LECTURE NOTES ON
ANATOMY

D.B. MOFFAT

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Preface

This is not a textbook of anatomy. As its name implies, it is meant to be a series of lecture notes from lectures of the proper type, i.e. they are not intended as a complete account of 'all you need to know about . . .' but rather offer explanations of those parts of human anatomy which students most often find difficult, and which therefore tend to be neglected, along with a variety of anecdotes, mnemonics and other aids to remembering the large amount of topographical detail which is needed by the student of medicine and associated subjects.

Anatomy is a visual subject. If you are explaining to a stranger how to get to the station you don't have to remember that the road is the third on the left from the church. In imagination you move along the road from the church, visualizing and counting the side turnings as you go until you reach the road to the station. Similarly in anatomy, you should never try to memorize the branches of the external carotid or the fifteen origins of psoas major. This could only be done by a genius. Instead, learn to draw simple diagrams and to memorize these so that you can visualize the structures you wish to describe. This is helped, of course, by recourse to dissections and museum specimens but your own rough diagrams are better in the long run unless the dissections are of outstanding quality.

Don't try to blind you colleagues or your examiners with science. Every examiner is familiar with the type of candidate who volunteers that there is a pseudoganglion on the branch of the axillary nerve to teres minor but who forgets about the branch to deltoid. Similarly, when answering a question, always begin with the important things and leave the unimportant things to the end (or forget them). The foramen spinosum transmits the middle meningeal artery; forget the nervus spinosus, it won't be mentioned again in this book.

You will appreciate by now that these *Lecture Notes* are not intended for medal and prize winners, who will have no difficulty in coping with the more ponderous tomes and who may even know all about the nervus spinosus! It is to help the average candidate to acquire a knowledge of the basic essentials of anatomy as required by medical students and while it possibly does not present all you need to know to pass 2nd MB, or the Primary Fellowship, it is fairly certain that it contains nothing that you do not need.

Some stress is laid on common sources of error such as confusion between the interoseous and lumbrical muscles and some repetition is used. This may annoy you, but you will remember the facts. Neuroanatomy has been omitted, since there are numerous excellent short textbooks which include some physiology as well as anatomy but the relationships between the bones of the skull and the underlying brain are discussed.

Terminology presents a difficulty. Occasionally, at International Congresses, a

Committee meets and makes various changes in anatomical terminology, for example the 'greater tuberosity' of the humerus has now been changed to 'greater tubercle'. When you start clinical work, however, you will find that clinicians (and indeed some senior anatomists) stick to the terminology with which they are most familiar. Clinically, too, eponymous terminology is often used so that you will hear surgeons speak of the foramen of Winslow instead of the epiploic foramen. In this book, therefore, the older terminology is sometimes given, as well as the more recent.

Diagrams, of course, play an important part in visualizing, and therefore in remembering, anatomical relationships and many of these have been taken from two other books with which I have been involved. These are *Anatomy and Physiology for Physiotherapists* and *Human Embryology*. I should like to thank Dr R.F. Mottram for permission to steal illustrations from the former and Professors F. Beck and D.P. Davies for the latter. The majority of the illustrations however, are new and it is a pleasure to thank Dave Gardner and Clare Williams of Oxford Illustrators Ltd. for the immense care and skill they have employed in preparing the diagrams from my rough sketches. I should also (publicly) like to thank my wife for typing the manuscript, no mean feat in view of my handwriting.

Finally, I must thank my friends and colleagues in Blackwell Scientific Publications, particularly Mr Per Saugman and Mr John Robson, for their part in bringing this book to fruition.

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Contents

Chapter I
General Anatomy

While the greater part of this book is concerned with details of the topographical anatomy of various regions of the body, there are many general principles that can be applied to all regions. A knowledge of these is essential and this is the subject of this chapter.

Cartilage

This is a connective tissue composed of *chondrocytes* embedded in a matrix of ground substance and fibres. In hyaline cartilage the fibres are fine collagen, in fibrocartilage they are large bundles of collagen, and in elastic cartilage they are coarse elastic fibres. Cartilage is an avascular tissue and so can be transplanted easily. With increasing age it tends to become calcified (*not* ossified, as no osteocytes or Haversian systems are present) and is then visible in X-rays. *Hyaline cartilage* is found, for example, in epiphyseal plates, as costal cartilages and as articular cartilage in synovial joints. *Fibrocartilage* is tougher and is found in secondary cartilaginous joints such as the joints between vertebral bodies. The largest piece of *elastic cartilage* in the body forms the skeleton of the pinna of the ear where its consistency can be examined. It also forms the 'skeleton' of the epiglottis.

Bone

Bone is one of the connective tissues and has two components, *organic* and *inorganic*. The former is the connective tissue proper and comprises the bone cells, *osteocytes*, and the interstitial matrix which itself consists of ground substance and fibres. The inorganic component consists of the 'bone salts', principally calcium, magnesium, phosphate and carbonate. Either of the two components may be removed artificially; the organic component by maceration and drying and the inorganic by decalcification with a mineral acid or a chelating agent. The 'bones' which are used for the study of osteology are thus merely skeletons of bones, consisting only of the inorganic component. It cannot be emphasised too strongly that, *in vivo*, bone is an active, living tissue, needing an adequate blood supply and capable of changing its form and structure very rapidly in response to changes in stress and in the chemical composition of the blood. In various diseases, and with increasing age it can undergo 'demineralization', with a loss of density in X-rays.

Bone, as a tissue, is found in two forms, namely *compact* and *cancellous* bone. The former is a dense ivory-like tissue and is found, for example, forming the shafts of the long bones. Cancellous, or spongy, bone consists of interlacing trabeculae and is found principally at the ends of long bones, in the bodies of the vertebrae and within various other bones. Histologically, bone is a highly organized tissue with the osteocytes embedded in the calcified matrix forming *Haversian systems* but in spite of their complicated appearance, these too are labile and may be broken down and reformed quite quickly.

The shape of bones

The bones that make up the skeleton are usually classified according to their shape as *long*, *short*, *flat*, and *irregular*. Long bones are long in relation to their width and they therefore include not only such bones as the femur and humerus but also the metacarpals, metatarsals and phalanges. The short bones are usually roughly spherical or cubical and they include the carpal and tarsal bones and the patella. The flat bones are typified by the bones of the vault of the skull and the scapula and they consist of a layer of cancellous bone sandwiched between two layers of compact bone. The irregular bones include the hip bone, the vertebrae and many skull bones. *Sesamoid bones* (i.e. shaped like a sesame seed) are bones that develop in tendons. They often articulate with an underlying bone and so have one surface covered with articular cartilage. The largest sesamoid bone is the patella but it is more usual to find them about the size of small peas such as the bones associated with the heads of the first metatarsal and metacarpal.

The structure of long bones

A major part of the orthopaedic surgeon's work is concerned with the long bones and a knowledge of their structure, blood supply and growth is therefore of great importance. Fig. 1.1 shows a diagram of a typical long bone such as the humerus. The shaft (*diaphysis*) consists of a thick-walled tube of compact bone which thins out at the expanded ends to form a shell around a mass of cancellous bone. The arrangement of the trabeculae is the result of the patterns of stress and their disposition may be altered when these patterns are changed. Running through the cancellous bone near the junction of the expanded end with the shaft is a thin line of dense bone called the *epiphyseal scar*. This marks the site of the original epiphyseal plate of cartilage and is visible as a thin line in X-rays.

The *medullary cavity* in the centre of the shaft contains *yellow marrow* (fat) in the healthy adult, as do the interstices of the cancellous bone at the ends although the latter may sometimes contain some *red (haemopoietic) marrow*. In the young person, or in certain diseases, red marrow may be formed in the spaces in the cancellous bone at each end of the shaft and possibly even replacing the yellow marrow in the shaft itself but, in the normal adult, it is usually found only in the ribs, sternum, vertebrae, hip bones and the flat bones of the skull.

In life, the surface of the shaft and part of the ends are covered by *periosteum*. This consists of two layers: an outer fibrous layer which acts as a limiting membrane, and a deeper vascular layer containing blood vessels and cells which can, when necessary, lay down new bone on the surface of the shaft. Towards the ends of the bones the periosteum blends with the fibrous capsule of the joints in which the bone is involved. The ends of long bones are covered with the articular cartilage of the joints, although in the case of the terminal phalanges, only one end is cartilage-covered.

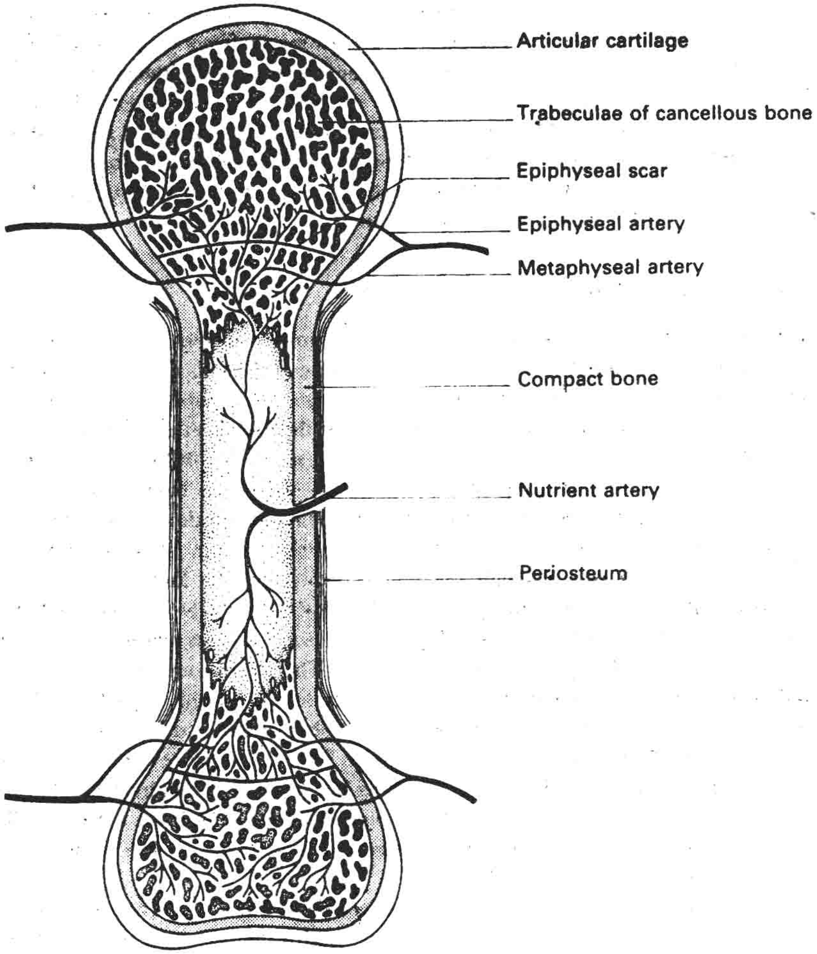

Fig. 1.1. Diagram of a typical long bone. Note the hollow tube of compact bone forming the shaft and the cancellous bone at each end.

One of the principal functions of long bones is to provide attachment for muscles, tendons and ligaments and an inspection of a dried bone will often give a good deal of information about these attachments. Where muscle fibres are attached directly to bone, or rather to the periosteum, there is usually no mark on the surface since the relative weakness of the muscle fibres leads to the need for a large smooth area of attachment. Thus the anterior surface of the lower part of the shaft of the humerus is quite smooth since the brachialis takes origin by direct muscle attachment. White fibrous tissue, which forms ligaments, tendons and aponeuroses, is on the other hand very strong indeed so that only a small 'concentrated' area of attachment is called for. This tissue therefore usually leaves a mark on the adult bone in the form of a roughened tubercle or ridge (or occasionally a depression such as that formed by the femoral attachment of popliteus). Thus the very strong iliofemoral ligament leaves a roughened line, called the intertrochanteric line, on the femur while the massive tendon of deltoid leaves a prominent deltoid tubercle on the lateral side of the shaft of the humerus. On the back of the femur, where numerous muscle origins and insertions are packed closely together, the attachments are necessarily by means of fibrous tissue and the result is the linea aspera. On young bones, however, there are no such markings and the surface of the bone is relatively smooth.

The blood supply of bone

The blood supply of long bones is derived from three principal sources: the main nutrient artery, the anastomosing vessels in the vicinity of the ends of the bone, and the small vessels in the vascular layer of the periosteum. The *nutrient artery*, which is accompanied by a vein, enters a *nutrient foramen* near the middle of the shaft, usually at an oblique angle directed away from the growing end (*see* below). Within the medullary cavity it divides and the divisions pass towards each end of the bone, giving numerous branches which enter the deep surface of the compact cortical bone. The finest branches enter the deep surface of the cortical bone. These branches enter the Haversian canals and pass through the bone, mainly running longitudinally. They finally reach the surface where they anastomose with the periosteal vessels. In addition to the main nutrient vessels, at each end of the bone some arteries and numerous veins enter the bone through foramina of various sizes. The arteries are branches of local vessels and also are derived from the arterial anastomosis around the corresponding joint. They enter the bone on both sides of the epiphyseal scar and are therefore often classified as *metaphyseal* and *epiphyseal* arteries. They anastomose within the bone across the epiphyseal scar although in the young bone, when an epiphyseal cartilage is present, they form separate systems. The epiphyseal arteries end up as a series of fine loops lying just deep to the articular cartilage, some of them, in fact, entering the deepest (calcified) layer of cartilage.

The direction of blood flow is said to be largely centrifugal, i.e. from the branches of the nutrient artery outwards to the anastomoses with the periosteal vessels but it is probable that the latter vessels are important in the nutrition of the outer layers of bone. Certainly in osteomyelitis, if the periosteum is stripped off the bone by subperiosteal pus, and the medullary vessels are thrombosed, the area of bone affected will die and form a *sequestrum*. The main supply to the periosteal vascular plexus is by means of vessels from the locally attached muscles; for this reason, large bare areas of bone have a poor blood supply. Thus fractures of the lower third of the tibia, where no muscles are attached, often suffer from delayed union.

In bones other than long bones there is no set pattern for blood vessels, so that nutrient arteries may enter the bone at various points. The distribution of blood vessels often has a bearing on the healing of fractures. In fractures of the scaphoid, for example, delayed union is liable to occur if one of the fragments has a poor blood supply.

Development of bone

There are two varieties of ossification, *intramembranous* and *intracartilaginous*(*enchondral*). The former is a process in which ossification occurs directly in embryonic mesenchyme and is found principally in the flat bones of the skull. The mesenchymal cells become transformed into *osteoblasts* which begin to lay down bone directly, becoming incorporated into the bone, as it develops, to form *osteocytes*. The process spreads from the primary centres of ossification until the whole bone has formed.

Enchondral ossification is more complicated and is the more important process clinically since all the limb bones (and many others) develop in this way. The process for a long bone is shown diagrammatically in Fig. 1.2. The bone is first laid down as a cartilaginous model which is approximately similar in shape to the final product. A *primary centre* of ossification then appears near the centre of the shaft and this spreads towards the ends. At the same time the periosteum lays down a collar of bone around the circumference of the shaft, this being carried out, in effect, by a process of intramembranous ossification. The primary centres of ossification begin to appear during intrauterine life, mostly during the 6th to 8th weeks. Much later, one or more secondary centres of ossification develop at each end of the cartilaginous model and these increase in size and (if more than one is present at each end) fuse with each other until a bony *epiphysis* can be recognized at each end. This is separated from the shaft, or *diaphysis*, by an *epiphyseal plate* of cartilage which, together with the articular cartilage at each end of the bone, is all that now remains of the original cartilaginous

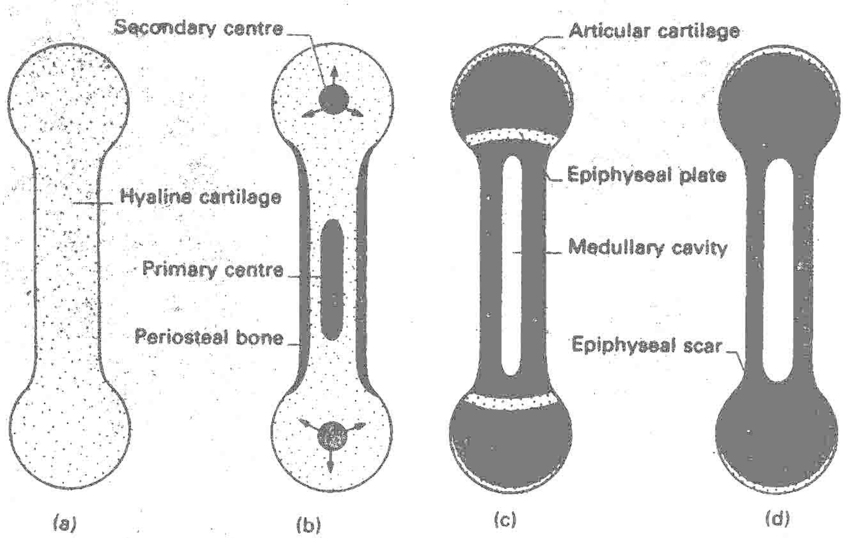

Fig. 1.2. Ossification of a long bone. Bone is represented by fine stippling (see text for description).

model. *The secondary centres of ossification all appear after birth except for that at the lower end of the femur (in the 9th intrauterine month) and possibly the upper end of the tibia.*

Before the mechanism of growth at the epiphyseal cartilage can be described it is necessary to explain the process of ossification in more detail. In the first stage of ossification the cartilage cells become flattened and arranged in columns, and the matrix then becomes calcified. The cartilage cells swell up and die and this dead calcified cartilage is eroded and then removed as blood vessels grow in. *Osteoblasts* and *osteoclasts* are brought in with the vessels and the former begin to lay down true bone. The process of ossification spreads from the primary centre towards each end of the shaft and in a section through a developing bone all the stages of ossification can be seen simultaneously in the zone where the process is taking place. After ossification has been going on for some time, so that a definite long shaft can be recognized, the osteoclasts begin to remove the new bone in the centre of the shaft so that a *medullary cavity* is produced. Ossification at the secondary centres follows a similar pattern except that a true medullary cavity does not form although the interstices between the trabeculae of the cancellous bone make their appearance. When the bone is completely formed but still increasing in dimensions, the various stages in the ossification process are found in a zone just on the diaphyseal side of the epiphyseal cartilage. This very vascular zone is the *metaphysis* and is particularly susceptible to infection in the immature bone.

The continuing process of ossification in the metaphyseal region is accompanied by the continuing production of new cartilage in the epiphyseal plate and in this way the bone is enabled to grow in length. Increasing deposits of bone by the periosteum produce the necessary increase in girth. As the bone grows, *remodelling* becomes necessary and this important process is carried out by the osteoclasts which break down the newly formed bone wherever necessary. When growth in length in finally complete, the remaining epiphyseal cartilage ceases to proliferate and becomes ossified leaving only an epiphyseal scar. In most long bones the epiphyses do not fuse simultaneously, one end fusing several years before the other. The end at which fusion occurs last is called the *growing end* and in almost all bones this is also the end at which the secondary centre of ossification appears first. Thus the growing end is the end at which most of the growth in length occurs, even though a great deal of growth also takes place at the other end. As has been mentioned already, the nutrient artery is directed away from the growing end, and since it passes towards the elbow and away from the knee (to the elbow, they go; from the knee, they flee), the growing end of the limb bones can easily be remembered. Disease or injury in the region of the epiphyseal cartilage at the growing end is liable to produce shortening (i.e. failure of growth) of the bone. This is particularly important in the lower limb. Once the epiphyses are fused, no further growth in length can occur although the periosteum can still lay down bone around the periphery of the shaft.

Joints

Joints are classified in various ways but the classification used here will be based on their structure. There are basically three types of joints, *fibrous*, *cartilaginous* and

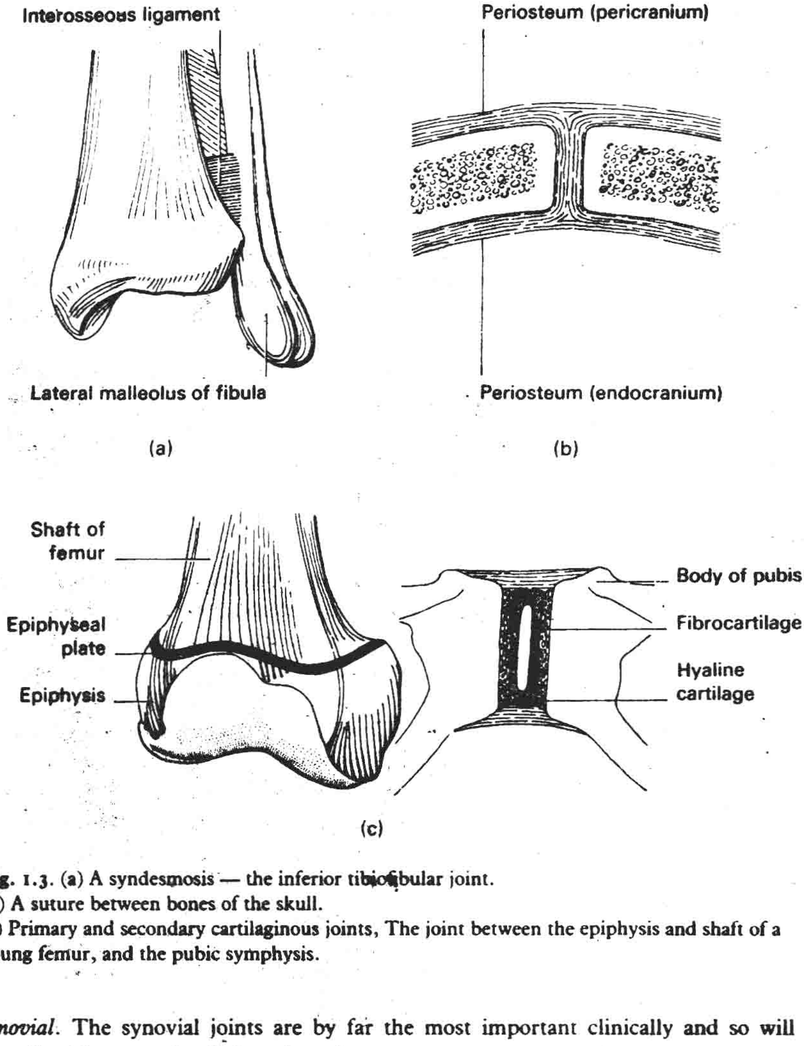

Fig. 1.3. (a) A syndesmosis — the inferior tibiofibular joint.
(b) A suture between bones of the skull.
(c) Primary and secondary cartilaginous joints, The joint between the epiphysis and shaft of a young femur, and the pubic symphysis.

synovial. The synovial joints are by far the most important clinically and so will be described in more detail than the others.

Fibrous joints

These are joints at which little or no movement is possible, the bones being held together by dense fibrous tissue. There are a number of different types of fibrous joints but only the two most important will be mentioned here. When there is sufficient fibrous tissue present to justify its being called an interosseous ligament, the joint is called a *syndesmosis*. An important example is the inferior tibiofibular joint. The other major type of fibrous joint is the *suture*. Sutures unite the flat bones of the skull, the fibrous pericranium being continuous with the endocranium (or fibrous layer of the dura) through the minute gap between the bones (Fig. 1.3).

Cartilaginous joints

These are of two types, *primary* and *secondary*. In primary cartilaginous joints two or more bones are held together by a plate of hyaline cartilage (Fig. 1.3). This type of joint is also called a *synchondrosis* and, typically, with increasing age, the cartilage disappears and the two bones fuse to form a *synostosis*. Examples are the joint between an epiphysis and a diaphysis or between the occipital bone and the body of the sphenoid in a young person.

In a secondary cartilaginous joint each bone is covered by a layer of hyaline cartilage and they are united by a plate of fibrocartilage (Fig. 1.3). These joints are often called *symphyses* and by coincidence they all lie in the midline. Examples are the joints between the vertebral bodies, the manubriosternal joint and the pubic symphysis.

Synovial joints

These are joints characterized by the presence of a synovial membrane. Most of them are freely moveable although some display very little movement, for example, the sacro-iliac joint. The synovial joints are classified according to the movements that can occur at them. The most elaborate of the synovial joints are those in which movement can occur about three axes, i.e. they can produce flexion and extension, abduction and adduction and medial and lateral rotation. These are called *ball and socket joints* and they are exemplified by the hip and shoulder joints. Similar planes of movement are found in the first carpometacarpal joint which is, however, classified as a *saddle-shaped joint*. In *ellipsoid joints*, such as the wrist and metacarpophalangeal joints, movement can occur in only two planes, viz. flexion and extension, abduction and adduction. *Hinge joints*, as their name implies, display movement in only one plane, i.e. flexion and extension. The elbow joint and the interphalangeal joints are hinge joints. Another simple type of movement is seen in *pivot joints* such as the radio-ulnar and atlanto-axial joints in which the movement is rotational. The least complicated variety of synovial joint is the *plane* or *gliding joint* in which only slight shifting can occur, as in the superior tibiofibular joint.

It must be mentioned that all the movements referred to above are active movements, i.e. performed by the patient himself. Most joints also show additional passive or *accessory movements*. These are movements which can be produced by the examiner, the patient's muscles being relaxed. For example, the wrist joint can be manipulated to display medial and lateral rotation, distraction and anteroposterior and sideways movements of the whole hand on the forearm.

The features of a typical synovial joint

The principal components of a typical synovial joint are shown in diagrammatic fashion in Fig. 1.4 and they will now be described individually.

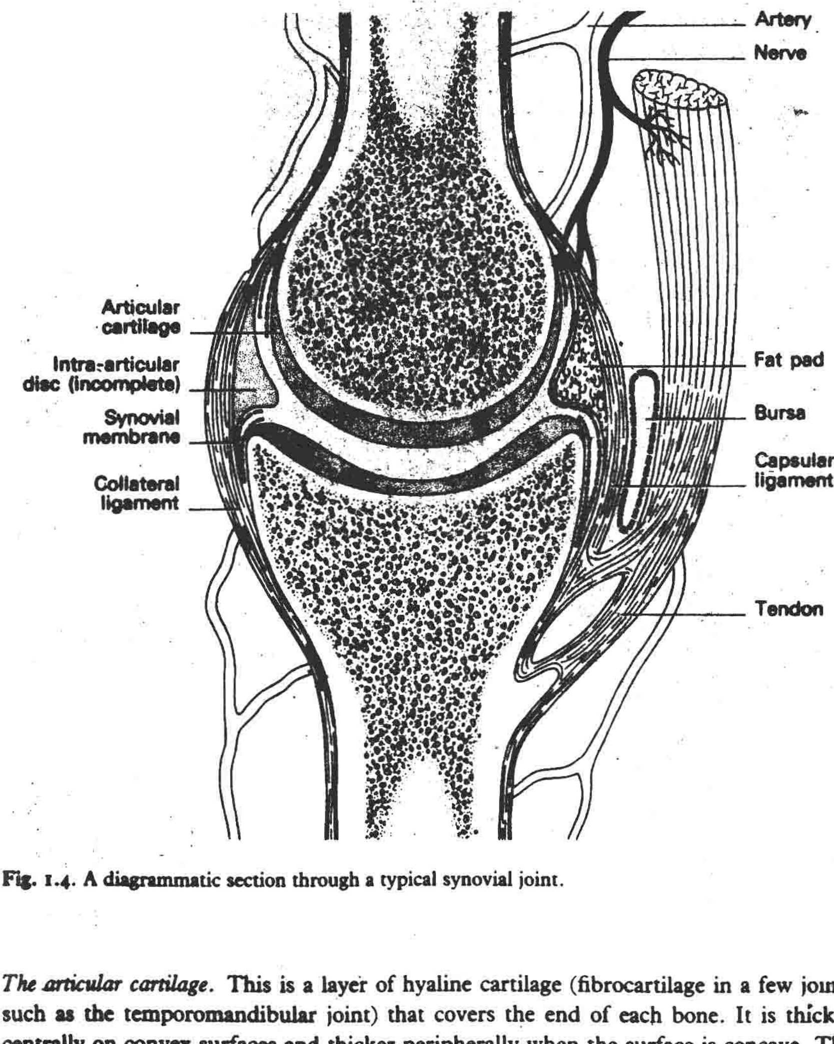

Fig. 1.4. A diagrammatic section through a typical synovial joint.

The articular cartilage. This is a layer of hyaline cartilage (fibrocartilage in a few joints such as the temporomandibular joint) that covers the end of each bone. It is thicker centrally on convex surfaces and thicker peripherally when the surface is concave. The articular cartilage adapts the shape of the bones more exactly to each other but the fit is still not perfect and the surfaces are very slightly noncongruent. In this way pockets of synovial fluid are pushed from one part of the joint to another and lubrication is much better than if the cartilage fitted perfectly over the entire contact area.

The most superficial layer of the cartilage contains compressed and rather flattened cells and forms an extremely durable and relatively frictionless surface. The deepest layer is calcified and may be penetrated for a short distance by blood vessels from the underlying bone. Surprisingly, very few mitoses are seen in adult articular cartilage and it does not seem to renew itself to compensate for wear and tear. The cartilage is nourished by diffusion from blood vessels in the underlying bone and in the synovial membrane, which reaches to the edge of the cartilage. The synovial fluid itself also provides nutrition so that 'joint mice' or loose cartilaginous bodies in joints are not only living but are said actually to increase in size.

The capsular ligament (fibrous capsule). This forms a sleeve around the joint, blending with the periosteum of the bones that form the joint. It is thickened in places to form *ligaments* and the disposition of these is related to the movements that occur at the joint. Thus, in hinge joints, the principal ligaments are found at the sides of the joint, the capsular ligament being thin and flexible in front and behind (see, for example, the elbow joint). *Accessory ligaments* are found in certain joints. These are ligaments which are separate from the capsular ligament and they may be intra- or extracapsular. Examples of accessory ligaments are the cruciate ligaments of the knee joint (intracapsular) and the coracoclavicular ligament (extracapsular), which is an accessory ligament of the acromioclavicular joint. The function of the ligaments is to hold the bones together while allowing the appropriate movements to take place. They also help to limit movements to the normal range, the surrounding muscles also playing an important role in this activity. In most joints there is a *close-packed* position in which the ligaments are all taut and the joint surfaces are virtually fully congruent and have the maximum area of contact. The close-packed position is the position in which the joint is most firm and rigid but it is also the position in which damage to intra-articular structures is most likely to occur.

It is important to know the precise attachments of the capsular ligament and its relation to the epiphyseal cartilage. If the cartilage, and thus the vulnerable metaphysis, is intracapsular, infections of the bone may affect the joint.

The synovial membrane. The lining membrane of synovial joints forms from the innermost layer of cells in the developing joint and one might expect it to cover all structures inside the joint. In fact, however, the cells never develop into synovial membrane over surfaces which are exposed to friction so that in the fully developed joint the membrane lines the inside of the capsular ligament, and covers the intra-articular parts of the bones but stops short at the edge of the articular cartilage. It also covers any intra-articular structures which are not exposed to wear and tear such as parts of intra-articular discs and also the fatty pads which fill up any dead space within a joint. In many joints the synovial membrane protrudes through a gap in the capsule and is continuous with the lining of one or more bursae around the joint. For example, the semimembranosus bursa may communicate with the knee joint and become palpable when there is an excess of synovial fluid in the joint cavity (*Baker's cyst*).

The functions of the synovial membrane are to produce synovial fluid and also to absorb the fluid when it is present in excess. Phagocytic cells in the membrane can remove bacteria and small particles from the joint. Synovial fluid (also present in bursae and in the synovial sheaths of tendons) is a viscous fluid, rich in mucopolysaccharides, which acts as a highly effective lubricant for the joint surfaces and which also serves as a source of nourishment for the articular cartilage. It exhibits anomalous viscosity in that its viscosity falls during rapid movement and rises during slow movements.

Intra-articular discs. Many joints contain intra-articular discs, partial or complete, which are composed of fibrocartilage or fibrous tissue. When complete, they subdivide the joint cavity into two separate joints at which different types of movement may occur, for example in the temporomandibular joint. The discs are covered by synovial membrane except over the regions that are exposed to friction.

Blood and nerve supply of joints

The blood supply of joints (and of the bones that make up the joint) is derived from the peri-articular network of arteries that surround the joint. In the knee joint, for instance, the various genicular arteries, derived from major arteries in the vicinity, form a complex anastomosis. The fibrous tissue of the ligaments only requires a relatively poor supply but there is a rich plexus of vessels in the synovial membrane that also helps to supply the periphery of the articular cartilage.

Hilton's law states that the nerves that supply a joint are derived from nerves that supply (some of) the muscles that pass over the joint. The femoral nerve, for example, supplies the quadriceps femoris. Each of the branches to the vasti (medialis, intermedius and lateralis) sends a branch to the knee joint while the branch to rectus femoris (the only member of quadriceps to cross the hip joint) sends a branch to that joint. The nerves end in various types of sensory nerve endings in the ligaments, including the capsular ligament, but the synovial membrane is poorly innervated and is relatively insensitive to pain.

Muscle

There are three types of muscle, skeletal (voluntary or striped), cardiac, and smooth. The latter two types are often classified as involuntary. In fact, the terms voluntary and involuntary are best avoided since some skeletal muscle is not under the control of the will (for example in the cremaster muscle and the upper part of the oesophagus) while some smooth muscle is voluntary (e.g. the ciliaris muscle in the eyeball which is responsible for focusing the lens). The following account is restricted to skeletal muscle.

Histology

The basic unit of skeletal muscle is the muscle fibre which consists of only one cell but has a very large number of nuclei. Each fibre is between 10 and 100 μm in diameter but the length is very variable, some fibres being only a few millimetres long while others may be 30–40 cm in length in a long strap-shaped muscle like sartorius. Each muscle fibre is surrounded by a connective tissue sheath, the *endomysium*, while bundles, or fasciculi, of fibres are enclosed in a *perimysium*. The connective, tissue which encloses the whole muscle is called the *epimysium*. Finally, a muscle, with its sheath may be enclosed in its own compartment of deep fascia, alone or with other muscles with a similar function. The striations are caused by the overlapping of actin and myosin fibres but the functional histology of muscle need not concern us here. As might be expected, such a highly specialized tissue does not easily regenerate and a severely damaged muscle is repaired mainly by the formation of scar tissue.