Chapter 1

Introduction

1.1 Meat and muscle

Meat is defined as the flesh of animals used as food. In practice this definition is restricted to a few dozen of the 3000 mammalian species; but it is often widened to include, as well as the musculature, organs such as liver and kidney, brains and other edible tissues. The bulk of the meat consumed in the United Kingdom is derived from sheep, cattle and pigs; rabbit and hare are, generally, considered separately along with poultry. In some European countries (and elsewhere), however, the flesh of the horse, goat and deer is also regularly consumed; and various other mammalian species are eaten in different parts of the world according to their availability or because of local custom. Thus, for example, the seal and polar bear are important in the diet of the Inuit, and the giraffe, rhinoceros, hippopotamus and elephant in that of certain tribes of Central Africa: the kangaroo is eaten by the Australian aborigines: dogs and cats are included in the meats eaten in Southeast Asia: the camel provides food in the desert areas where it is prevalent and the whale has done so in Norway and Japan. Indeed human flesh was still being consumed by cannibals in remote areas until only recently past decades; (Bjerre, 1956).

Very considerable variability in the eating and keeping quality of meat has always been apparent to the consumer; it has been further emphasized in the last few years by the development of prepackaging methods of display and sale. The view that the variability in the properties of meat might, rationally, reflect systematic differences in the composition and condition of the muscular tissue of which it is the post-mortem aspect is recognized. An understanding of meat should be based on an appreciation of the fact that muscles are developed and differentiated for definite physiological purposes in response to various intrinsic and extrinsic stimuli.

1.2 The origin of meat animals

The ancestors of sheep, cattle and pigs were undifferentiated from those of human beings prior to 60 million years ago, when the first mammals appeared on Earth. By
2–3 million years ago the species of human beings to which we belong (*Homo sapiens*) and the wild ancestors of our domesticated species of sheep, cattle and pigs were probably recognizable. Palaeontological evidence suggests that there was a substantial proportion of meat in the diet of early *Homo sapiens*. To tear flesh apart, sharp stones – and later fashioned stone tools – would have been necessary. Stone tools were found, with the fossils of hominids, in East Africa (Leakey, 1981).* Our ape-like ancestors gradually changed to present day human beings as they began the planned hunting of animals. There are archaeological indications of such hunting from at least 500,000 bc. The red deer (*Cervus elaphus*) and the bison (referred to as the buffalo in North America) were of prime importance as suppliers of hide, sinew and bone, as well as meat, to the hunter-gatherers in the areas which are now Europe and North America, respectively (Clutton-Brock, 1981). It is possible that reindeer have been herded by dogs from the middle of the last Ice Age (about 18,000 bc), but it is not until the climatic changes arising from the end of this period (i.e. 10,000–12,000 years ago) that conditions favoured domestication by man. It is from about this time that there is definite evidence for it, as in the cave paintings of Lascaux.

According to Zeuner (1963) the stages of domestication of animals by man involved first loose contacts, with free breeding. This phase was followed by the confinement of animals, with breeding in captivity. Finally, there came selected breeding organized by man, planned development of breeds having certain desired properties and extermination of wild ancestors. Domestication was closely linked with the development of agriculture and although sheep were in fact domesticated before 7000 bc, control of cattle and pigs did not come until there was a settled agriculture, i.e. about 5000 bc.

Domestication alters many of the physical characteristics of animals and some generalization can be made. Thus, the size of domesticated animals is, usually, smaller than of their wild ancestors.** Their colouring alters and there is a tendency for the facial part of the skull to be shortened relative to the cranial portion; and the bones of the limbs tend to be shorter and thicker. This latter feature has been explained as a reflection of the higher plane of nutrition which domestication permits; however, the effect of gravity may also be important, since Tulloh and Romberg (1963) have shown that, on the same plane of nutrition, lambs to whose back a heavy weight has been strapped, develop thicker bones than controls. (As is now well documented, exposure to prolonged periods of weightlessness causes loss of bone and muscle mass.) Many domesticated characteristics are, in reality, juvenile ones persisting to the adult stage. Several of these features of domestication are apparent in Fig. 1.1 (Hammond, 1933–4). It will be noted that the domestic Middle White pig is smaller (45 kg; 100 lb) than the wild boar (135 kg; 300 lb), that its skull is more juvenile, lacking the pointed features of the wild boar, that its legs are shorter and thicker and that its skin lacks hair and pigment.

Apart from changing the form of animals, domestication encouraged an increase in their numbers for various reasons. Thus, for example, sheep, cattle and pigs came

* Rixson (2000) presented convincing arguments showing how the development of butchery skills, deriving from the use of stone tools, promoted a settled communal life; and, thereafter, led to civilized societies.
** It appears, however, that the sizes of domestic cattle, sheep and pigs in Anglo-Saxon times were much smaller than those of their modern counterparts (Rixson, 2000).
to be protected against predatory carnivores (other than man), to have access to regular supplies of nourishing food and to suffer less from neonatal losses. Some idea of the present numbers and distribution of domestic sheep, cattle and pigs is given in Table 1.1 (Anon., 2003).

1.2.1 Sheep
Domesticated sheep belong to the species *Ovis aries* and appear to have originated in western Asia. The sheep was domesticated with the aid of dogs before a settled

Fig. 1.1 Middle White Pig (aged 15 weeks, weighting 45 kg; 100 lb) and Wild Boar (adult, weighting about 135 kg; 300 lb), showing difference in physical characteristics. Both to same head size (Hammond, 1933–4). (Courtesy of the late Sir John Hammond.)
agriculture was established. The bones of sheep found at Neolithic levels at Jericho, have been dated as being from 8000–7000 BC (Clutton-Brock, 1981). Four main types of wild sheep still survive – the Moufflon in Europe and Persia, the Urial in western Asia and Afghanistan, the Argali in central Asia and the Big Horn in northern Asia and North America. In the United Kingdom, the Soay and Shetland breeds represent remnants of wild types.

By 3500–3000 BC several breeds of domestic sheep were well established in Mesopotamia and in Egypt: these are depicted in archaeological friezes. Domestication in the sheep is often associated with a long or fat tail and with the weakening of the horn base so that the horns tend to rise much less steeply. The wool colour tends to be less highly pigmented than that of wild sheep.

Nowadays about 55 different breeds of sheep exist in the United Kingdom. Some of these are shown in Table 1.2. Further information on numbers of sheep in each breed, the size of crossbred ewe populations and the general structure of the sheep industry can be found in ‘Sheep in Britain’ (Meat & Livestock Commission, 1988).

The improved breeds, such as the Suffolk, tend to give greater carcass yield than semi-wild breeds such as the Soay or Shetland sheep, largely because of their increased level of fatness (Hammond, 1932a). Again, of the improved breeds, those which are early maturing, such as the Southdown and Suffolk, have a higher percentage of fat in the carcass than later maturing breeds, such as the Lincoln and Welsh; moreover, the subcutaneous fat appears to increase, particularly in the former. The English mutton breeds (e.g. Southdown and Cotswold) have a greater development of subcutaneous connective tissue than wool breeds, e.g. Merino.

### Table 1.1 Numbers of sheep, cattle and pigs in various countries, 2003

<table>
<thead>
<tr>
<th>Country</th>
<th>Approx. million head</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Sheep</td>
<td>Cattle</td>
<td>Pigs</td>
</tr>
<tr>
<td>Argentina</td>
<td>12.5</td>
<td>51</td>
<td>4</td>
</tr>
<tr>
<td>Australia</td>
<td>98</td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td>Brazil</td>
<td>4</td>
<td>189.5</td>
<td>33</td>
</tr>
<tr>
<td>China</td>
<td>144</td>
<td>103.5</td>
<td>47</td>
</tr>
<tr>
<td>Denmark</td>
<td>negligible</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Eire</td>
<td>5</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>France</td>
<td>9</td>
<td>19.5</td>
<td>15</td>
</tr>
<tr>
<td>Germany</td>
<td>3</td>
<td>14</td>
<td>26</td>
</tr>
<tr>
<td>Italy</td>
<td>11</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Japan</td>
<td>negligible</td>
<td>4.5</td>
<td>10</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>10</td>
<td>4.5</td>
<td>1</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>New Zealand</td>
<td>39</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>Poland</td>
<td>negligible</td>
<td>5.5</td>
<td>19</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>14</td>
<td>26.5</td>
<td>17</td>
</tr>
<tr>
<td>Turkey</td>
<td>27</td>
<td>10.5</td>
<td>negligible</td>
</tr>
<tr>
<td>Ukraine</td>
<td>1</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>UK</td>
<td>36</td>
<td>10.5</td>
<td>5</td>
</tr>
<tr>
<td>USA</td>
<td>6</td>
<td>96</td>
<td>59.5</td>
</tr>
</tbody>
</table>

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The coarseness of grain of the meat from the various breeds tends to be directly related to overall size, being severe in the Large Suffolk sheep: the grain of the meat from the smaller sheep is fine. Breed differences manifest themselves in a large number of carcass features – in the actual and relative weights of the different portions of the skeleton, in the length, shape and weight of individual bones, in the relative and actual weights of muscles, in muscle measurements, colour, fibre size and grain and in the relative and actual weights and distribution of fat (Pállson, 1939, 1940).

The shape of the \textit{l. dorsi}\* muscle (back fillet) in relation to fat deposition is shown for several breeds of sheep in Fig. 1.2: the relative leanness of the hill sheep (Blackface) will be immediately apparent.

1.2.2 Cattle

The two main groups of domesticated cattle, \textit{Bos taurus} (European) and \textit{B. indicus} (India and Africa), are descended from \textit{B. primigenius}, the original wild cattle or aurochs. The last representative of the aurochs died in Poland in 1627 (Zeuner, 1963). Although variation in type was high amongst the aurochs, the bulls frequently had large horns and a dark coat with a white stripe along the back. These characteristics are found in the cave paintings of Lascaux. Certain wild characteristics survive more markedly in some domestic breeds than in others, for example, in West Highland cattle and in the White Park cattle. Some of the latter may be seen at Woburn Abbey in England: similar animals are also represented pictorially at Lascaux.

Domestication of cattle followed the establishment of settled agriculture about 5000 bc. Domesticated hump-backed cattle (\textit{B. indicus}, ‘Zebu’) existed in Mesopotamia by 4500 bc and domesticated long-horned cattle in Egypt by about

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* In this text the term ‘longissimus dorsi’ (abbrev. ‘l. dorsi’) signifies ‘\textit{M. longissimus thoracis et lumborum}’ (or parts thereof).
Fig. 1.2 The effect of breed on the shape and fat cover of the *L. dorsi* muscle of sheep (Hammond, 1936).

<table>
<thead>
<tr>
<th>Breed</th>
<th>A (mm)</th>
<th>B (mm)</th>
<th>Shape index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackface</td>
<td>52</td>
<td>24</td>
<td>46</td>
</tr>
<tr>
<td>Suffolk</td>
<td>65</td>
<td>35</td>
<td>54</td>
</tr>
<tr>
<td>Hampshire</td>
<td>58</td>
<td>33</td>
<td>57</td>
</tr>
<tr>
<td>Southdown</td>
<td>62</td>
<td>43</td>
<td>69</td>
</tr>
</tbody>
</table>

All the photographs have been reduced to the same muscle width (A) in order to show the proportions. (Courtesy of the late Sir John Hammond.)

4000 BC: both of these appear on pottery and friezes of the period (Zeuner, 1963). Several breeds of domesticated cattle were known by 2500 BC. An interesting frieze from Ur, dating from 3000 BC, shows that cows were then milked from the rear. According to Zeuner, this is further evidence that the domestication of sheep preceded that of cattle. About this same time the fattening of cattle by forced feeding was practised in Egypt.
According to Garner (1944) the more immediate wild predecessor of most breeds of British cattle was *B. longifrons*, which was of relatively small frame, rather than *B. primigenius*, which is said to have been a massive animal. Indirectly, the development of many present British breeds was due to the early improvements initiated by Bakewell in the middle of the eighteenth century, who introduced in-breeding, the use of proven sires, selection and culling. In the United Kingdom prior to that time cattle had been developed, primarily, for draught or dairy purposes. A deliberate attempt was now made to produce cattle, primarily for meat, which would fatten quickly when skeletal growth was complete. During the last 200 years the trend has been towards smaller, younger and leaner animals; and there has been growing realization that breed potential will not be fully manifested without adequate food given at the right time in the growth pattern of the animal (Hammond, 1932a; Garner, 1944). Some of the present breeds of British cattle are listed in Table 1.3; they are grouped according to whether they are of beef, dairy or dual-purpose types.

A beef animal should be well covered with flesh, blocky and compact – thus reducing the proportion of bone. Muscle development should be marked over the hind, along the back and down the legs. In a dairy animal, on the other hand, the frame should be angular with relatively little flesh cover, the body should be cylindrical (thus accommodating the large digestive tract necessary for efficient conversion of food into milk) and mammary tissue should be markedly developed.

Aberdeen Angus has been regarded as the premier breed for good-quality meat (Gerrard, 1951). The carcass gives a high proportion of the cuts which are most in demand; there is, usually, a substantial quantity of intramuscular (marbling) fat and the eating quality of the flesh is excellent; on the other hand, the carcass is relatively light. One of the reasons for the good eating quality of the Aberdeen Angus is its tenderness, which is believed to be partly due to the small size of the muscle bundles, smaller animals having smaller bundles. Because of the small carcass, however, such meat is relatively expensive. One way of making available large quantities of the relatively tender meat would be to use large-framed animals at an early age when the muscle bundles would still be relatively small (Hammond, 1963a). This may be done by feeding concentrates such as barley to Friesians (Preston et al., 1963). Aberdeen Angus, Herefords and Shorthorns (beef-types) have been extensively used to build up beef herds overseas, as in Argentina and Queensland.

### Table 1.3 Some breeds of cattle found in the United Kingdom (courtesy G. Brown, Meat & Livestock Commission)

| (a) Principal beef breeds | Charollais, Limousin, Simmental, Hereford, Aberdeen Angus, Belgian Blue, Blonde d’Aquitaine, South Devon, Beef Shorthorn, Welsh Black, Devon, Lincoln Red, Murray Grey, Sussex, Galloway |
| (b) Dairy breeds | Holstein/Friesian, Jersey, Ayrshire, Guernsey, Dairy Shorthorn |
| (c) Dual-purpose breeds | Meuse Rhine Issel, Dexter, Red Poll |

In terms of numbers. Holstein/Friesian are predominant and the Hereford is now about the fifth most popular beef breed, following the Charollais, Limousin, Simmental and Aberdeen Angus. In the United Kingdom about 64 per cent of home killed beef is derived from dairy breeds.
Callow (1961) suggested that selection for beef qualities has brought about various differences between beef and dairy breeds. Thus, Friesians (a milk breed) have a high proportion of fat in the body cavity, and low proportion in the subcutaneous fatty tissue. In Herefords (a beef breed), on the other hand, the situation is reversed. The distribution of fat in Shorthorns (a dual-purpose breed) is intermediate between that of Herefords and Friesians. In the United Kingdom about 65 per cent of home-killed beef is derived from dairy herds.

There are, of course, many other modern breeds representative of \textit{B. taurus}, for example the Simmentals in Switzerland, the ‘Wagyu’ in Japan, the Charollais in France; and, in warmer areas, \textit{B. indicus} is widely represented. Attempts have been made to cross various breeds of \textit{B. indicus} (Indian Hissar – ‘Zebu’ – cattle have been frequently involved) with British breeds, to combine the heat-resisting properties of the former with the meat-producing characteristics of the latter. Such experiments have been carried out for example in Texas and Queensland. A fairly successful hybrid, the Santa Gertrudis, consists of three-eighths ‘Zebu’ and five-eighths Shorthorn stock.

Unusual types of cattle are occasionally found within a normal breed. Thus, dwarf ‘Snorter’ cattle occur within various breeds in the USA; and pronounced muscular hypertrophy, which is often more noticeable in the hind quarters and explains the name ‘doppelender’ given to the condition, arises in several breeds – e.g. Charollais and South Devon (McKeller, 1960). Recessive genes are thought to be responsible in both cases.

### 1.2.3 Pigs

The present species of domesticated pigs are descendants of a species-group of wild pigs, of which the European representative is \textit{Sus scrofa} and the eastern Asiatic representative \textit{S. vittatus}, the banded pig (Zeuner, 1963). As in the case of cattle, pigs were not domesticated before the permanent settlements of Neolithic agriculture. There is definite evidence for their domesticity by about 2500 \text{bc} in what is now Hungary, and in Troy. Although pigs are represented on pottery found in Jericho and Egypt, dating from earlier periods, these were wild varieties. The animal had become of considerable importance for meat by Greco-Roman times, when hams were salted and smoked and sausages manufactured.

About 180 years ago European pigs began to change as they were crossed with imported Chinese animals derived from the \textit{S. vittatus} species.

These pigs had short, fine-boned legs and a drooping back. Then in 1830, Neapolitan pigs, which had better backs and hams, were introduced. According to McConnell (1902) it was customary in the past to classify British pigs by their colour – white, brown and black – and the older writers mention 30 breeds. Few of these are now represented.

The improvement of pigs has not been continuous in one direction, but has been related to changing requirements at different periods. Of the improved breeds of pig now in use in the world the majority originated in British stock (Davidson, 1953). The first breed to be brought to a high standard was the Berkshire: it is said to produce more desirably shaped and sized \textit{l. dorsi} muscles than any other breed. Berkshire pigs, crossed with the Warren County breed of the USA, helped to establish the Poland China in that country a century ago. The change of type which can be swiftly effected within a breed is well exemplified by the Poland China, which
altered over only 12 years from a heavy, lard type to a bacon pig (Fig. 1.3: Hammond, 1932b). Berkshire pigs have also been employed to upgrade local breeds in Germany, Poland and Japan.

In Britain about 70 per cent of the pigs slaughtered are produced from F1 hybrids of Large White x Landrace. The predominant sire type used is the Large White, with an increasing use of 'meat type' sires produced by the major pig breeding companies. When considering pedigree breeds, the Large White is the most numerous in the United Kingdom (Table 1.4).

In recent years Landrace pigs from Scandinavia have strongly competed with them as bacon producers. The Landrace was the first breed to be improved

![Fig. 1.3](image)

**Fig. 1.3** The effect of intensive selection over 12 years on the conformation of the Poland China pig in changing from a lard to a bacon type (Hammond, 1932b): (a) 1895–1912, (b) 1913, (c) 1915, (d) 1917, (e) 1923. (Courtesy of the late Sir John Hammond.)
scientifically. In Denmark, these animals have been intensively selected for leanness, carcass length and food-conversion efficiency with a view to the production of Wiltshire bacon. Pigs of 200 lb (100 kg) live weight, irrespective of breed, have been used for pork, bacon or manufacturing purposes in Denmark, according to the conformation and level of fatness (Hammond, 1963b). In Hungary, there is a meat pig (the Mangalitsa) which is particularly useful for making salami, partly because it has a rather highly pigmented flesh.

### 1.3 Current trends and developments

The increasing pressure of world population, and the need to raise living standards, has made the production of more and better meat, and its more effective preservation, an important issue. Thus, progeny testing, based on carcass measurement, is being increasingly recognized as an efficient way of hastening the evolution of animals having those body proportions which are most desirable for the meat consumer. It has been applied especially to pigs (Harrington, 1962); but progeny testing of both cattle and sheep is developing. Artificial insemination has afforded a means of vastly increasing the number of progeny which can be sired by a given animal having desired characteristics. In the future, it may well be that young bulls of under 15 months will increasingly replace steers of this age since they produce the lean flesh which is now in demand in greater quantities – and more economically. The somewhat higher incidence of ‘dark-cutting’ beef in bulls is probably a reflection of their stress susceptibility (cf. §5.1.2) and can be overcome by careful handling. During recent decades, and especially since the report on the relationship between diet and cardiovascular disease by the Committee on Medical Aspects of Food Policy (1984), there has been a marked reduction in the percentage of saturated fat derived from meat. The fat content of beef, pork and lamb has fallen from 20–26 per cent to 4–8 per cent (Higgs, 2000). This has been achieved not only by selective breeding for leanness (aided by the development of carcass classification schemes by the Meat & Livestock Commission (UK)), but also by changed methods of butchery applied to the hot carcass, whereby not only is backfat removed, but also inter-

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**Table 1.4** Relative numbers of pigs of various breeds in the United Kingdom (based on 1995 data supplied by G. E. Welsh, Chief Executive, British Pig Association)

<table>
<thead>
<tr>
<th>Breed</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large White</td>
<td>49.5</td>
</tr>
<tr>
<td>Landrace</td>
<td>35.5</td>
</tr>
<tr>
<td>Welsh</td>
<td>4.5</td>
</tr>
<tr>
<td>British Saddleback</td>
<td>2.0</td>
</tr>
<tr>
<td>Gloucester Old Spot</td>
<td>2.5</td>
</tr>
<tr>
<td>Berkshire</td>
<td>2.0</td>
</tr>
<tr>
<td>Tamworth</td>
<td>1.5</td>
</tr>
<tr>
<td>Middle White</td>
<td>1.0</td>
</tr>
<tr>
<td>Large Black</td>
<td>1.0</td>
</tr>
<tr>
<td>Others</td>
<td>0.5</td>
</tr>
</tbody>
</table>
muscular fat by ‘seaming out’ the muscles (cf. §§ 5.2.2 and 7.1.1.3). This trend has been strengthened by the increasing sale of meat as consumer-portion, prepackaged cuts. For this purpose the larger continental breeds have certain advantages over traditional British beef animals. Such breeds as Limousin, Charollais and Chianina produce leaner carcasses at traditional slaughter weights; and attain these weights faster. There are occasionally reproductive problems; but these can be controlled by improved management (Allen, 1974). There has been a tendency towards the consumption of lamb in recent years, since it is more tender than mutton and produces the small joints now in demand. To some extent the increased costs which this trend entails have been offset by increasing the fertility of the ewe and thus the number of lambs born. The Dorset Horn ewe breeds throughout the year; but ewes of other breeds are being made to breed with increased frequency by hormone injections which make them more responsive to mating with the rams (Hammond, 1963b). The goat, being able to thrive in poor country, may well be developed more intensively. Public pressure to reduce the use of pesticides in crops has led to the development of so-called ‘organic’ farming, in which no ‘artificial’ additives are employed to assist the growth of plants and animals. Nevertheless, this approach is not ideal. Thus, ‘organically’ reared pigs show no organoleptic benefits over those reared conventionally, and, indeed, in some respects, compare unfavourably with the latter (Ollson et al., 2003).

Increasing attention is being directed to the potential of hitherto unexploited animals for meat production. Berg and Butterfield (1975), in studying the muscle/weight distribution in a number of novel species, noted that those which were more agile had greater muscle development in the fore limbs; in mobile species the musculature of all limbs was highly developed. In the elephant seal, the abdominal muscles are especially involved in locomotion, and their relative development is about threefold that of corresponding muscles in cattle, sheep or pigs.

In large areas, such as Central Africa, where the more familiar European types of domestic animal do not thrive well, there are a number of indigenous species in game reserves, well adapted to the environment, which could be readily used for meat production, e.g. the giraffe, roan antelope and springbok (Bigalke, 1964). Satisfactory canned meats can be prepared from the wildebeest antelope, if it is processed on the day of slaughter (Wismer Pedersen, 1969a). The meat may become pale and watery if the animals are not killed by the first shot. Of the East African ungulates the meat quality of wildebeest, buffalo and zebra is probably the most acceptable organoleptically. Onyango et al. (1998), in a comparative study of game as meat in Kenya, found that the lipids of zebra were markedly more unsaturated than those of beef. Combined with its high content of myoglobin, this causes zebra meat to undergo rapid oxidative deterioration under aerobic conditions.

As game farming has developed in South Africa, there has been increasing interest in the impala as a meat animal. They feed well on the bushveld and are able to consume the foliage of both trees and bushes. Their flesh has low levels of intermuscular and intramuscular fat and has a high titre of polyunsaturated fatty acids (Hoffman et al., 2005).

The water buffalo is a species which shows considerable promise. The world population of buffalo is already one-ninth of that of cattle; in the Amazon basin they are increasing at 10 per cent per year (Ross Cockrill, 1975). The eating quality of the meat is similar to that of beef (Jocsimovic, 1969); and, indeed, may be preferred.
in some areas. Having less fat, the flesh of the water buffalo conforms to current
trends. On the other hand the flesh has more connective tissue, and is darker, fea-
tures which tend to make it compare less favourably with beef (Robertson et al.,
1986). It thrives in the wet tropics – an extensive area which European cattle find
distressing. The eland antelope shows particular promise for development in Africa.
For example, it has behavioural and physiological characteristics which enables it
to survive even when no drinking water is available and temperatures are high. It
feeds mainly at night when the bushes and shrubs have a tenfold higher water
content than in day-time (Tayler, 1968).

Such species as oryx can withstand body temperatures of 45 °C for short periods
by a specialized blood flow whereby the brain is kept relatively cool (Tayler, 1969).
The meat of the oryx has a lower myoglobin content than that of beef, but it is more
susceptible to the formation of metmyoglobin (Onyango et al., 1998).

In those parts of Africa where drought conditions prevail, the one-humped camel
(dromedary) thrives much better than cattle: it constitutes an important source of
meat in arid regions. The proportion of edible meat on the camel carcass is compa-
rable with that of cattle, red muscles contributing ca. 60 per cent of the overall yield
(Babiker, 1984). Most of the joints are devoid of fat: the exception is the sirloin
because it includes the hump. Most of the camel’s fat is deposited in the hump rather
than being distributed throughout the carcass (Yousif and Babiker, 1989). The meat
of young camels is comparable in taste and texture to that of beef (Knoess, 1977),
but, not surprisingly, that of those which have been slaughtered after a working life
as draught animals is tough.

Since cattle eat grasses wherein the proportion of lignin in the stem is below a
certain maximum and eland prefer to eat the leaves of bushes, there are advantages
in mixed stocking (Kyle, 1972). Indeed a surprising number of species can subsist in
the same area, without encroaching upon one another’s feed requirements, by eating
different species of plant, or different parts of the same species of plant, and by
feeding at different heights above the ground (Lamprey, 1963).

In Scotland there is interest in the development of the red deer as an alternative
meat producer to sheep in areas where cattle rearing or agriculture is not feasible.
It has been shown that, when fed on concentrates after weaning, stags can achieve
feed conversion efficiencies better than 3 lb (1.4 kg) feed dry matter per pound
(kilogram) of gain (Blaxter, 1971–2). This conversion rate is better than that
achieved with cattle or intensive lamb production.

In New Zealand, the introduction of deer for sport led to serious denudation of
plant species; and culling was thus undertaken, using helicopters to reach otherwise
inaccessible areas. Thereafter the development of an export trade in venison, and
an even more profitable one in velvet from the antlers of stags, has stimulated inter-
est in the controlled production of deer. Half of the world’s farmed deer popula-
tion is now found in New Zealand (Wiklund et al., 2001), and this has greatly
increased interest in the red deer as meat. Live deer are now being captured from
the air, immobilization (prior to aerial transport) being effected by firing tranquil-
lizing darts, or pairs of electrodes (for anaesthetization), into the animals. Because
derer and goats are naturally lean species, procedures are being sought to reduce
their fat content even further by selection since there is currently a demand for lean
meat. For both species, a wide range of breed sizes are available, making this objec-
tive relatively easy (Yerex and Spiers, 1987). In Scandinavia the meat of the rein-
deer is eaten. It is a relatively small animal and its reputed tenderness may well be
a function of the correspondingly small diameter of the muscle fibres (Keissling and Keissling, 1984).

In the period 1965–85 world goat numbers increased by 30 per cent, particularly in developing countries such as Africa. Because of their early sexual maturity and the relative shortness of their gestation period, goats are a valuable species in situations where herd numbers require to be rapidly built up after drought (Norman, 1991). Moreover, because goats have low per head feed requirements, they are able to utilize marginal grazing land and small plots on which larger ruminants could not thrive. Yet goat meat accounts for only ca. 1.5 per cent of total world meat production. It is true, of course, that goat meat tends to be less desirable in flavour and tenderness than beef, lamb and pork when samples of comparable maturity and fatness are considered (Smith et al., 1974); but the acceptability of the meat of any species is often determined by local custom. At a time when populations are increasingly moving from rural areas into cities in developing countries, further use of a species which can quickly respond to intensification and to fluctuations in demand would seem desirable (Norman, 1991).

A more general interest in the exploitation of non-mammalian species for meat is reflected by the increasing availability of flesh from the crocodile, the emu and the ostrich. Meat from the ostrich is derived mainly from the muscles of the well-developed legs. It has a relatively high myoglobin content, resembling beef or mutton rather than pork or poultry. Since it has relatively less cholesterol and total lipid, and a higher content of polyunsaturated fatty acids, than beef (Paleari et al., 1998), whilst its tenderness is greater than that of the latter, its consumption could well become more popular. Although the ostrich has been farmed for many years in South Africa, primarily for its hide and plumage, the species has been introduced into other countries wherein the meat of the ostrich is now available to the public.

Currently there is increasing concern – whether soundly based or unfounded – expressed by consumers respecting the safety of meat (e.g. chemical residues, allergens, microbial and parasitic hazards) and increasing selectivity in the demand for palatability (e.g. guaranteed and reproducible levels of eating quality attributes) (Tarrant, 1998). Improved methods of preservation (e.g. refrigeration, high pressure) are being devised and authoritative assurances on the safety of meat subjected to low levels of ionizing radiation, in combination with chilling, predict its renewed importance.

Techniques for identifying the molecular morphologies that are essential for generating the attributes of eating quality in meat (and knowledge of the means of controlling their expression, once identified) are developing rapidly. Genetic manipulation of the live animal, to eliminate undesirable features in its meat and to incorporate those which are desirable, is now a reality (de Vries et al., 1998).

In studying biological systems it has hitherto been necessary to isolate their components and, therefrom, to deduce the nature of the systems from which they were derived; but it has long been appreciated that these systems are exceedingly complex and highly organized and, that from their components in isolation, only limited information can be obtained about their interactions in vivo. Recently, however, techniques such as two-dimensional electrophoresis have made it possible to obtain patterns that show all the representatives of groups such as genes, nucleic acids, proteins and functional metabolites simultaneously. Concomitantly, the rapid growth of computing science has afforded the means of distinguishing and classifying the
patterns obtained whereby they can be related to specific tissues and, in the case of muscle, to organoleptic properties of the meat postmortem. (Eggen and Hocquette, 2003) The potential of proteomics (‘panoramic protein characterization’) has been reviewed by Bendixen (2005) and its value in accurately understanding and controlling organoleptic properties has already been established.

Such developments demonstrate that meat continues to be a significant commodity for the human consumer.