Wilson's Practical Meat Inspection

Seventh Edition

William G. Wilson
CIEH

Revised from the original text
Practical Meat Inspection
by Andrew Wilson

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Preface to Seventh Edition

The contents have been updated since the sixth edition to reflect changes in knowledge of diseases, alterations in legislation and events since 1998, such as the foot and mouth outbreak in 2001.

A new chapter relating to illegal meat has been included to reflect the increased media and public awareness of this subject. I hope the information contained in this chapter will assist enforcement officers in detecting illegal meat and ensure its removal from the food chain. I am grateful once again to Mr R. Butler *MSc*, *BA Hons*, *BA*, *CIEH* for his technical knowledge and assistance in producing this edition. I would also like to add my thanks to my wife, Stephanie, for her encouragement and support.

William Wilson

Dedication

I would like to dedicate this edition to the memory of my late parents, Andrew and Jean Wilson. It was my father's knowledge and foresight in producing the first five editions of this book which still, even now, provides a firm foundation for this the seventh edition. God bless you both.

Preface to First Edition

This book is based on a course of lectures on meat inspection, and is intended for all those interested in the practical aspects of the subject, particularly veterinary students, trainee public health inspectors and trainee meat inspectors. While the sections dealing with physiology and anatomy have been deliberately made somewhat elementary, they do provide all the information required by meat inspectors, while veterinary students and, to a lesser degree, public health inspectors learn these subjects as a separate part of their course.

I have tried to deal comprehensively with meat inspection, but it must be stressed that it is essentially a practical subject which cannot be learned from books alone. I have, however, designed both text and illustrations to emphasise all the important facts that students should remember, excluding all irrelevant material.

It is most important that students should familiarise themselves with normal tissues so that when something abnormal turns up it can be recognised.

In writing this book I have had much helpful criticism from colleagues in Birmingham; in particular from Mr George E. Bousfield *MAPHI*. I am most grateful for his help. I also wish to thank Mr Jack Baker *FRSH* for the section on preservation by heat, and Mr Donald J. Knight, meat inspector, for the section on bacon curing and meat products.

Andrew Wilson

Chapter 1

Cells and Tissues

Physiology is the study of the various activities of living organisms. Such activities include:

(1) Assimilation of food and oxygen to produce energy necessary for existence.
(2) Excretion of waste products.
(3) Growth.
(4) Reproduction.

All living organisms are composed of cells, the form of which can be seen microscopically. The simplest form of life is composed of only one cell, e.g. the amoeba. Most animals, however, are made of a great number of cells and tissues. Each tissue has its own particular type of cell, e.g. muscle cells differ in size and shape from those of the liver. Basically each cell has the same structure (Fig. 1.1).

Cells

A cell consists of *protoplasm* enclosed within a *cell membrane*. The protoplasm contains a *nucleus* which is surrounded by *cytoplasm*. Mammalian red blood cells are unusual in that they do not contain nuclei.

The nucleus consists of a *nuclear membrane*, *nucleoplasm* and *nucleolus*. The nuclear membrane is a perforated structure which separates the nucleus from the cytoplasm. The nucleoplasm contains the chromosomes which are constructed mainly of deoxyribonucleic acid (DNA), and the nucleolus is rich in ribonucleic acid (RNA).

The cytoplasm contains many living inclusions:

(1) *Mitochondria*. These are found in most abundance in situations where there is great activity, e.g. in the muscles. They are concerned with the conversion of adenosine diphosphate (ADP) to the triphosphate form (ATP) for energy purposes.
(2) *Ribosomes*. These are the site of protein synthesis.
(3) *Golgi bodies*. These are involved in the production of enzymes and hormones.
(4) *Lysosomes*. These break down food particles.

The cytoplasm also contains non-living inclusions, such as fat and glycogen.

Cells are constantly dying and being replaced by new cells, e.g. the red blood cell cycle is about 14 days.
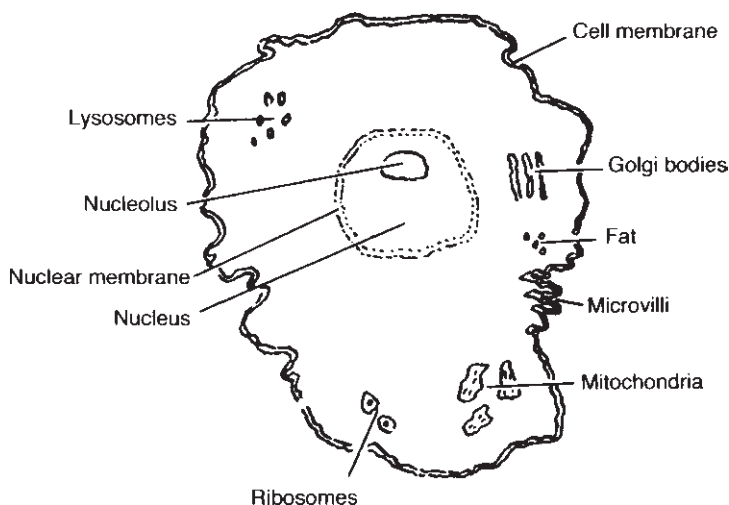
Fig. 1.1   Animal cell.

Tissues

The animal body is composed of tissues. The main tissues are: epithelial, connective, muscular, blood, lymphatic and nervous.

Epithelial tissues

These cover the free surfaces of the body. There are various types:

(1)   *Stratified epithelium* is many cells thick. It covers the anterior surface of the cornea and forms the epidermis of the skin, the superficial cells of which are dead, flattened and scale-like, whereas the deeper cells are polyhedral and columnar in shape.

(2)   *Transitional epithelium* is a type of stratified epithelium that has only three or four layers of cells. Most of the urinary tract has this type of epithelium.

(3)   *Pavement epithelium* covers the unexposed parts of the body, e.g. the pleural and peritoneal cavities, and the blood and lymph vessels.

(4)   *Columnar epithelium* is a more active type of epithelium and is found lining the stomach and intestines.

(5)   *Ciliated epithelium* is found in the lungs and trachea, in the fallopian tubes, uterus and efferent tubes and ducts of the testes.

Connective tissues

Connective tissues, as the name implies, connect the various cells of other tissues and organs and their function is largely mechanical. They include the following tissues: (1)

areolar, (2) elastic, (3) lymphatic or reticular, (4) adipose, (5) fibrous, (6) cartilaginous and (7) bony.

(1) *Areolar tissue* is composed of white and elastic fibres forming meshworks that enclose spaces or *areolae*, e.g. *subcutaneous tissue*.
(2) *Elastic tissue* is composed of yellow elastic fibres. It is found in the walls of blood vessels, the lungs and most characteristically in the *ligamentum nuchae*.
(3) *Lymphatic* or *reticular tissue* is composed of networks of collagenous fibres enclosing *lymph*.
(4) *Adipose tissue* or *fat* is composed of a network in which are embedded *fat cells*. The chief constituents of animal fat are *stearin*, *olein* and *palmitin*. The body fat comes partly from fat in the diet and is in part manufactured, within the body, from carbohydrates and sometimes proteins in the diet.

   The fat is soft during life but quickly hardens after death. This is due to the fall in temperature and not to *rigor mortis*. Fat is found under the skin, the *subcutaneous fat* or *panniculus adiposus*, and collects around the heart and particularly around the kidneys. It is also found in the pleura, peritoneum and mesentery and in small quantities in the tissues of most organs. Fat provides a store of energy for the body. Being a poor conductor of heat it prevents loss of body heat. In well-fed animals it is found between the muscle fibres and is called *marbling*.

   Unlike ruminants, horses and pigs tend to deposit fat unchanged. Fat varies in consistency, colour and distribution (Table 1.1). Some animals have white fat and some yellow due to the presence of *carotene*. In some the fat is firm, in others soft. In chronic diseases the fat may not set and remains soft. The colour may vary not only with the species but also with the age and breed of the animal.

   In old cows the fat is yellow. The Channel Island breeds of cattle have a yellow fat although young calves of those breeds have white fat. The colour may also vary with the feeding, e.g. a grass diet with high levels of *carotene* gives a yellow fat compared to the white fat in barley beef.

   The consistency of fat varies according to the amounts of stearin, olein and palmitin in it. A high stearin content gives a firm consistency, whilst a high olein content gives an oily consistency. A good knowledge of the different kinds of fat is very helpful in identifying the source of specimens.

Table 1.1 Characteristics of fat.

Animal	Colour	Consistency
Calf	White or greyish-white	Soft and gelatinous
Heifer and bullock	White or yellowish-white	Firm and smooth
Cow	Yellow	Fairly firm and ragged
Bull	White or yellowish-white	Firm (sparse)
Sheep and goat	Very white	Very firm and crisp
Pig	White	Fairly firm and greasy
Horse	Yellowish-white	Soft and greasy
Deer	White	Firm (very sparse)

Brown fat is a type of fat, deposits of which are found scattered throughout the body, mainly in the neck and axillary regions. It has a richer blood supply than normal fat, and can be converted more easily into energy. Therefore it has the ability to keep animals lean. Lean animals have more brown fat than fat animals.

(5) *Fibrous tissue* is composed almost entirely of white fibres. It is found in ligaments, tendons and fasciae and in the serous membranes.

(6) *Cartilaginous tissue* (cartilage), commonly known as gristle, is a specialised dense connective tissue. It forms most of the temporary skeleton of the mammalian embryo and persists in the adult, e.g. at the joint surfaces, in the respiratory passages, in the ears, and as the costal cartilages of the ribs. The most common and characteristic form of cartilage is known as *hyaline cartilage* because of its glassy translucent appearance. Cartilage in some areas, e.g. at the pelvic symphysis and at the dorsal extremities of the spines of the first five or six thoracic vertebrae, gradually ossifies with age. It is therefore helpful in deciding upon the age of an animal.

(7) *Bony tissue*. Bone is a connective tissue that is impregnated with salts of lime, chiefly phosphate, these salts constituting about two-thirds the weight of the bone.

Bony tissue is either *compact* or *spongy*. Compact bone is white, dense and almost like ivory. Spongy bone consists of delicate bony plates and spicules that run in various directions and intercross. The spaces between the plates are called *marrow spaces* and are filled with *marrow*. Externally, bones are covered, except at the joints, by a vascular, fibrous membrane – the *periosteum* (Fig. 1.2).

The bones are commonly divided into four classes:

(a) Long bones – typically elongated cylindrical form with enlarged extremities, e.g. femur.

(b) Flat bones – bones of the skull.

(c) Short bones – e.g. those of carpus and tarsus, with somewhat similar dimensions in length, breadth and thickness. They diminish friction or change directions of tendons.

(d) Irregular bones – bones of irregular shape, e.g. vertebrae.

Marrow

There are two distinct varieties of marrow – the red marrow and the yellow marrow.
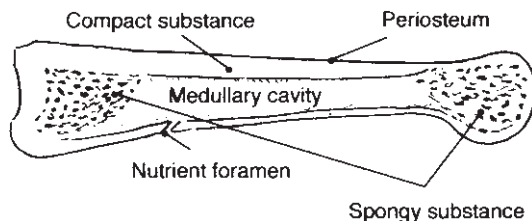
Fig. 1.2 Long bone.

(1)   The red marrow occupies the spaces in the spongy bone; it is highly vascular and thus maintains the nutrition of the spongy bone. It is in these situations that the red blood corpuscles are formed.

(2)   The yellow marrow fills the medullary cavity of long bones and consists chiefly of fat cells with numerous blood vessels.

NB In young animals there is only red marrow, i.e. as the animal ages the proportion of red to yellow decreases.

Short descriptions of the muscular and lymphatic tissues are given in the relevant chapters.

Systems of the Body

For ease of description, the systems of the body have been grouped under nine headings: skeletal, muscular, circulatory, lymphatic, respiratory, digestive, urogenital, nervous and endocrine. The information on these systems is very basic and is almost entirely concerned with identification purposes. Fuller information should be obtained from anatomy textbooks.

Chapter 2
Skeletal System

The skeletal system consists of a framework composed of the bones of the body. These are joined together in their natural positions by ligaments and joints. The softer tissues of the body are built on this framework and the organs are enclosed and partly protected by it.

Bones

The skull and lower jaw

The upper jaw is attached to the skull and contains the upper teeth. The lower jaw or mandible, carrying the lower teeth, is a separate bone joined to the skull by means of ligaments. The skull articulates with the first cervical vertebra, the atlas, by a ball-and-socket joint.

The vertebral column

The vertebral column, spine or backbone consists of many vertebrae, which form a long, fairly flexible chain extending from the head to the tail. The vertebrae are divided into groups named according to their position:

(1) Cervical (C) or neck vertebrae.
(2) Dorsal or thoracic (T) vertebrae – those of the back with which the ribs articulate.
(3) Lumbar (L) vertebrae – situated in the region of the loin.
(4) Sacral (S) vertebrae – in the pelvic region. These are generally fused together to form the sacrum and articulate with the pelvic bones to form the pelvis.
(5) Coccygeal (Cy) or tail vertebrae.

The vertebral formulae for the various animals are shown in Table 2.1. From this it will be noted that they all have seven cervical vertebrae. Even the giraffe with its very long neck has the same number.

The spinal cord passes through the vertebral foramen of each vertebra down to about the third sacral vertebra. Between the bodies of the vertebrae (except in the sacral region

Table 2.1   Vertebral formulae.

	C	T	L	S	Cy
Horse	7	18	6	5	15–21
Ox	7	13	6	5	18–20
Deer	7	13	6–7	4	10
Sheep	7	13	6–7	4	16–18
Pig	7	14–15	6–7	4	20–23

where they are fused together) are found elastic cartilaginous pads or *intervertebral discs* (see Figs 2.1 and 2.2).

The ribs

These are long curved paired bones that help to form the sides of the chest wall. They are attached above on each side to the dorsal or thoracic vertebrae (same number) and below to the sternum, or to one another. The ribs that articulate with the sternum are known as true ribs, while those that fail to reach the sternum articulate with each other and are known as false ribs. The ribs are separated from one another by spaces, the intercostal spaces containing muscle tissue (the intercostal muscles).

The sternum

The sternum or breast bone is a long bone made up of six to eight segments joined together by cartilage. The superior surface is concave and forms part of the floor of the thorax.

The sacrum

The sacrum is formed by the fusion of the sacral vertebrae and is commonly described as one bone. It is triangular in outline, articulates very firmly on each side and is wedged between the ilia.

The os coxae (pelvic bones) (Fig. 2.3)

Each os coxae, right and left, consists of the following three bones, which fuse together to form one large flat bone:

(1)   The *ilium* is the largest of the three. It articulates with the sacrum.
(2)   The *ischium* is the most posterior and forms the posterior part of the floor of the pelvis.
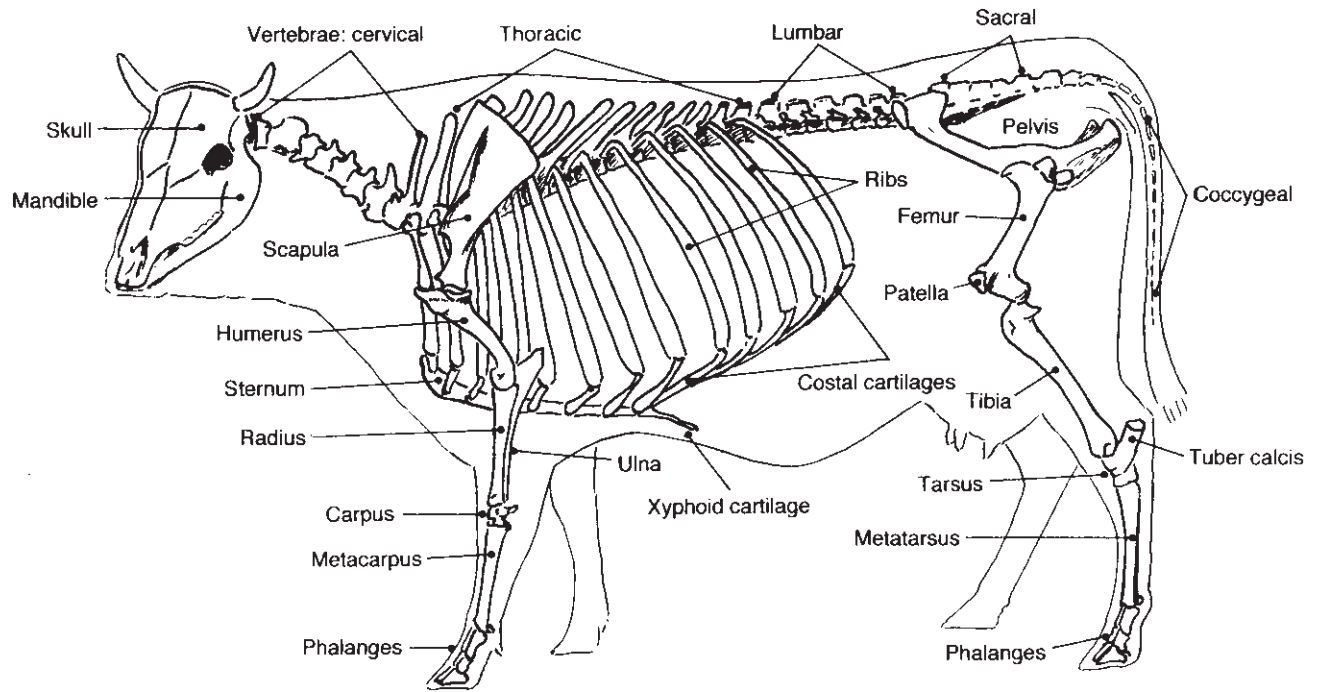(3)   The *pubis* is the smallest of the three bones and forms the anterior floor of the pelvis.
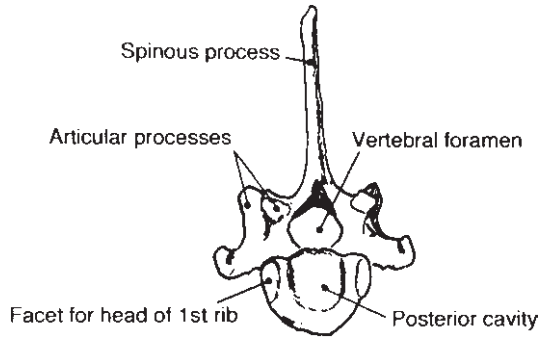
Fig. 2.1 Skeleton of cow.

Fig. 2.2   The 7th cervical vertebra of ox.
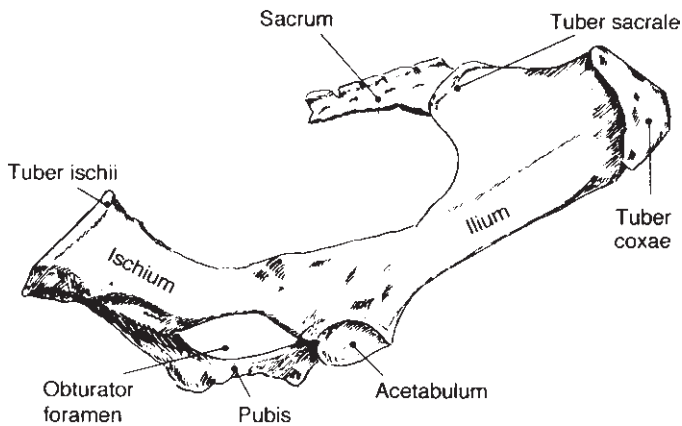
Fig. 2.3   Right pelvic bones of ox.

All three bones join to form the *acetabulum* into which the head of the femur fits.

The ischium and pubis join with their opposite bones at the *symphysis pelvis*, the anterior part of which is the *symphysis pubis*.

The body cavities

(1)   The cranial cavity is the cavity formed by the bones of the skull. It contains the brain.

(2)   The *thorax* or thoracic cavity is formed by the thoracic vertebrae above, the ribs at the sides and the sternum below. It is cone-shaped and is separated from the abdominal cavity by a strong muscular membrane, the *diaphragm*. The thorax contains part of the oesophagus, part of the trachea or windpipe, the heart, the lungs, part of the thymus gland and portions of the great blood vessels.

(3)   The *abdomen* or abdominal cavity is formed by the lumbar vertebrae above, while the abdominal muscles form its sides and lower wall. The front wall is formed by

the diaphragm. The abdomen contains the stomach, intestines, liver, spleen, pancreas, kidneys and bladder when it is extended, and the uterus in the pregnant female.

(4)   The *pelvis* or pelvic cavity is formed by the sacrum above and the pelvic bones on either side and below. It contains the rectum, the non-extended bladder and, in the non-pregnant or newly pregnant female, the uterus and ovaries.

The bones of the fore limb (Fig. 2.1)

(1)   The *scapula* or shoulder blade is a flat triangular bone which has no articulation with the chest wall but is attached to it by muscles.
(2)   The *humerus* is a long cylindrical bone that extends from the shoulder to the elbow joint.
(3)   The *radius* and *ulna*. The radius is the larger bone and extends from the elbow to the knee joint. The ulna in cattle is fused to the radius. Its upper end forms a projection known as the olecranon process or 'point of the elbow'.
(4)   The *carpus* or knee joint is made up of six small bones disposed in two rows. The upper row articulates with the radius, the lower with the metacarpus.
(5)   The *metacarpus* or cannon bone is a cylindrical bone that extends from the knee joint to the digits.
(6)   The *digits*, or bones of the foot. In the ox there are two digits separated by a cleft ('cloven footed'). Each digit is composed of three phalanges. The terminal portion of each digit is surrounded by the hoof.
(7)   The *navicular* bone is a small bone at the back of the last joint.

The bones of the hind limb (Fig. 2.1)

(1)   The *femur* or thigh bone is a large, strong, cylindrical bone that extends from the hip joint above to the stifle below. The upper rounded head fits into the socket or acetabulum in the os coxae to which it is attached by the *round ligament*. The lower end articulates with the tibia, fibula and patella or kneecap.
(2)   The *patella* or kneecap is a small flat bone roughly triangular with the apex below. It articulates with the femur and is attached to the tibia by means of three strong fibrous bands or ligaments.
(3)   The *tibia* and *fibula* or leg bones articulate above with the femur and below with the tarsal bones, i.e. they extend from the stifle to the tarsus. The fibula is rudimentary in ruminants.
(4)   The *tarsus* or hock, like the carpus, consists of two rows of small bones. The upper row contains two segments, the posterior of which – the os calcis – has a marked projection, the 'point of the hock'. The lower row has three bones.
(5)   The *metatarsus* extends from the hock to the fetlock and is similar to but slightly longer than the metacarpus in the fore limb.
(6)   The *digits* are the same as in the fore limb.

1st Dorsal vertebrae

Horse   Bovine

Scapulae (left)

Horse   Bovine

Humeri (left)

Horse

Bovine

Horse

Bovine

Horse

Bovine

Ulnae
+
Radii
(left)

Horse
(right)

Fibulae
+
Tibiae

Bovine (left)

8th Ribs (left)

Horse

Bovine

Fig. 2.4 Bones of horse and ox.
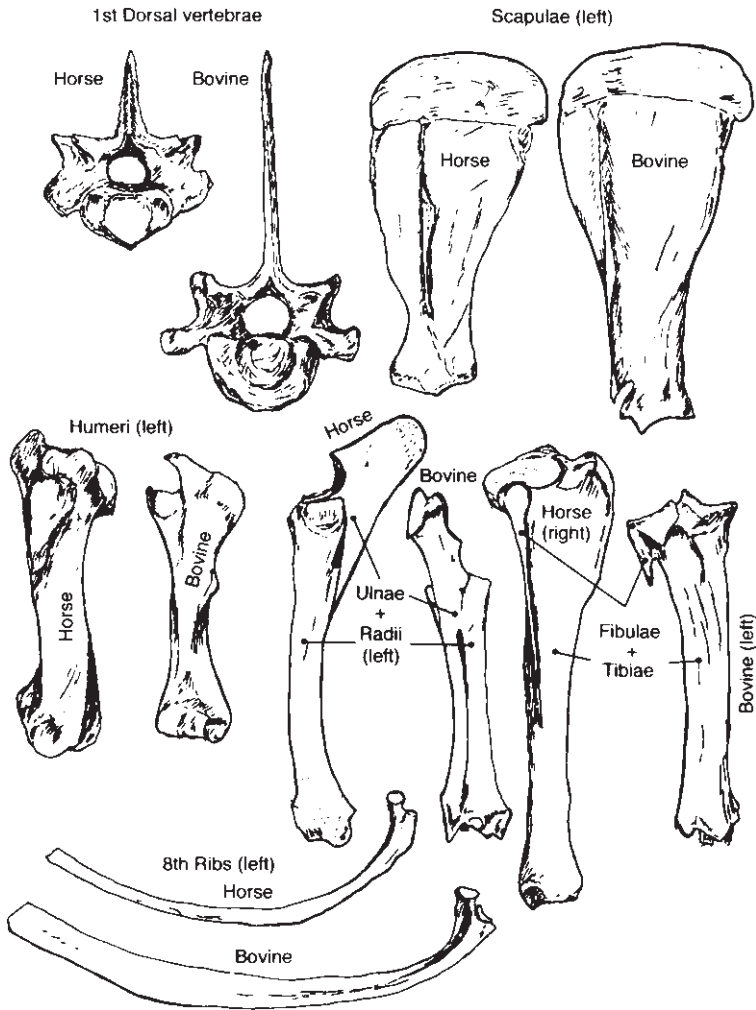
Differential features of bones

The following discusses some of the distinctions between bones of the various animals.

Horse and ox (Fig. 2.4)

(1) The spinal processes of the anterior dorsal vertebrae of the horse are shorter and stouter.

(2) The ribs of the ox are smoother and in the lower two-thirds are broader. The ox has 13 pairs of ribs whereas the horse has 18 pairs.

(3)   The scapula of the ox is more regularly triangular than that of the horse and the spine is more prominent and placed further forward, so that the supraspinous fossa, i.e. the part in front of the spine, is narrow and does not extend to the lower part of the bone. Instead of subsiding as in the horse, the spine rises and has a pointed projection – the acromion. There is a distinct notch in the glenoid cavity of the horse, but not in that of the ox. The glenoid cavity is the articular surface of the scapula.

(4)   The humerus of the horse has three tuberosities, i.e. the lateral tuberosity is divided into two, giving a bicipital groove. In the ox the lateral tuberosity is very large and rises 2.5–5 cm above the level of the bone.

(5)   The ulna extends only half way down the radius in the horse. In the ox it is more developed and reaches the carpus.

(6)   The small head of the fibula in the ox is hook-shaped. In the horse it is separate and extends two-thirds down the tibia.

Sheep, goat and deer

(1)   The bones of the goat and deer are more slender and longer than those of the sheep, and the bony processes are longer and more sharply edged than in the sheep.

(2)   The scapula of the sheep is shorter compared with its breadth and the edge of the spine in the centre is thickened backwards, while in the goat and deer it is straight and unthickened.

Cat and rabbit (Figs 2.5 and 2.6)

(1)   The lateral processes of the lumbar vertebrae in the cat are pointed, whereas in the rabbit there are two extensions, one backwards and one forwards.

(2)   In the cat there are 13 pairs of rounded ribs, whilst in the rabbit there are 12 pairs which are more flat.

(3)   The rabbit has a long metacromion on the scapula directed backwards, which is absent in the cat.

(4)   The tibia and fibula in the cat are separate for their complete length. In the rabbit they are separate only in the upper half.

(5)   The radius and ulna are separate in the cat but united in the rabbit.

(6)   The male cat has an os penis.

(7)   The coccygeal vertebrae in the rabbit are very small.

   Cat bones are included because of complaints from members of the public that they have been served cat meat instead of rabbit or chicken in restaurants.

Fowl and rabbit (Figs 2.6, 2.7 and 24.4)

(1)   The bones of fowl tend to be whiter in colour and larger in all dimensions than the rabbit.
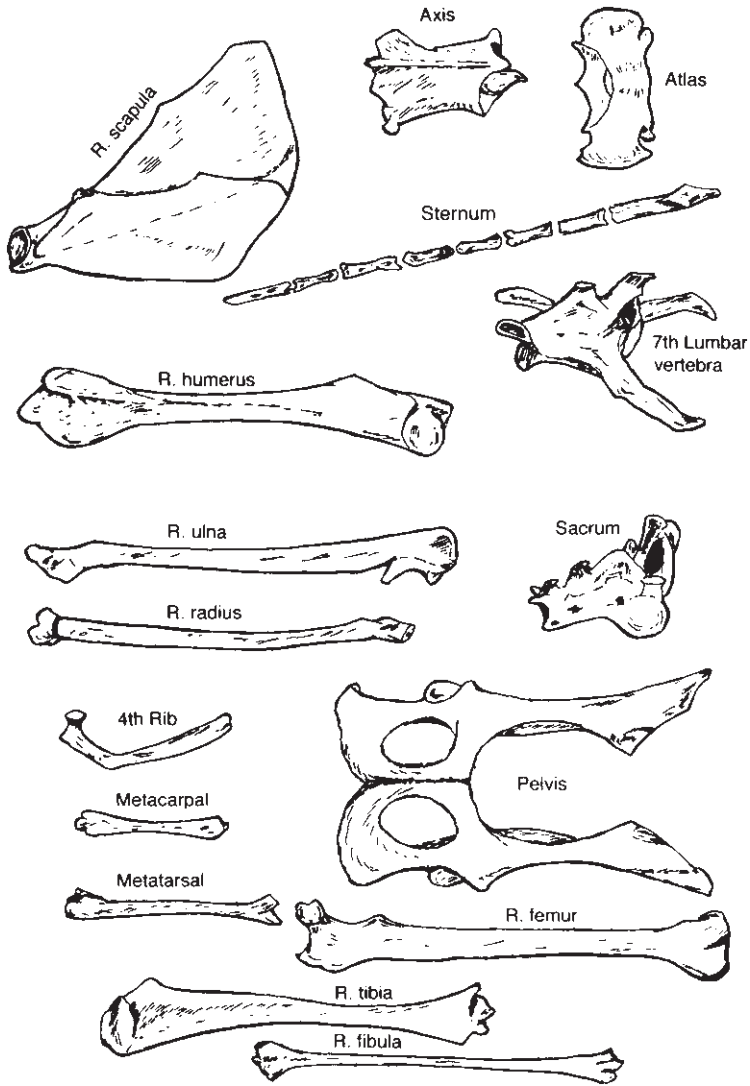
(2)   The humerus is hollow in fowl.

Fig. 2.5 Bones of cat.

(3)   The metatarsus is very large in fowl and has a spur in the male.
(4)   The ribs are flat with uncinate processes projecting backwards in fowl. In the rabbit the ribs are long and slender with no uncinate processes.
(5)   In fowl the pelvis and sternum are very typical and not at all like those in mammals.
(6)   In fowl the clavicle (wishbone) is present as also is the coracoid, but these are absent in the rabbit.
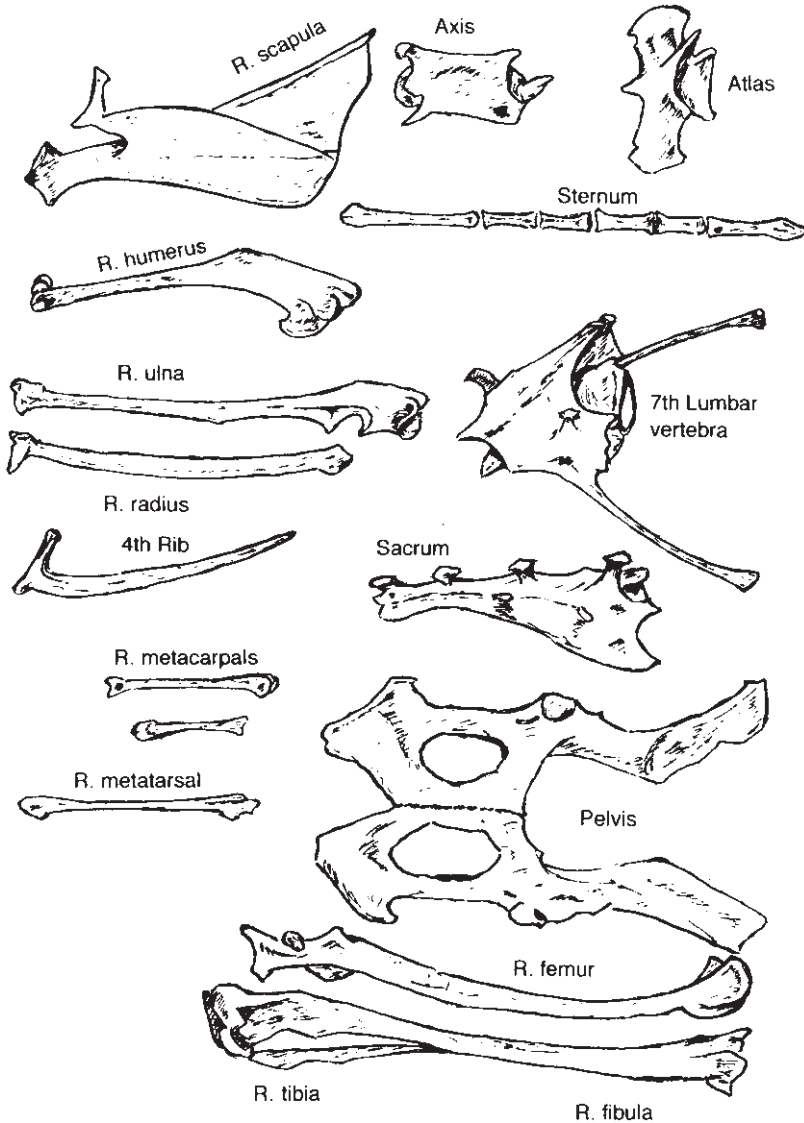(7)   The fowl scapula is not the typical triangular shape.

Fig. 2.6 Bones of rabbit.

(8)   The sternal bones are fused in fowl, but not in the rabbit.
(9)   The pygostyle is present in fowl.

In food inspection departments it is very useful to have skeletons of the various animals. This is of course difficult with the large animals because of the space they occupy. However, with the small animals, e.g. rabbit, fowl and duck, it is quite simple to mount their bones on thick plastic sheets.

This makes it much easier to identify bones, the origin of which may be in question.
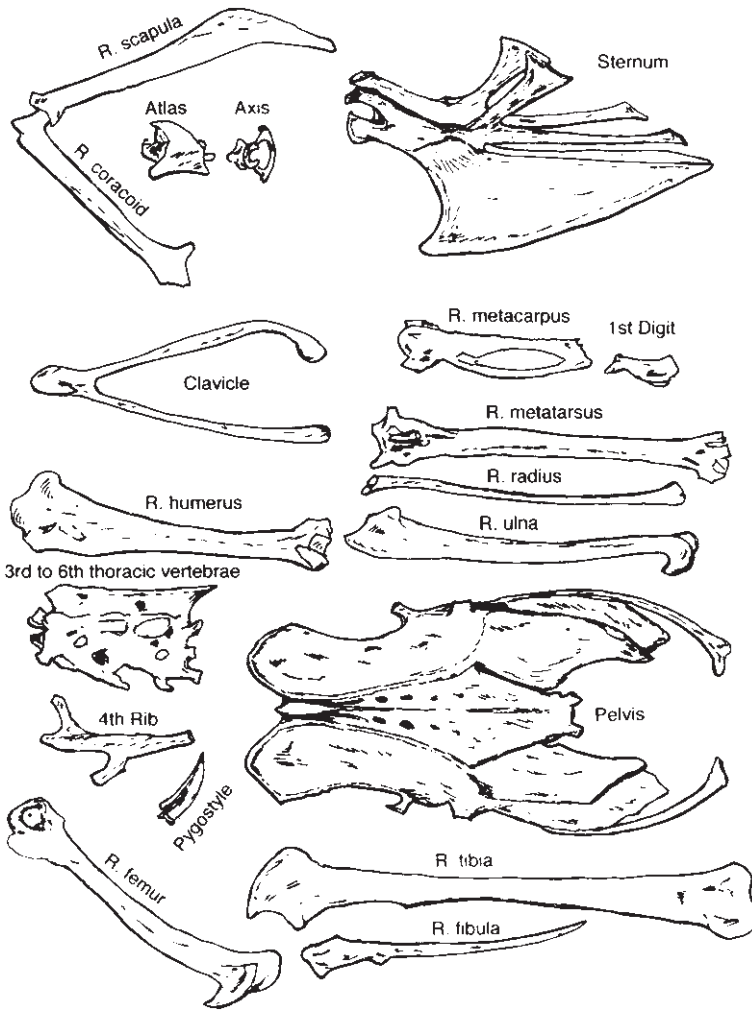
Fig. 2.7 Bones of fowl.

Joints

An articulation or joint is formed by the union of two or more bones or cartilage by other tissue. Bone is the fundamental part of most joints; in some cases a bone and a cartilage, or two cartilages, form a joint.

Joints are classified in various ways, but the simplest way is as follows:

(1) *Immovable joints*, e.g. those of the skull and pelvis. The bones of the skull are united by means of irregular saw-like edges known as sutures, which firmly bind them together without intervention of cartilage.

(2) *Slightly movable joints*. In this type of joint the opposed bony surfaces are covered by hyaline cartilage and connected by a fibrocartilaginous pad. Two examples are
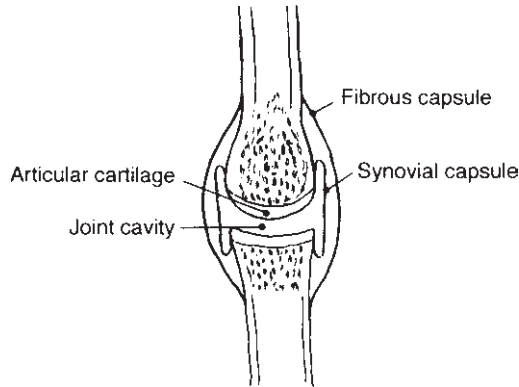
Fig. 2.8   Simple joint.

joints between the bodies of vertebrae and the joint between the two pubic bones in young animals.

(3) *Movable joints* (Fig. 2.8). These are made up of the following tissues:

    (a) Cartilage, known as articular cartilage, covers the surface of the part of the bone that enters into the joint.

    (b) The capsule, which consists of strong fibrous tissue, is attached to the rim of the articular cartilage. The capsule encloses the joint cavity.

    (c) The synovial membrane. This is composed of endothelial cells, and lines the inside of the joint cavity. It secretes an oily liquid, *synovial fluid*, which facilitates smooth movement.

    (d) Blood vessels, lymph vessels and nerves supply the joint.

Movable joints are further classified by their type of movement:

(1) Ball-and-socket joint, e.g. the hip joint.
(2) Gliding joint, e.g. the joints between the articular processes of the vertebrae.
(3) Hinge joint, which allows movement in one plane, e.g. the elbow joint.
(4) Condyloid joint, which allows movement in two planes, e.g. the joint between skull and lower jaw.
(5) Pivot joint, which allows rotation, e.g. the atlanto-axial joint.

Ligaments

These are usually composed of strong bands of white fibrous tissue that bind the bones together. They are very pliable but not elastic. An exception to this is the *ligamentum nuchae*, which is composed of yellow elastic tissue. It is a very strong ligament that extends from the occipital bone to the top of the spines of the thoracic vertebrae where it is continuous with the *supraspinous ligament*.

Chapter 3
Muscular System

The movements of animals are brought about by the contraction of muscles. The muscles contract or shorten in response to impulses conveyed to them by nerves. Muscles only stretch beyond the normal in abnormal situations resulting in strains or torn muscles. Most are attached to bones which, with joints, act as levers and hinges. For convenience the term *origin* is used for the attachment that remains stationary when the muscle contracts, whereas the movable attachment is called the *insertion*.

Muscle tissue is composed of small elongated cells or *muscle fibres*. These are bound in *bundles* by connective tissue. The fibres vary in size but average $2.5\,\text{cm} \times 0.05\,\text{mm}$. They are cylindrical in shape with rounded ends. Many become elongated into *tendons*, which attach or insert into bones. The fibres consist of a sheath or *sarcolemma* enclosing the *contractile substance*.

There are three types of muscles:

(1) *Voluntary*, *skeletal* or *cross-striated muscles*, which are under the control of the will. They constitute the muscular apparatus attached to the bones and are commonly called meat or flesh.
(2) *Cardiac* or *heart muscle* is also striated but otherwise different from voluntary muscle. It is not under the control of the will but, like the involuntary muscles, is controlled by the autonomic nervous system.
(3) *Involuntary*, *plain* or *non-striated muscles* are not under the control of the will, e.g. the muscular layer of the intestinal wall.

Again it is emphasised that detailed information on the muscular system should be obtained from textbooks on anatomy.

Chapter 4

Circulatory System

The circulatory system consists of the blood and the means by which it is circulated round the body, i.e. the heart, arteries, veins and capillaries.

The *blood* is concerned with external and internal respiration, i.e. in the lungs and in the tissues. Together with the lymph it is the transport medium of the body. The arterial blood, which is bright red, carries nutrients and oxygen to the tissues. The venous blood is dark red and carries waste products, including carbon dioxide, away from the tissues.

Blood consists of a yellowish fluid called *plasma* in which the blood cells are suspended. There are three main types of blood cells:

(1) *Red blood corpuscles* or *erythrocytes*, which are made in the bone marrow.
(2) *White blood corpuscles* or *leucocytes*, which are made in the bone marrow, spleen and lymph nodes.
(3) *Platelets.*

The erythrocytes have no nuclei in mammals but are nucleated in birds. The leucocytes are nucleated. In mammals there are 7 000 000–10 000 000 erythrocytes per cubic millimetre of blood and 8000–20 000 leucocytes.

Blood normally remains fluid in the blood vessels during life but rapidly clots when shed. Clotting is due to the formation of a jelly by the deposition of an insoluble protein called *fibrin*. Calcium, which is a normal constituent of the blood, is necessary for clotting. If blood is collected and citrate added immediately, clotting does not occur. This is because the calcium is taken out of solution. Practical use is made of this fact when blood is collected for making black puddings.

Clotting can also be prevented by adding *heparin* or by stirring vigorously, when the fibrin can be removed as a white stringy material. Plasma with the fibrin and blood cells removed is called *serum*. Clotting can be shown as a series of reactions:

(1) Injured tissue cells + platelets → *thrombokinase*.
(2) *Thrombokinase + prothrombin* + calcium → *thrombin*.
(3) *Thrombin + fibrinogen* → *fibrin* (insoluble clot). The fibrin entangles the corpuscles forming the clot.

The heart (Fig. 4.1) is the muscular pump of the circulatory system (Fig. 4.2). It lies in the thoracic cavity between the right and left lungs and is enclosed in a fibro-serous sac called the *pericardium*. This is relatively thin but strong and inelastic. It is smooth
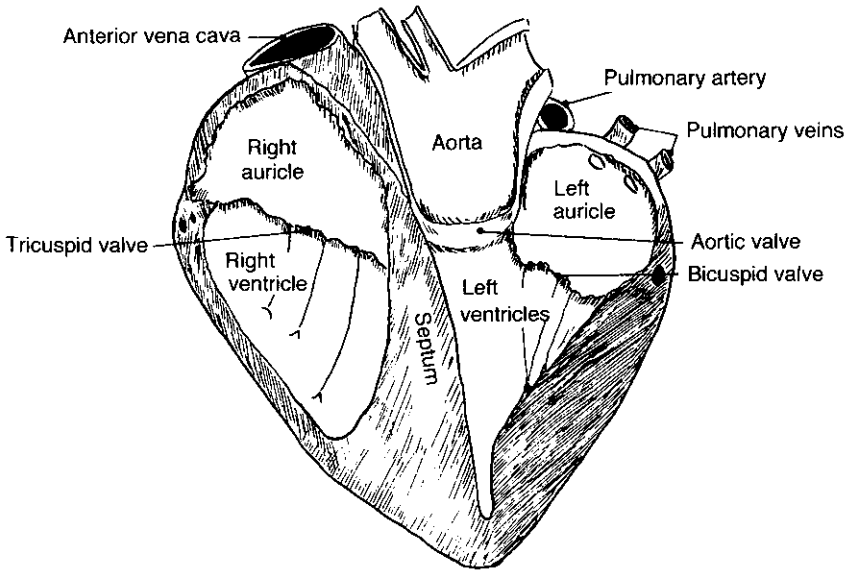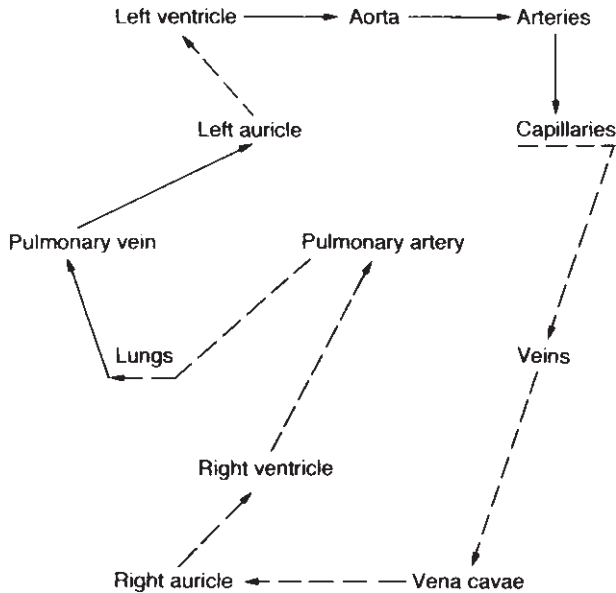
Fig. 4.1 Heart.

Fig. 4.2 Circulation of the blood. ***NB*** The pulmonary vein carries *arterial* blood and the pulmonary artery carries *venous* blood.

and glistening and contains a small amount of *pericardial fluid*. Like other serous membranes it is regarded as consisting of a *parietal* and a *visceral* part. The parietal part lines the fibrous part to which it is closely attached. The visceral part covers the heart and part of the large blood vessels and is called the *epicardium*.