Unit
1A

Chapter 11
Support and movement systems

Figure 11.1 The skeletal system supports all the soft tissues of our bodies

Unit content

Body systems
The body is organised from cells to tissues, organs and systems. The major body systems are the digestive, excretory, skeletal, muscular, respiratory, circulatory, nervous, endocrine, immune and reproductive systems and are related to life processes.

Organisation:
- hierarchy of organisation in the body
- introduction to tissues types and cell organisation
- location of organs associated with each body system in the body.

Functions:
- function of each organ system related to life processes.

The human body is mostly water. It makes up 60% of the body mass in males and 55% in females. Some tissues have even higher proportions of water—blood 83% and muscle 75%. Why, then, do our bodies not just collapse into a puddle of water?

Of all the tissues, bone has the smallest proportion of water, just 23%.

It is our bones, together with cartilage, that make up the framework that supports all the soft tissues of the body. This framework is the **skeletal system**. Attached to the bones of the skeleton are muscles that help to hold the bones in position and contract to move the bones. It is our muscular system that enables our bodies to move.

In this chapter we examine the body's support and movement systems—the skeletal and muscular systems.

The skeletal system

Most of the bones we see are from dead animals and we usually think of bone as hard, dry white material. Bone is actually a living tissue. It has cells that need oxygen and nutrients and produce wastes, just like all the other cells of the body.

Structure of bone

The bones of our legs and arms are called long bones. The structure of a long bone is shown in Figure 11.2. Long bones have a hollow shaft filled with fat that is known as **yellow bone marrow**. In flat bones, such as the ribs and breast bone, the spaces between the plates of spongy bone are filled with **red bone marrow**. It is in the red bone marrow that blood cells are made.

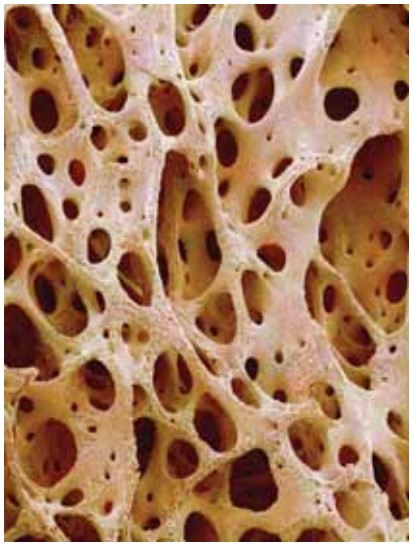

Figure 11.3 Spongy bone is a network of struts and plates that is found on the inside of bones

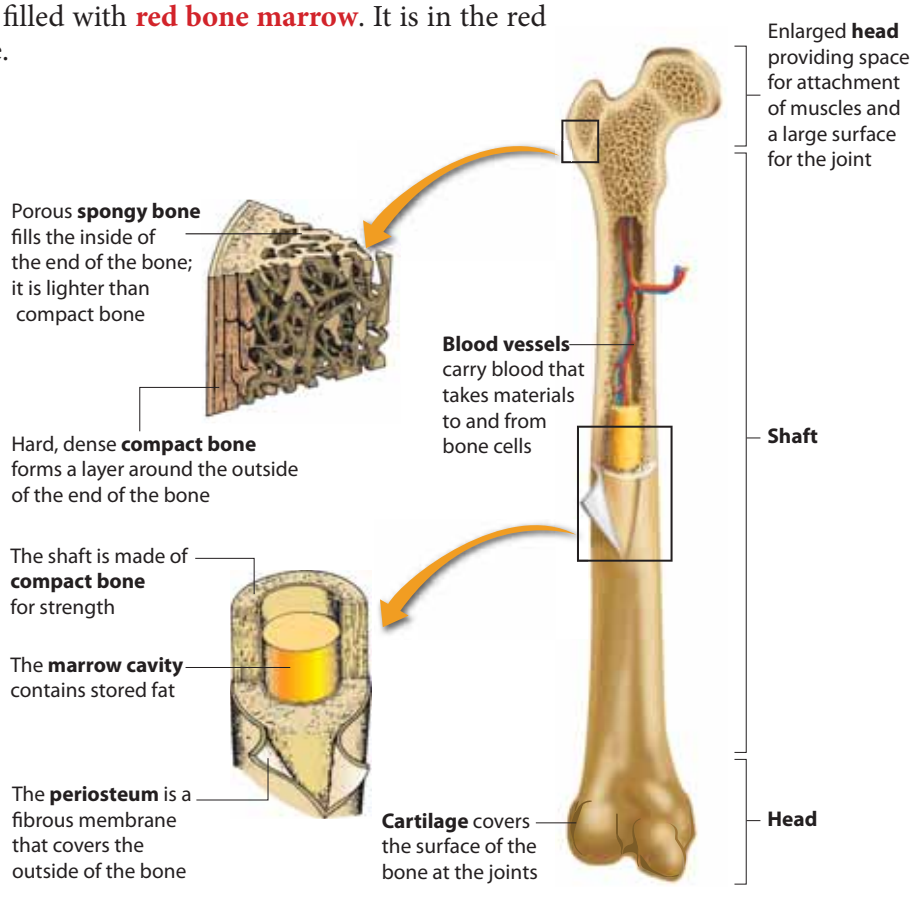

Figure 11.2 The structure of a long bone

Microscopic structure of bone

Bone is a type of connective tissue (see Chapter 4). In connective tissues the cells are separated from each other by large amounts of material called **matrix**. Matrix is not made of cells. In bone the matrix is made hard by deposits of calcium and phosphorus compounds.

When thin slices of bone are examined under a microscope the bone can be seen to have a very complex structure. Compact bone consists of units called **osteons**. These are shown in Figure 11.4.

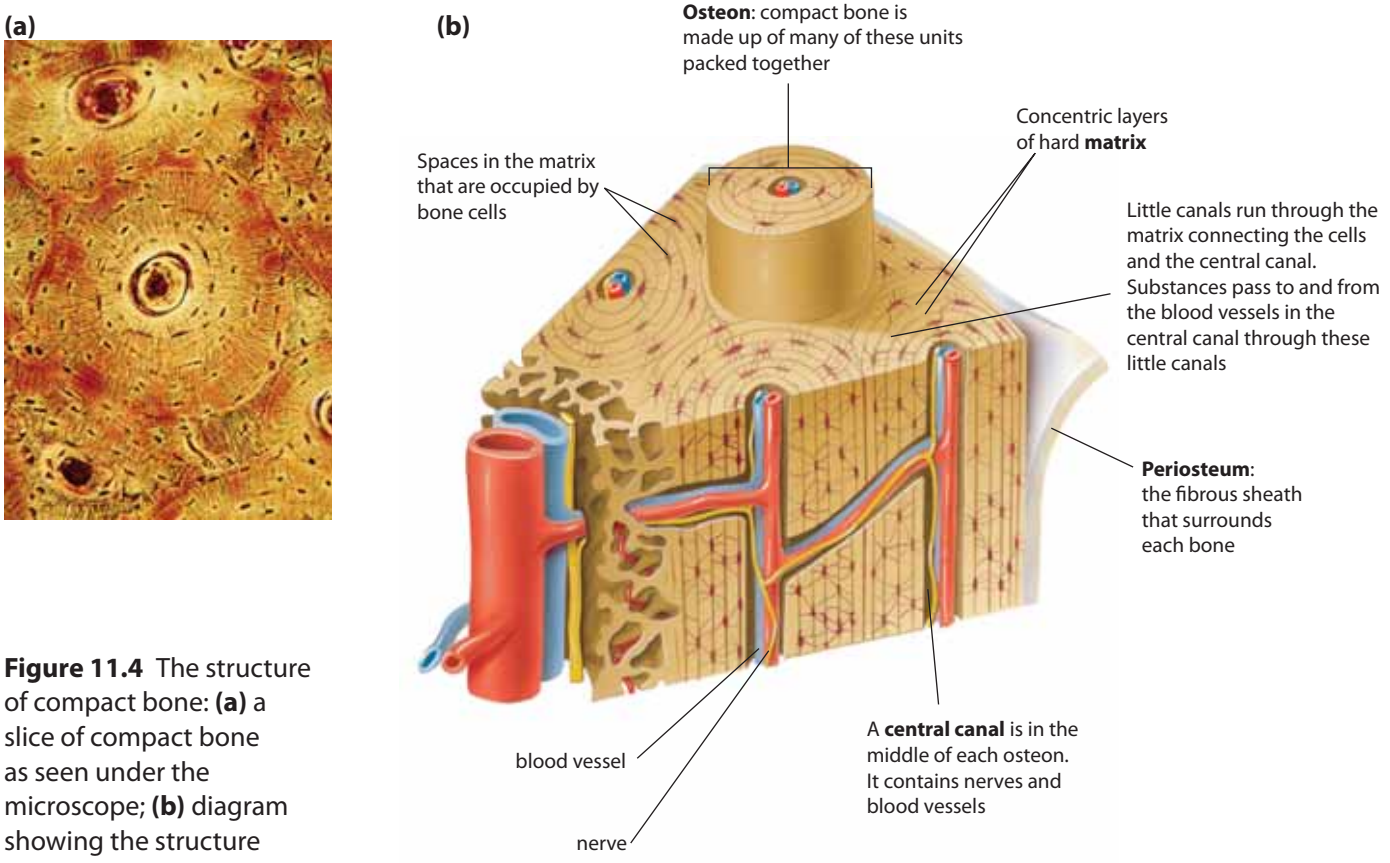

Figure 11.4 The structure of compact bone: **(a)** a slice of compact bone as seen under the microscope; **(b)** diagram showing the structure

Functions of the skeleton

The skeleton is an important framework for the body but it is much more than that.

The functions of the skeleton include:

- **Support**: the skeleton gives shape to the body and supports its parts.
- **Movement**: the bones provide points of attachment for most of the muscles of the body. When the muscles contract, they allow movement to take place.
- **Protection**: many of the vital organs are protected by bones. The brain, for example, is encased within the skull, and the spinal cord is contained within the spinal canal formed by the vertebrae. The ribs protect the heart and lungs, while the internal reproductive organs and bladder are protected by the pelvis.

- **Storage**: bones are storage areas for minerals and fat. Calcium, phosphorus, sodium and potassium are the main minerals stored within bone. These can be sent to other regions of the body by the circulatory system when required. If, during pregnancy, the mother's diet does not contain enough calcium, calcium can be removed from her skeleton and used in the development of the baby's bones.
- **Blood cell production**: the red marrow contained within certain bones produces blood cells.

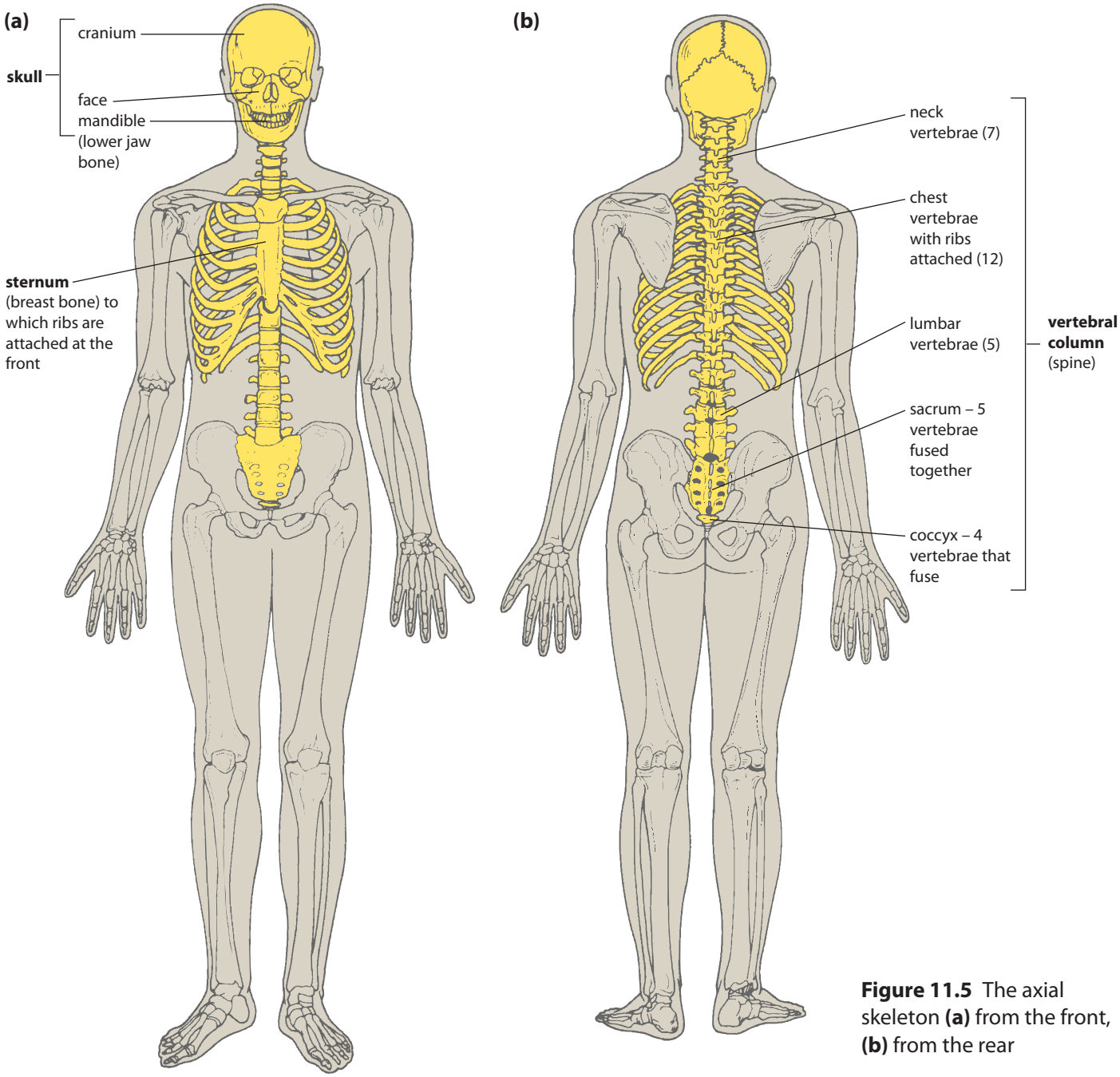

Figure 11.5 The axial skeleton **(a)** from the front, **(b)** from the rear

The bones of the skeleton

For links to web resources on the human skeleton plus games and puzzles go to http://www.42explore.com/skeleton.htm
To see X-rays of the bones of the skeleton check out http://www.accessexcellence.org/RC/VL/xrays/index.php

There are normally 206 individual bones that make up the human skeleton (see Fig. 11.5 and 11.6). The bones may be fused to one another to form structures like the skull, which has twenty-nine different bones, or the bones may be arranged to allow movement.

The bones of the skeleton are divided into two groups: the axial skeleton and the appendicular skeleton. The **axial skeleton** consists of the bones that lie around the central *axis* of the body. It provides the main support for erect posture, and protects the central nervous system and the organs contained within the chest. The bones that form the skull, vertebral column, ribs and sternum (breastbone) make up the axial skeleton (see Fig. 11.5).

The **appendicular skeleton** consists of the bones making up the upper and lower limbs and the bones of the shoulder and hip girdles. These two girdles allow the limbs to be joined to the axial skeleton.

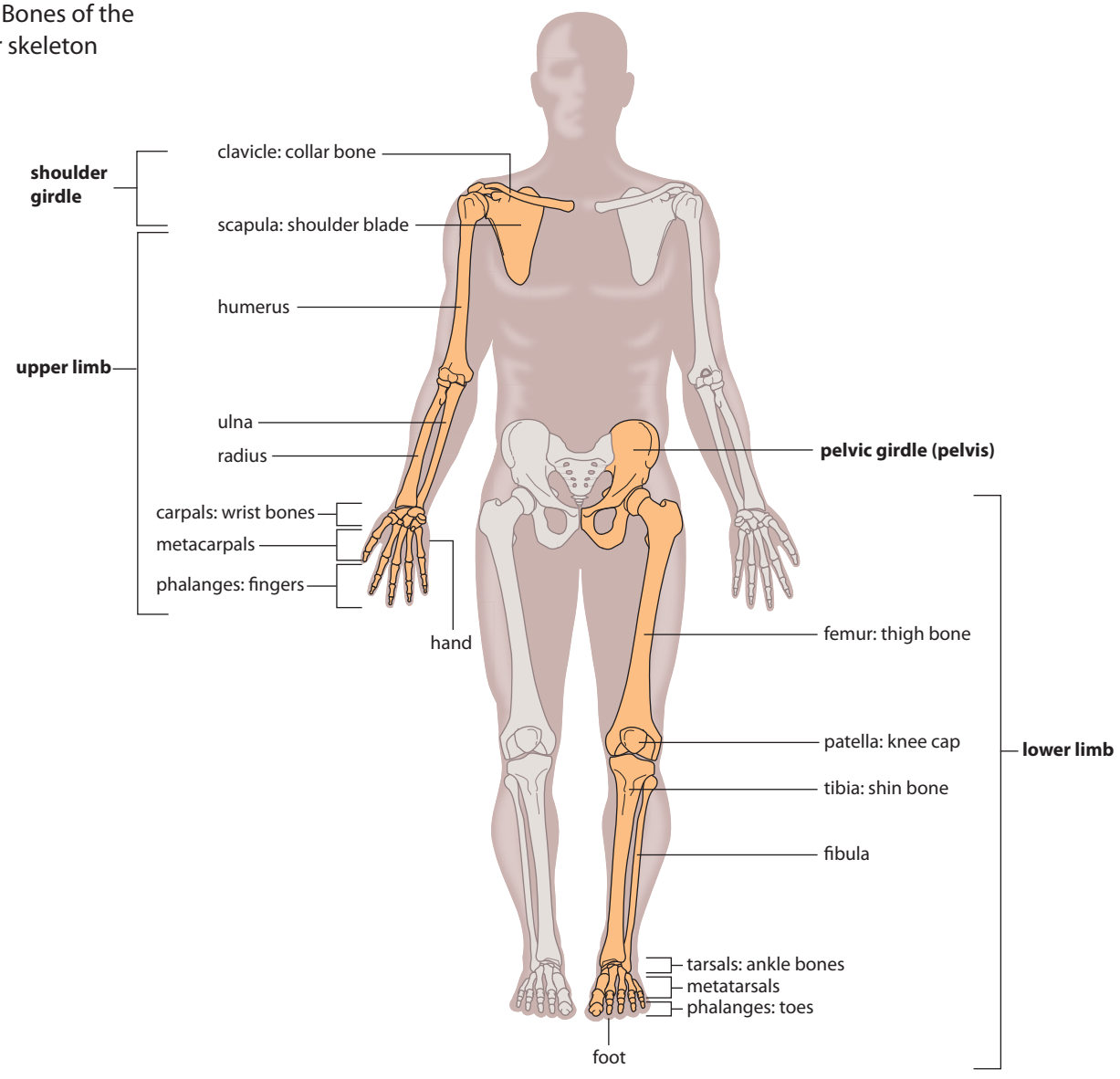

Figure 11.6 Bones of the appendicular skeleton

Bone fractures

Bones are structured in such a way that they are normally able to withstand the twisting and pressing forces on the skeleton. Despite their strength, bones do sometimes break. Any break in a bone is called a **fracture**.

Bones usually require months to heal properly after a fracture has occurred. A fractured femur, for example, may take six months to heal. The deposition of calcium to strengthen and harden the new bone is a gradual process. Growth and reproduction of bone cells is also quite slow.

Some disorders of bone

Osteoporosis

Osteoporosis is a disease in which the bones become fragile and are therefore more easily broken than normal bones (see Fig. 11.7). It is a common condition in older people, especially women. The factors that contribute to the development of osteoporosis are a decrease in the production of sex hormones (especially in women after menopause), inadequate calcium in the diet, vitamin D deficiency, inactivity, smoking and a high-protein diet.

Figure 11.7 Osteoporosis as seen under a microscope. Notice the large gaps where bone has been lost

Spina bifida

The rear parts of the vertebrae of the spinal column sometimes fail to form a complete bony arch around the spinal cord during a baby's embryonic development. This condition is called **spina bifida**. If the defect is large enough, the coverings of the spinal cord and the wall of the spinal cord itself may stick out beyond the skin surface.

Vitamin deficiency

For normal bone growth and maintenance, **vitamin D** is essential. It is required for making a protein that helps the absorption of calcium in the intestine. Without vitamin D, the body cannot absorb calcium and phosphorus. As a result, rickets may occur in children.

Rickets is a condition in which the bones remain soft. When the child walks, the weight of the body causes the legs to bow (see Figure 11.8). Other bones are also affected, including the bones of the head, chest and pelvis. To prevent rickets, generous amounts of calcium, phosphorus and vitamin D should be added to the diet. Exposure of the skin to the ultraviolet rays of sunlight also helps the body to manufacture vitamin D.

Joints

The place where two or more bones come together is called a **joint**. Some joints are quite rigid, with little or no movement between the bones. Most joints, however, allow the bones to move in relation to each other. Joints will be discussed in more detail in the next chapter.

The muscular system

Figure 11.8 Rickets

There are about 600 skeletal muscles attached to the bones of the skeleton. These muscles make up the **muscular system**. Involuntary muscle that is not attached to bones, such as the muscle of the wall of the intestine and heart muscle (see Chapter 4), are not included in the muscular system.

Muscle tissue has the ability to contract, meaning to shorten in length. It is also elastic: able to be pulled back to its original length after being stretched. Note that while muscles are able to shorten their length and can be stretched, they are not able to increase their own length.

The structure of skeletal muscles

Typical skeletal muscle cells are about 3 cm long but they can be up to 30 cm long. Because of their great length they are not usually called cells; skeletal muscle cells are called **muscle fibres**. Each fibre has several nuclei and, when seen under a microscope, bands can be seen across the fibres (see Fig. 11.9).

Muscle fibres are held together in bundles. Red meat is muscle and it is these bundles of muscle cells that give meat its 'stringy' appearance when cut lengthwise. Each bundle of fibres is surrounded by a sheath of connective tissue so that the bundle can function as an individual unit (see Fig. 11.10). The connective tissue allows adjacent bundles to slide easily over one another as they contract. The sheaths of connective tissue around each bundle join each other, and towards the end of the muscle they taper and blend to form a tendon. The **tendon** joins the muscle to a bone. Inside each of the muscle fibres (or cells) there are even smaller structures called **fibrils**.

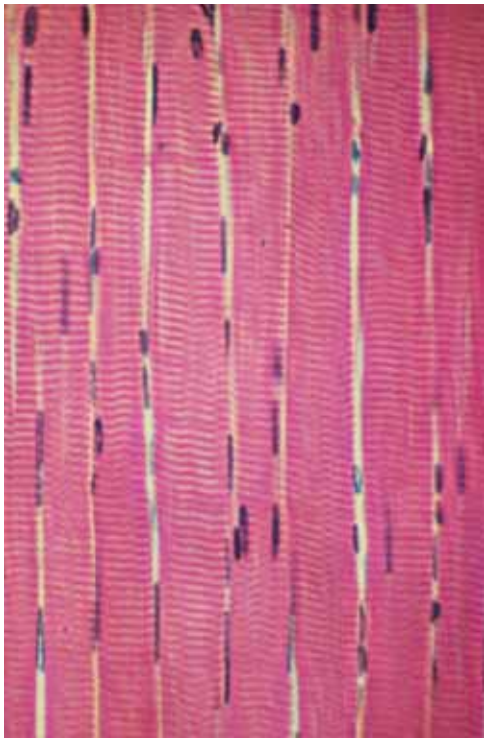

Figure 11.9 Skeletal muscle fibres: note the bands and nuclei

Muscle tone

Muscle tone is maintaining partial contraction of skeletal muscles. At any one time, some muscle fibres are contracted while others are relaxed. Such partial contraction tightens a muscle, but not enough fibres are contracting at the one time to produce movement. Muscle tone is not caused by the constant contraction of the same fibres, but by many different fibres taking turns to contract. The fibres relieve one another so smoothly that the contraction can be kept up for long periods of time.

Muscle tone holds many of our body parts in position. For example, the head is held up by the partial contraction of the neck muscles. When a person falls asleep in a chair, the head droops forward. This is due to loss of tone in the neck muscles.

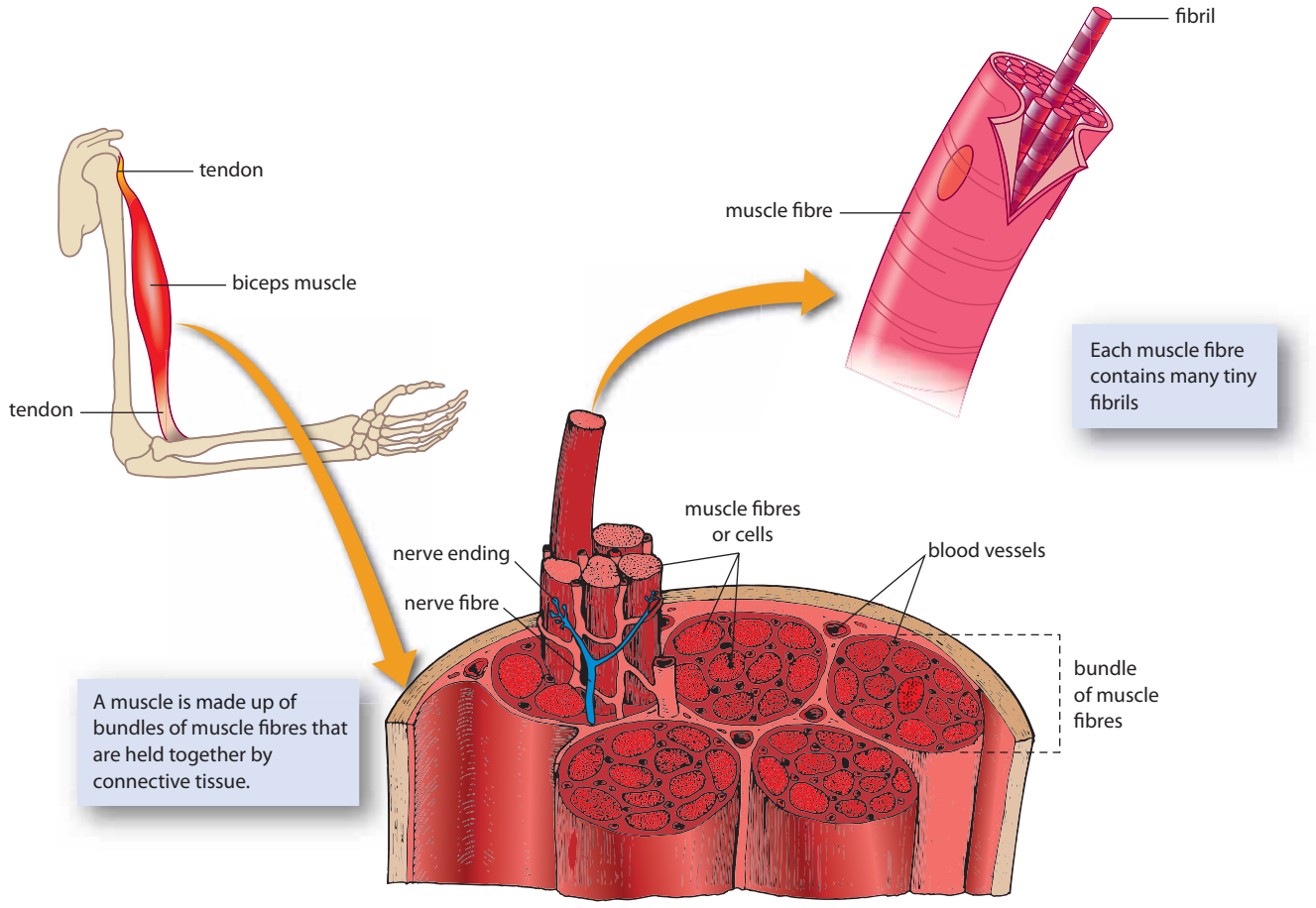

Figure 11.10 The structure of a skeletal muscle

Disorders of muscles

Injuries to muscle tissue

The most common injury to muscle tissue is a strain. A **strain** is caused by overstretching a muscle or a tendon. There is usually sudden pain in the region of injury and a loss of power in the limb concerned. The area is tender to touch, and any movement usually causes the pain to increase.

Abnormal contractions

A number of abnormal contractions may occur in muscle tissue including:

- **Cramps**: involuntary, prolonged muscle contractions without even partial relaxation. Cramps may be caused by heavy exercise, cold, low blood glucose or mineral imbalances in the body fluids.
- **Convulsions**: violent, involuntary contractions of a group of muscles. They may be caused when muscle fibres receive impulses from nerves that are stimulated by fever, poisons, hysteria or changes in body chemistry due to withdrawal of certain drugs.
- **Tics**: involuntary, spasmodic twitching of muscles that are normally under voluntary control. They usually have psychological causes and often affect the eyelids and face muscles.

To find out the names of individual muscles go to http://www.innerbody.com/image/musfov.html

Muscular dystrophy

Muscular dystrophy refers to a number of inherited diseases in which the muscles lose their strength. Individual muscle cells degenerate, which leads to a gradual reduction in the size of the skeletal muscle. As the muscles decrease in size there is an increase in connective tissue within the muscles and, in some forms, fatty tissue replaces muscle fibres.

Tendinitis

Tendinitis is the inflammation of a tendon—the tough, fibrous cord that attaches a muscle to a bone. It causes pain and swelling around a joint. Tendinitis most commonly affects the shoulders, elbows and knees, and usually only one part of the body is affected at a time.

The most common cause of tendinitis is overuse of a muscle with repetitive movements. Repetitive strain injury, or RSI, is a form of tendinitis that may affect the wrists of computer keyboard operators. The treatment for tendinitis is rest of the affected muscle and joint.

Working scientifically

Activity 11.1 The human skeleton

Examination of the structure of the human skeleton will help you to understand how it carries out its various functions.

You will need

A model of a human skeleton; charts or diagrams of the skeleton (some of the diagrams in this book may be useful); X-rays of parts of the skeleton (if possible)

What to do

Answer the questions listed below under 'Studying your observations'. As you answer the questions, refer constantly to the model of the skeleton and make use of any charts, diagrams or X-rays that are available. Feeling the bones of your own skeleton may help. You can also view the bones of the human skeleton at http://www.eskeletons.org

Studying your observations

1. If your skeleton has a brain case that can be opened, compare the thickness of the skull at each side with the thickness in the facial region. What part of the skull provides least protection for the brain?
2. Describe any features of the skull that help to protect the eyes.
3. At each side of the skull, just behind the joint of the jaw bone, is an opening. What do you think would be the purpose of such openings?
4. On the underside of the skull is a single large opening called the foramen magnum. What is the function of the foramen magnum?
5. At the back of the skull there are roughened areas with small bony ridges. Suggest a function for these rough areas.
6. How many neck vertebrae are there?

7. The first two neck vertebrae are the atlas and the axis. See if you can work out how these two vertebrae allow the head to turn from side to side and to nod up and down. Write an explanation of how nodding and turning can occur.
8. What is the purpose of the large hole through each vertebra?
9. Suggest why there is a disc of cartilage between one vertebra and the next.
10. The lumbar vertebrae are those in the small of the back. Suggest why these vertebrae have longer projections than those in other parts of the spinal column.
11. Describe the arrangement of the three long bones that form the upper limb. Which bone forms the elbow?
12. How many carpal bones are in the wrist? Why are so many bones necessary in this part of the skeleton?
13. How many phalanges are in each finger? Does the thumb have the same number?
14. One of the tarsals in the foot has a large projection that forms the heel. What function would this large heel bone serve?

Activity 11.2 Bone composition

As bone forms, hard substances are deposited in the matrix between the cells. In this activity you will investigate the effect of removing some of this hard material.

You will need

Two small bones or pieces of bone; two 100 mL beakers; forceps; nitric acid 2M

What to do

1. Place a small bone, or piece of bone, in a beaker and cover with nitric acid. In a second beaker place a similar piece of bone and cover with water.
2. After leaving the bones to stand for at least two days, use forceps to remove the bones and rinse them under running water.
3. Feel, and try bending, each of the two bones.

Studying your observations

1. Describe any differences that you observed between the bone left in the acid and the bone left in the water.
2. Propose a hypothesis to account for any differences that you observed.
3. If a person does not consume enough calcium in the diet for normal body functioning, calcium is removed from the bones. What would be one of the symptoms of a severe deficiency of calcium in the diet?

REVIEW QUESTIONS

1. Draw a diagram showing the inside of a long bone. Label the following parts: head, shaft, marrow cavity, joint cartilage, compact bone, spongy bone, periosteum.
2. List the functions of the skeleton.
3. What are the differences between red bone marrow and yellow bone marrow?
4. Explain the difference between the axial skeleton and the appendicular skeleton.
5. **(a)** What is a fracture?
   (b) Why do fractures take a long time to heal?
6. **(a)** What is osteoporosis?
   (b) What can you do now to avoid getting osteoporosis later in life?
7. **(a)** What are muscle fibres?
   (b) What are fibrils?
8. What is muscle tone?
9. Explain the difference between a strain and a sprain.

APPLY YOUR KNOWLEDGE

1. Heart muscle in the heart and involuntary muscle in the wall of the stomach are not part of the muscular system. To which systems would each of these muscles belong?
2. Suggest reasons why the heads of long bones are made up of spongy bone while the shaft is made up of compact bone.
3. Describe how the muscular system is related to the skeletal system.
4. The adult human skeleton has 206 bones. When a baby is born, its skeleton has over 270 different bones. As we mature some of the bones grow together to form single bones. Use references to find out which bones of the skeleton fuse in this way. Use a search engine to search for 'human skeleton' and you will be able to find websites that should help you find out about the 'disappearing bones'.
5. Forensic scientists can examine a skeleton and determine whether the person was a male or a female. Find out the differences between male and female skeletons.