td>
<td>Action: extension of arm and forearm</td>
<td></td>
<td>Action: flexion and adduction of arm</td>
</tr>
<tr>
<td>Erector spinae (sacrospinalis)</td>
<td>Origin: base of skull</td>
<td>External obliques</td>
<td>Origin: lower 8 ribs</td>
</tr>
<tr>
<td></td>
<td>Insertion: sacrum</td>
<td></td>
<td>Insertion: iliac crest</td>
</tr>
<tr>
<td></td>
<td>Action: extension of back (trunk)</td>
<td></td>
<td>Action: flexion and rotation of trunk</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>Origin: posterior surface of pelvis, sacrum</td>
<td>Lower limb Hamstrings</td>
<td>Origin: ischium, femur</td>
</tr>
<tr>
<td></td>
<td>Insertion: femur</td>
<td></td>
<td>Insertion: tibia, head of fibula</td>
</tr>
<tr>
<td></td>
<td>Action: extension and abduction of thigh</td>
<td></td>
<td>Action: extension of thigh, flexion of lower leg</td>
</tr>
</tbody>
</table>

(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</td>
<td>Quadriceps</td>
<td>Origin: iliac crest, femur Insertion: tibia (proximal end), patella</td>
</tr>
<tr>
<td></td>
<td>Action: flexion of trunk</td>
<td></td>
<td>Action: flexion of hip, extension of lower leg</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Origin: femur (distal end) Insertion: heel bone (posterior)</td>
<td>Tibialis anterior</td>
<td>Origin: tibia Insertion: ankle, tarsal, metatarsal</td>
</tr>
<tr>
<td></td>
<td>Action: knee flexion, plantar flexion of foot</td>
<td></td>
<td>Action: dorsiflexion and inversion of foot</td>
</tr>
<tr>
<td>Soleus</td>
<td>Origin: tibia and fibula Insertion: heel bone (posterior)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Action: plantar flexion of foot</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Application
Identifying muscle groups and their role in movement
The Major muscle groups in the body weblink in the Resources tab is a useful resource review muscle names and their involvement in movement.

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

Inquiry
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.

4.2.2 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.

### 4.2.3 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.
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.

**Application**

**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>
Inquiry

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

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**4.3 Respiratory system**

**4.3.1 Structure and function**

Every cell in our body needs a constant supply of oxygen (O\textsubscript{2}) 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 (CO\textsubscript{2}) 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:

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

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 (CO\textsubscript{2} and O\textsubscript{2}) 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).

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.

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

**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.

---

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

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

Inquiry
Inspiration and expiration
Watch a short video of how inspiration and expiration function using either the Respiratory system weblink in the Resources tab or another online video.
1. Describe what happens during inspiration and expiration.
2. How does inspiration and expiration respond to sudden changes in exercise intensity?

4.3.3 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.
TABLE 4.4 The composition of inspired and expired air by percentage at rest

<table>
<thead>
<tr>
<th>Gas</th>
<th>Inhaled air (per cent)</th>
<th>Exhaled air (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (O$_2$)</td>
<td>20.93</td>
<td>16.4</td>
</tr>
<tr>
<td>Carbon dioxide (CO$_2$)</td>
<td>0.03</td>
<td>4.1</td>
</tr>
<tr>
<td>Nitrogen (N) and other gases</td>
<td>79.04</td>
<td>79.5</td>
</tr>
</tbody>
</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.

Inquiry
The exchange of gases
Use the What do the lungs do? weblink in the Resources tab to watch a video about how the gaseous exchange process takes place.
Use the information in this section to help describe how the exchange of gases takes place in the lungs.

Inquiry
What happens to your lungs when you exercise?
Watch a video about what happens to your lungs when you exercise, using either the Exercise and lung function weblink in the Resources tab or search online.
1. How is air forced in and out of the lungs?
2. How do the lungs benefit from exercise?
4.3.4 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 in subtopic 4.4).

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 lung volume and rate of ventilation from rest to exercise
**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.

### 4.4 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); see figure 4.26. 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.

#### 4.4.1 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
- 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 (see figure 4.27).

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

**Inquiry**
**Anaemia**
Discuss how being anaemic could affect physical performance. You can find more information about this condition by following the **Anaemia** weblink in the Resources tab.

**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 tiny structures made from bone marrow cells that have no nucleus. They help to produce clotting substances that are important in preventing blood loss when a blood vessel is damaged.

**On Resources**
**Weblink:** Anaemia
4.4.2 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).
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 the:

- **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 electrical impulses initiated and sent out from the cardiac conduction system located in the walls of the heart.

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

Arteries
**Arteries** are blood vessels that carry blood away from the heart (see figure 4.32). 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**

The capillaries are the smallest of all blood vessels. They function to exchange oxygen and nutrients for waste. They 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 4.36).

Veins
The venules collect deoxygenated (low oxygen content) blood from the capillaries and transfer it to the veins. Veins carry deoxygenated blood from the body tissues back to the right atrium.

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 (see figure 4.37).
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 4.38). 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 reoxygenating. It also promotes the disposal of waste products such as lactic acid.

4.4.3 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 (deoxygenated) 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
The circulatory system in action
How do the circulatory and respiratory systems function together?
Use the Circulation system in action weblink in the Resources tab to learn more.

Application
Circulatory system and movement performance
Examine figure 4.40 representing the body’s cardiovascular and respiratory system. You may also refer to the Circulation of blood throughout the body eLesson in the Resources tab. Imagine you are a drop of blood. Describe your passage through the entire circulatory system, beginning with entry into the right atrium. How would the oxygen level vary on reaching the capillaries, pulmonary artery, pulmonary vein and aorta?

FIGURE 4.40 Interaction of the respiratory and cardiovascular systems
4.4.4 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 4.41). 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 4.42).

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.

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.
FIGURE 4.42 (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.

FIGURE 4.43 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?

**Application**

**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 34–6, 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 table 4.5.
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 4.5 Blood pressure readings

<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>

Inquiry
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.

Inquiry
The cardiorespiratory system and movement
Copy and complete a mind map similar to figure 4.44, to respond to the question:

FIGURE 4.44 Sample mind map

How does the cardiorespiratory system of the body influence and respond to movement?
Weblink: Blood pressure

4.5 Topic review

4.5.1 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.
4.5.2 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) (4 marks)

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. How can exercise improve lung function? Use the weblinks Respiration 3D Medical Animation (a summary of lung structure, function and exchange of gases) and Can exercise improve lung function? (a video) in the Resources tab to help you answer this question: (P7, P10, P16) (5 marks)

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

4.5.3 Key terms

The muscle action refers to movement made at the joint when the muscle contracts. p. 164
Arteries are blood vessels that carry blood away from the heart. p. 179
Articular cartilage is a firm, smooth, flexible connective tissue that covers the end of bones where they form joints. p. 152
Bone marrow is a soft, fatty vascular tissue in which blood cells are made, located in the interior cavities of bones. p. 152
Cancellous bone is the spongy or porous inner structure of bone that often contains and protects bone marrow. p. 152
Capillaries are the smallest of all blood vessels. They function to exchange oxygen and nutrients for waste. p. 180
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. p. 176
A concentric contraction is the most common type of muscular contraction. During this contraction, the muscle shortens, causing movement at the joint. p. 168
Diastolic pressure is the minimum or lowest pressure recorded when the heart is relaxing and filling (diastole). p. 184
An eccentric contraction occurs when the muscle lengthens while under tension. The action often happens with the assistance of gravity. p. 168
Expiration is air movement from the lungs to the atmosphere; breathing out. p. 168
Flat bones have a broad surface and serve as places of attachment for muscles and to protect vital organs. p. 152
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. p. 152
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. *p.152*

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. *p. 164*

**Inspiration** is air movement from the atmosphere into the lungs; breathing in. *p. 172*

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. *p. 168*

Long bones are longer than they are wide and they function as levers. *p. 152*

**Origin** the muscle’s point of attachment to the more stationary bone is called its origin. In most cases, this point is nearer the trunk. *p.160*

Plasma is a straw-coloured liquid mainly consisting of water (about 90 per cent). *p. 177*

Platelets are fragments of cells found in blood and are responsible for clotting. *p. 177*

**Pulmonary circulation** is the flow of blood from the heart to the lungs and back to the heart. *p. 182*

**Respiration** is the process by which the body takes in oxygen and removes carbon dioxide. *p. 170*

Short bones have a short axis and are found in small spaces such as the wrist. They serve to transfer forces. *p. 152*

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. *p.152*

A sphygmomanometer is an instrument used to measure blood pressure. *p. 184*

Systemic circulation is the flow of blood from the heart to body tissue and back to the heart. *p. 182*

**Systolic pressure** is the highest (peak) pressure recorded when blood is forced into the arteries during contraction of the left ventricle (systole). *p. 184*

**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. *p. 181*