GRAY'S ANATOMY FOR STUDENTS

Fifth Edition

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Body systems

SKELETAL SYSTEM

The skeleton can be divided into two subgroups, the axial skeleton and the appendicular skeleton. The axial skeleton consists of the bones of the skull (cranium), vertebral column, ribs, and sternum, whereas the appendicular skeleton consists of the bones of the upper and lower limbs (Fig. 1.14).

The skeletal system consists of cartilage and bone.

Cartilage

Cartilage is an avascular form of connective tissue consisting of extracellular fibers embedded in a matrix that contains cells localized in small cavities. The amount and kind of extracellular fibers in the matrix vary depending on the type of cartilage. In heavy weight-bearing areas or areas prone to pulling forces, the amount of collagen is greatly increased and the cartilage is almost inextensible. In contrast, in areas where weight-bearing demands and stress are less, cartilage containing elastic fibers and fewer collagen fibers is common. The functions of cartilage are to:

- support soft tissues,
- provide a smooth, gliding surface for bone articulations at joints, and
- enable the development and growth of long bones.

There are three types of cartilage:

- hyaline—most common; matrix contains a moderate amount of collagen fibers (e.g., articular surfaces of bones);
- elastic—matrix contains collagen fibers along with a large number of elastic fibers (e.g., external ear);
- fibrocartilage—matrix contains a limited number of cells and ground substance amidst a substantial amount of collagen fibers (e.g., intervertebral discs).

Cartilage is nourished by diffusion and has no blood vessels, lymphatics, or nerves.

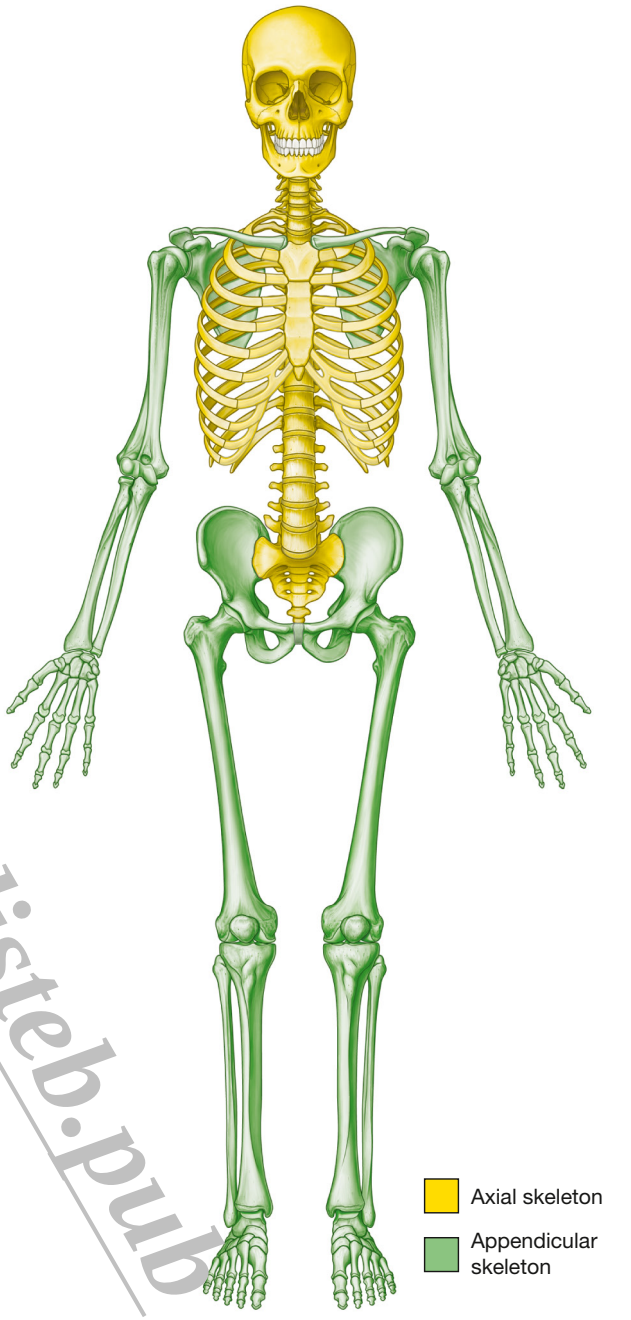

Fig. 1.14 The Axial Skeleton and the Appendicular Skeleton.

Bone

Bone is a calcified, living, connective tissue that forms the majority of the skeleton. It consists of an intercellular calcified matrix, which also contains collagen fibers, and several types of cells within the matrix. Bones function as:

- supportive structures for the body,
- protectors of vital organs,
- reservoirs of calcium and phosphorus,
- levers on which muscles act to produce movement, and
- containers for blood-producing cells.

There are two types of bone, compact and spongy (trabecular or cancellous). Compact bone is dense bone that forms the outer shell of all bones and surrounds spongy bone. Spongy bone consists of spicules of bone enclosing cavities containing blood-forming cells (marrow). Classification of bones is by shape.

- Long bones are tubular (e.g., humerus in upper limb; femur in lower limb).
- Short bones are cuboidal (e.g., bones of the wrist and ankle).
- Flat bones consist of two compact bone plates separated by spongy bone (e.g., skull).
- Irregular bones are bones with various shapes (e.g., bones of the face).
- Sesamoid bones are round or oval bones that develop in tendons.

In the clinic

Accessory and sesamoid bones

These are extra bones that are not usually found as part of the normal skeleton but can exist as a normal variant in many people. They are typically found in multiple locations in the wrist and hands, ankles, and feet (Fig. 1.15). These should not be mistaken for fractures on imaging.

Sesamoid bones are embedded within tendons, the largest of which is the patella. There are many other sesamoids in the body, particularly in tendons of the hands and feet, and most frequently in flexor tendons of the thumb and big toe.

Degenerative and inflammatory changes of, as well as mechanical stresses on, the accessory bones and sesamoids can cause pain, which can be treated with physiotherapy and targeted steroid injections, but in some severe cases it may be necessary to surgically remove the bone.

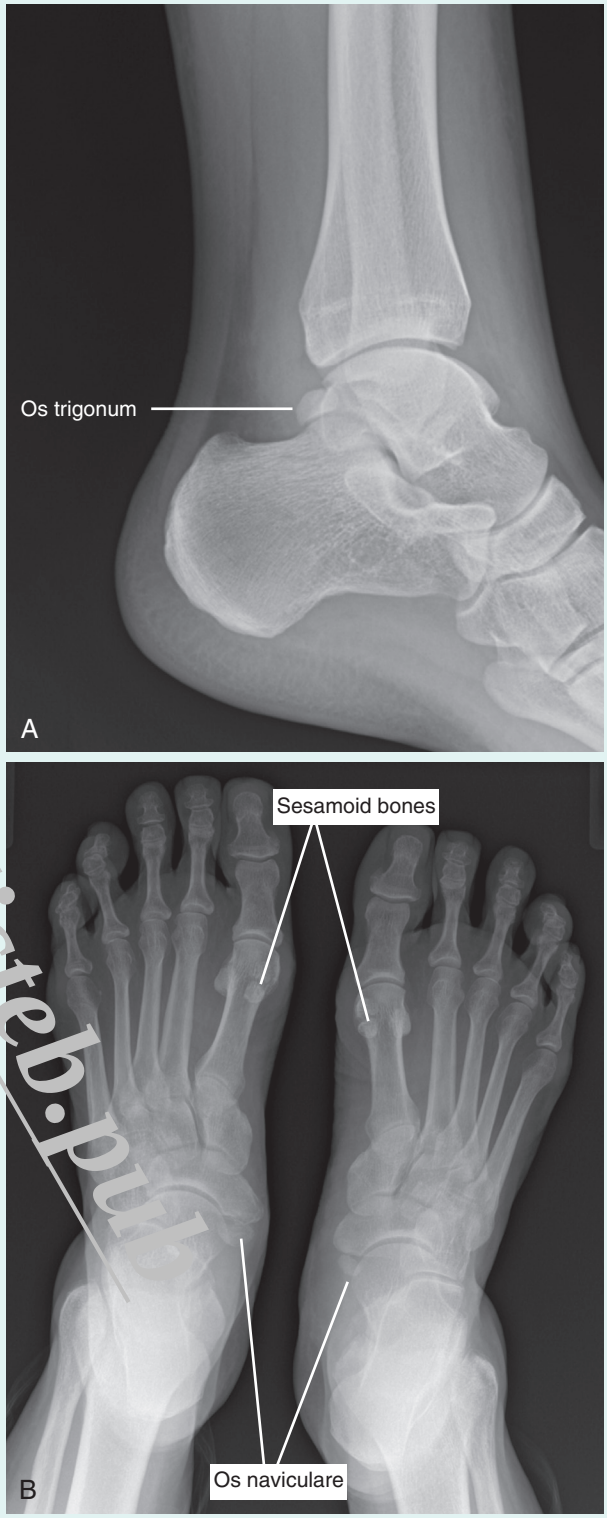

Fig. 1.15 Accessory and Sesamoid Bones. (**A**) Radiograph of the ankle region showing an accessory bone (os trigonum). (**B**) Radiograph of the feet showing numerous sesamoid bones and an accessory bone (os naviculare).

In the clinic

Bone marrow transplants

The bone marrow serves an important function. There are two types of bone marrow, red marrow (otherwise known as myeloid tissue) and yellow marrow. Red blood cells, platelets, and most white blood cells arise from within the red marrow. In the yellow marrow, a few white cells are made; however, this marrow is dominated by large fat globules (producing its yellow appearance) (Fig. 1.17).

From birth most of the body's marrow is red; however, as the subject ages, more red marrow is converted into yellow marrow within the medulla of the long and flat bones.

Bone marrow contains two types of stem cells. Hemopoietic stem cells give rise to the white blood cells, red blood cells, and platelets. Mesenchymal stem cells differentiate into structures that form bone, cartilage, and muscle.

There are a number of diseases that may involve the bone marrow, including infection and malignancy. In patients who develop a bone marrow malignancy (e.g., leukemia) it may be possible to harvest nonmalignant cells from the patient's bone marrow or cells from another person's bone marrow. The patient's own marrow can be destroyed with chemotherapy or radiation and the new cells infused. This treatment is bone marrow transplantation.

Fig. 1.17 T1-weighted image in the coronal plane, demonstrating the relatively high signal intensity returned from the femoral heads and proximal femoral necks, consistent with yellow marrow. In this young patient, the vertebral bodies return an intermediate darker signal that represents red marrow. There is relatively little fat in these vertebrae, hence the lower signal return.

In the clinic

Bone fractures

Fractures occur in normal bone because of abnormal load or stress, in which the bone gives way (Fig. 1.18A). Fractures may also occur in bone that is of poor quality (osteoporosis); in such cases a normal stress is placed upon a bone that is not of sufficient quality to withstand this force and subsequently fractures.

In children whose bones are still developing, fractures may occur across the growth plate or across the shaft. These shaft fractures typically involve partial cortical disruption, similar to breaking a branch of a young tree; hence they are termed "greenstick" fractures.

After a fracture has occurred, the natural response is to heal the fracture. Between the fracture margins a blood clot is formed into which new vessels grow. A jelly-like matrix is formed, and further migration of collagen-producing cells occurs. On this soft tissue framework, calcium hydroxyapatite is produced by osteoblasts and forms insoluble crystals, and then bone matrix is laid down. As more bone is produced, a callus can be demonstrated forming across the fracture site.

Treatment of fractures requires a fracture line reduction. If this cannot be maintained in a plaster of Paris cast, it may require internal or external fixation with screws and metal rods (Fig. 1.18B).

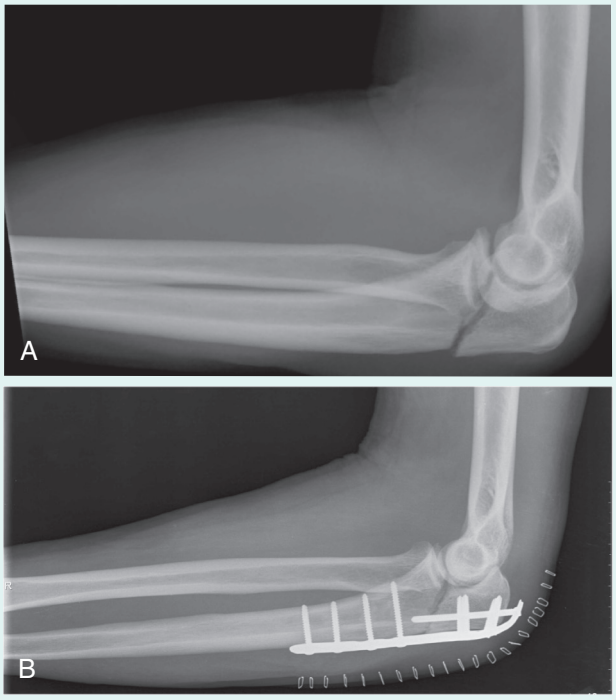

Fig. 1.18 Radiograph, lateral view, showing fracture of the ulna at the elbow joint (**A**) and repair of this fracture (**B**) using internal fixation with a plate and multiple screws.

In the clinic

Avascular necrosis

Avascular necrosis is cellular death of bone resulting from a temporary or permanent loss of blood supply to that bone. Avascular necrosis may occur in a variety of medical conditions, some of which have an etiology that is less than clear. A typical site for avascular necrosis is a fracture across the femoral neck in an elderly patient. In these patients there is loss of continuity of the cortical medullary blood flow with loss of blood flow deep to the retinacular fibers. This essentially renders the femoral head bloodless; it subsequently undergoes necrosis and collapses (Fig. 1.19). In these patients it is necessary to replace the femoral head with a prosthesis.

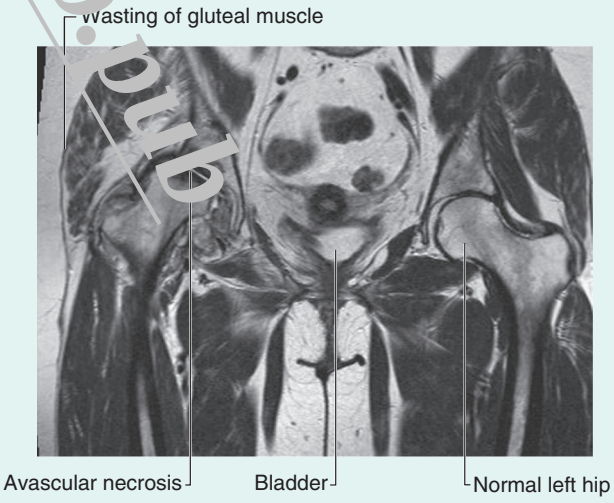

Fig. 1.19 Image of the hip joints demonstrating loss of height of the right femoral head with juxta-articular bony sclerosis and subchondral cyst formation secondary to avascular necrosis. There is also significant wasting of the muscles supporting the hip, which is secondary to disuse and pain.

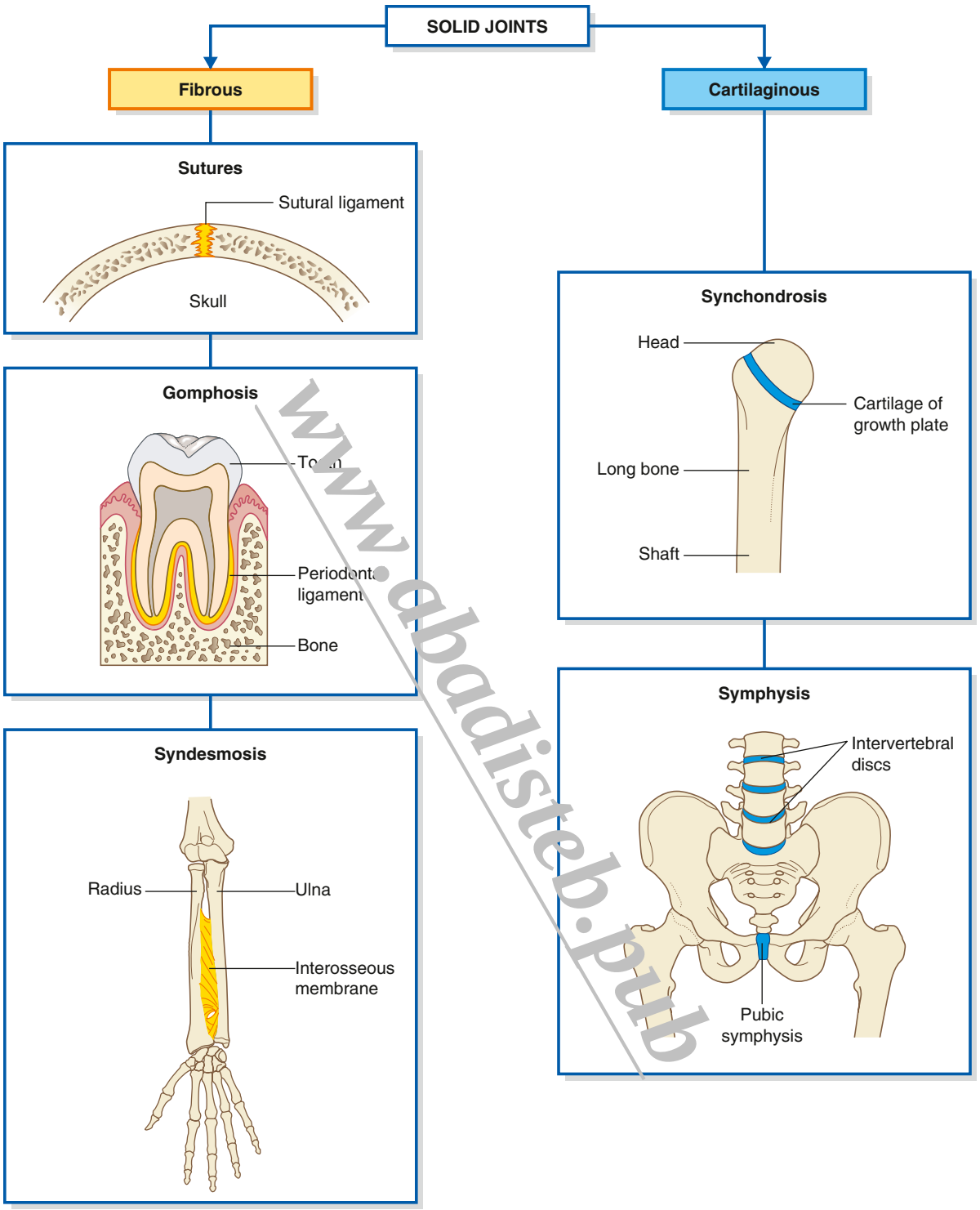

Fig. 1.23 Solid Joints.

- **Synchondroses** occur where two ossification centers in a developing bone remain separated by a layer of cartilage, for example, the growth plate that occurs between the head and shaft of developing long bones. These joints allow bone growth and eventually become completely ossified.
- **Symphyses** occur where two separate bones are interconnected by cartilage. Most of these types of joints occur in the midline and include the pubic symphysis between the two pelvic bones, and intervertebral discs between adjacent vertebrae.

In the clinic

Degenerative joint disease

Degenerative joint disease is commonly known as osteoarthritis or osteoarthrosis. The disorder is related to aging but not caused by aging. Typically there are decreases in water and proteoglycan content within the cartilage. The cartilage becomes more fragile and more susceptible to mechanical disruption (Fig. 1.24). As the cartilage wears, the underlying bone becomes fissured and also thickens. Synovial fluid may be forced into small cracks that appear in the bone's surface, which produces large cysts. Furthermore, reactive juxta-articular bony nodules are formed (osteophytes) (Fig. 1.25). As these processes occur, there is slight deformation, which alters the biomechanical forces through the joint. This in turn creates abnormal stresses, which further disrupt the joint.

Osteoarthritis accounts for a large percentage of primary health care visits and is regarded as a significant problem.

The etiology of osteoarthritis is not clear; however, osteoarthritis can occur secondary to other joint diseases, such as rheumatoid arthritis and infection. Overuse of joints and abnormal strains, such as those experienced by people who play sports, often cause one to be more susceptible to chronic joint osteoarthritis.

Various treatments are available, including weight reduction, proper exercise, anti-inflammatory drug treatment, and joint replacement.

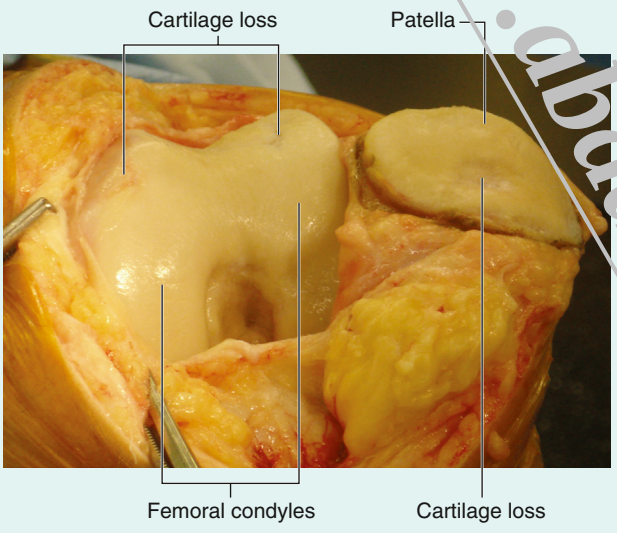

Fig. 1.24 This operative photograph demonstrates the focal areas of cartilage loss in the patella and femoral condyles throughout the knee joint.

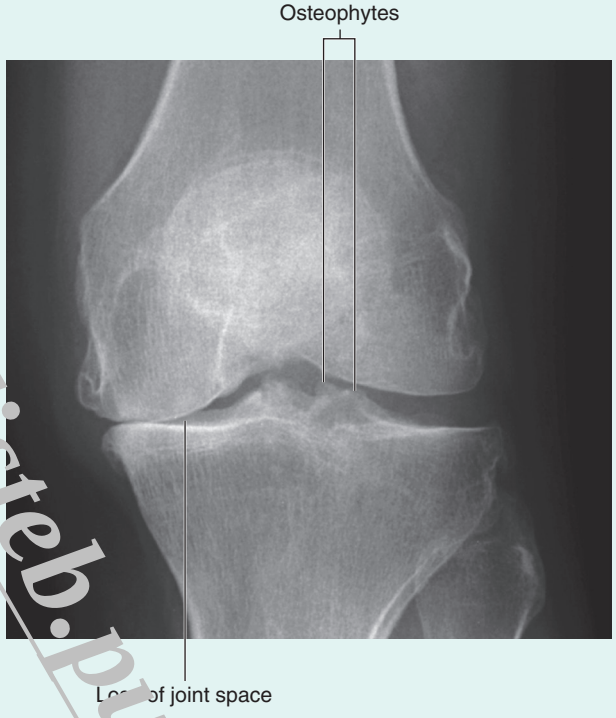

Fig. 1.25 This radiograph demonstrates the loss of joint space in the medial compartment and presence of small spiky osteophytic regions at the medial lateral aspect of the joint.

In the clinic

Joint replacement

Joint replacement is undertaken for a variety of reasons. These predominantly include degenerative joint disease and joint destruction. Joints that have severely degenerated or lack their normal function are painful. In some patients, the pain may be so severe that it prevents them from leaving the house and undertaking even the smallest of activities without discomfort.

Large joints are commonly affected, including the hip, knee, and shoulder. However, with ongoing developments in joint replacement materials and surgical techniques, even small joints of the fingers can be replaced.

Typically, both sides of the joint are replaced; in the hip joint the acetabulum will be reamed, and a plastic or metal cup will be introduced. The femoral component will be fitted precisely to the femur and cemented in place (Fig. 1.27).

Most patients derive significant benefit from joint replacement and continue to lead an active life afterward. In a minority of patients who have been fitted with a metal acetabular cup and metal femoral component, an aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL) may develop, possibly caused by a hypersensitivity response to the release of metal ions in adjacent tissues. These patients often have chronic pain and might need additional surgery to replace these joint replacements with safer models.

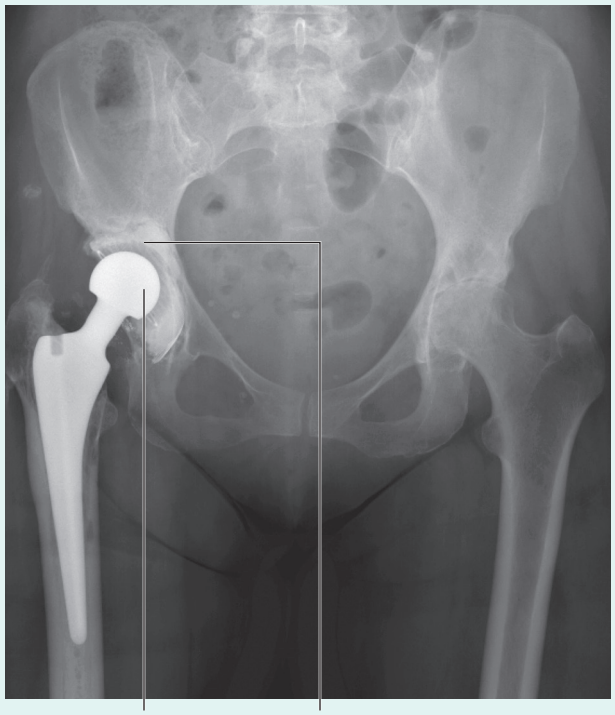

Fig. 1.27 Radiograph, Anteroposterior View, of the Pelvis After a Right Total Hip Replacement. There are additional significant degenerative changes in the left hip joint, which will also need to be replaced.

SKIN AND FASCIAS

Skin

The skin is the largest organ of the body. It consists of the epidermis and the dermis. The epidermis is the outer cellular layer of stratified squamous epithelium, which is avascular and varies in thickness. The dermis is a dense bed of vascular connective tissue.

The skin functions as a mechanical and permeability barrier, and as a sensory and thermoregulatory organ. It also can initiate primary immune responses.

Fascia

Fascia is connective tissue containing varying amounts of fat that separate, support, and interconnect organs and structures, enable movement of one structure relative to another, and allow the transit of vessels and nerves from one area to another. There are two general categories of fascia: superficial and deep.

- Superficial (subcutaneous) fascia lies just deep to and is attached to the dermis of the skin. It is made up of loose connective tissue usually containing a large amount of fat. The thickness of the superficial fascia (subcutaneous tissue) varies considerably, both from one area of the body to another and from one individual to another. The superficial fascia allows movement of the skin over deeper areas of the body, acts as a conduit for vessels and nerves coursing to and from the skin, and serves as an energy (fat) reservoir.
- Deep fascia usually consists of dense, organized connective tissue. The outer layer of deep fascia is attached to the deep surface of the superficial fascia and forms a thin fibrous covering over most of the deeper region of the body. Inward extensions of this fascial layer form intermuscular septa that compartmentalize groups of muscles with similar functions and innervations. Other extensions surround individual muscles and groups of vessels and nerves, forming an investing fascia. Near some joints the deep fascia thickens, forming retinacula. These fascial retinacula hold tendons in place and prevent them from bowing during movements at the joints. Finally, there is a layer of deep fascia separating the membrane lining the abdominal cavity (the parietal peritoneum) from the fascia covering the deep surface of the muscles of the abdominal wall (the transversalis fascia). This layer is referred to as **extraperitoneal fascia.** A similar layer of fascia in the thorax is termed the **endothoracic fascia.**

In the clinic

The importance of fascias

Clinically, fascias are extremely important because they often limit the spread of infection and malignant disease. When infections or malignant diseases cross a fascial plain, a primary surgical clearance may require a far more extensive dissection to render the area free of tumor or infection.

A typical example of the clinical importance of a fascial layer would be of that covering the psoas muscle. Infection within an intervertebral body secondary to tuberculosis can pass laterally into the psoas muscle. Pus fills the psoas muscle but is limited from further spread by the psoas fascia, which surrounds the muscle and extends inferiorly into the groin, pointing below the inguinal ligament.

In the clinic

Placement of skin incisions and scarring

Surgical skin incisions are ideally placed along or parallel to lines of skin tension (Langer's lines) that correspond to the orientation of the dermal collagen fibers. They tend to run in the same direction as the underlying muscle fibers and incisions that are made along these lines tend to heal better with less scarring. In contrast, incisions made perpendicular to these lines are more likely to heal with a prominent scar and, in some severe cases, can lead to raised, firm, hypertrophic, or keloid, scars.

MUSCULAR SYSTEM

The muscular system is generally regarded as consisting of one type of muscle found in the body—skeletal muscle. However, there are two other types of muscle tissue found in the body, smooth muscle and cardiac muscle, that are important components of other systems. These three types of muscle can be characterized by whether they are controlled voluntarily or involuntarily, whether they appear striated (striped) or smooth, and whether they are associated with the body wall (somatic) or with organs and blood vessels (visceral).

- Skeletal muscle forms the majority of the muscle tissue in the body. It consists of parallel bundles of long, multinucleated fibers with transverse stripes, is capable of powerful contractions, and is innervated by somatic and branchial motor nerves. This muscle is used to move bones and other structures, and provides support and gives form to the body. Individual skeletal muscles are often named on the basis of shape (e.g., rhomboid major muscle), attachments (e.g., sternohyoid muscle), function (e.g., flexor pollicis longus muscle), position (e.g., palmar interosseous muscle), or fiber orientation (e.g., external oblique muscle).
- Cardiac muscle is striated muscle found only in the walls of the heart (myocardium) and in some of the large vessels close to where they join the heart. It consists of a branching network of individual cells linked electrically and mechanically to work as a unit. Its contractions are less powerful than those of skeletal muscle, and it is resistant to fatigue. Cardiac muscle is innervated by visceral motor nerves.
- Smooth muscle (absence of stripes) consists of elongated or spindle-shaped fibers capable of slow and sustained contractions. It is found in the walls of blood vessels (tunica media), associated with hair follicles in the skin, located in the eyeball, and found in the walls of various structures associated with the gastrointestinal, respiratory, genitourinary, and urogenital systems. Smooth muscle is innervated by visceral motor nerves.

In the clinic

Muscle paralysis

Muscle paralysis is the inability to move a specific muscle or muscle group and may be associated with other neurological abnormalities, including loss of sensation. Paralysis may be due to abnormalities in the brain or the spinal cord, or in the nerves supplying the muscles. Major causes include stroke, trauma, poliomyelitis, and iatrogenic factors.

In the long term, muscle paralysis will produce secondary muscle wasting and overall atrophy of the region due to disuse.

In the clinic

Muscle hypertrophy/atrophy due to gender-affirming hormones

Testosterone for masculinizing hormone therapy results in muscle hypertrophy of the arms and legs with an increase in strength, depending on an individual's diet, exercise and genetics. For individuals on feminizing hormones, the opposite occurs with a corresponding decrease in strength and muscle bulk.

In the clinic

Muscle atrophy

Muscle atrophy is a wasting disorder of muscle. It can be produced by a variety of causes, which include nerve damage to the muscle and disuse.

Muscle atrophy is an important problem in patients who have undergone long-term rest or disuse, requiring extensive rehabilitation and muscle-building exercises to maintain normal activities of daily living.