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Introduction – The Dairy Cow of Today

Understanding the dairy cow is a matter of heart and mind. We need to consider her scientifically as a complex and elegant biological instrument to provide us with milk, the nearest thing in nature to a complete food. Equally, we need to recognise her as a sentient (and highly engaging) creature who deserves a reasonable quality of life and, at the end, a gentle death. In both senses of the word this understanding is not static. The more we study the workings of the dairy cow, the more we can exploit her capacity to produce food for human consumption from milk, butter, yoghurt and a dazzling variety of cheeses. The more we study her health, behavioural and environmental requirements, the better we can ensure her welfare.

The cow was one of the first animals to be domesticated for human use and has come a very long way since then. The traditional role of the family cow was to provide milk, work, fertiliser, fuel, clothing and the occasional fatted calf, while sustained by fibrous feeds that the family could not digest for themselves, usually from land that the family did not own. The modern dairy cow, typified by the Holstein breed, is a very different creature: bred, fed and managed to produce as much milk as possible within intensive, highly mechanised dairy units. Meat production has become a relatively minor consideration, with calves destined for beef or veal sent, more often than not, off farm to other specialist rearing units. Other roles for the milch cow have disappeared altogether. The modern Holstein is most unlikely to be harnessed to a plough! Most of this change has taken place in the last 80 years since the industrialisation and mechanisation of agriculture made it more convenient to bring the feed to the cows than expect them to forage for themselves on a year-round basis. This has had a profound effect on the types of cow that we have bred to suit our current purpose. Consider the four pictures in Figure 1.1. All illustrate top quality cows from breeds in use today. The Dairy Shorthorn (Figure 1.1a), now something of a rare breed, has the traditional, functional shape of a dual-purpose cow bred to produce milk and beef, primarily from grazed and conserved pasture. In the second half of the 20th Century this breed was largely replaced in the UK by the British Friesian (Figure 1.1b), which, when managed essentially within a pastoral system but given more concentrate, was able to produce more income from the sale of milk (with beef

Understanding the Dairy Cow, Third Edition. John Webster.

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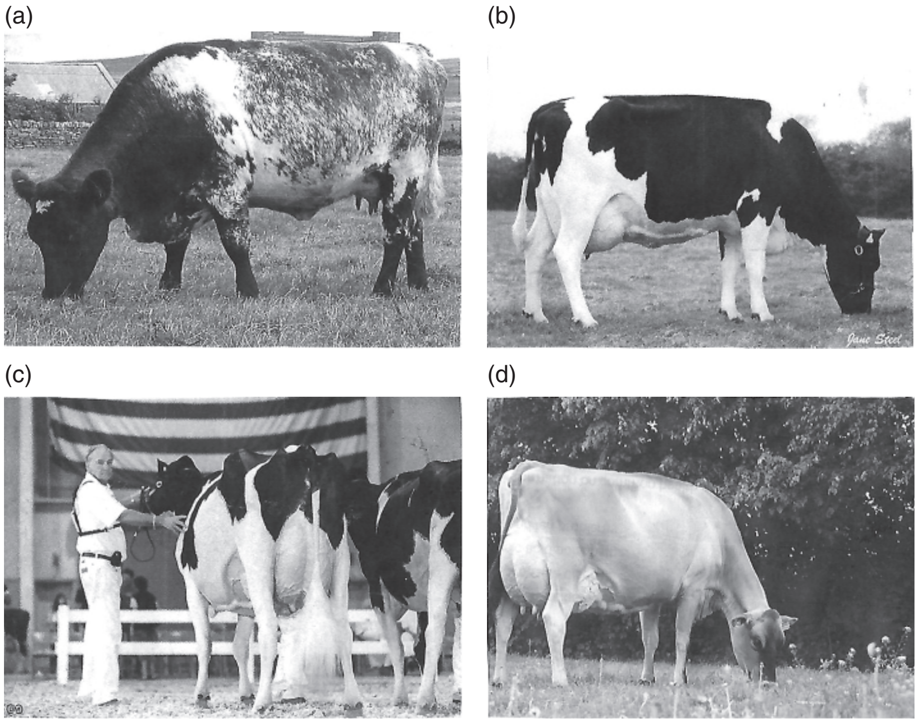

Figure 1.1 Shapes of dairy cows. (a) Dairy Shorthorn, (b) British Friesian, (c) American Holstein, (d) Jersey.

as a good secondary enterprise). The two cows are rather similar in appearance (phenotype). Both have deep bodies, containing a large rumen able to digest large quantities of forage. Both also carry a substantial amount of muscle (and fat when well fed) which enables them to sustain health and production at times when the quantity and quality of feed may be in relatively short supply. This trait is, obviously, consistent with the potential to produce good beef. These two breeds may be said to be at the dairy-type end of dual-purpose (milk and beef) cows.

The modern Holstein, however, is a very different creature (Figure 1.1c). Not only does she have a conspicuously larger udder, she is bigger framed, much more rhomboid in shape and carries much less muscle. This phenotype is the consequence of a breeding policy designed to ensure the production of as much milk as possible from individual cows spending most of their adult life in barns on a diet of rich feed. The fourth picture is of a Jersey cow (Figure 1.1d), much smaller and daintier than the Holstein, but essentially similar in shape and conformation. These breeds are both examples of the extreme dairy type.

This book will explore our understanding of the physiology, behaviour, feeding and breeding of the modern dairy cow mostly within the context of specialist, intensive systems of dairy production. There are several good textbooks on dairy farming (see section on Further Reading) and the information given in these is constantly augmented and brought up to date by booklets from the advisory services: in the UK, the Agricultural Development and Advisory Service (ADAS), the Milk Marketing Board

(MMB) and a number of private enterprises (e.g. GENUS, etc.). This book is not intended to compete with these excellent sources of information but to complement them. It is intended for those who wish to enrich their concern for the dairy cow with better understanding based on sound evidence. It is primarily addressed to students in agriculture and veterinary science but will, I hope, be of interest and value to farmers, stockpersons (herders), those supporting the dairy industry as feed advisors and in other agricultural support trades; also for those with no direct contact with the dairy industry but that have real concerns for the welfare of farm animals and the environment.

If we wish to achieve this better understanding, we have no option but to take a deep breath and plunge into the principles of nutrition, physiology, genetics, animal health and behaviour. This poses a different set of problems. Most textbooks and scientific papers that deal with the workings of the cow, i.e. the physiology of digestion, reproduction, lactation etc. are written by scientists (such as myself) who have spent most or all their working lives in academic research. They tend to carry a degree of complexity that may be necessary for those directly involved in agriculture or veterinary science, but which are prone to tell the farmer, student or advisor rather more than they actually want (or need) to know. Publications of this sort that are full of information important to the fundamental scientist may provoke from the farmer, non-specialist student or concerned member of the general public, the question 'gee whiz, but so what?'. They are of interest to the microbiologist, for example to identify the thousands of species of microorganisms that inhabit the rumen and fundamental information of this sort has undoubtedly contributed much to (e.g.) the development of feed additives, and current efforts to restrict production of methane, a significant contributor to climate change. Similarly, they are of interest to the reproductive physiologist to investigate in ever greater depth the cascade of hormones that regulate sexual function and such research has led to major innovations in the practical control of reproduction. However, knowing the names and specific biochemistry of the individual microorganisms in the rumen, or all the specific hormones involved in reproduction, is not really of much practical use to the dairy farmer. My aim in this book is therefore to concentrate on those aspects of cow function in health and disease that are of economic or welfare importance and amenable to improvement through action on the farm. These will be presented in sufficient detail to convey a basic understanding – but no more.

Part I: How the Cow Works deals with the physiology of digestion and metabolism, reproduction and lactation, together with the science of animal behaviour in the context of welfare and adaptation to the environment. True scientists may find this section rather simplistic, although it is undoubtedly more complex that that found in most textbooks of husbandry and management. It assumes no more than a good general knowledge of chemistry and biology and is, I hope, largely self-explanatory. Recommendations for further reading are given at the end of the book.

Parts II–IV deal respectively with feeding, breeding and fertility, housing, and health and welfare. In each case husbandry practices are evaluated critically in the context of the physiology, behaviour and welfare of the cow. This is not an instruction manual that says 'do this, do that'. It assumes that the reader has reasonable practical knowledge of dairy cow management and addresses the question 'when I do this, or if I do this, how will the cow respond?'.

Part V goes beyond simple consideration of how the cow works, behaves and responds to various inputs and management practices to examine important current themes within the broad context of cows, humanity and the living environment. When the first edition of 'Understanding the Dairy Cow' was published in 1987, the objectives of dairy farming for most producers were simple: to produce wholesome milk in large quantities as effectively and efficiently as possible, in the confident assumption that it would all sell at a fair price and the consumer would not ask too many questions. Since then, times have changed. Relatively affluent consumers with far greater access to information, more-or-less supported by evidence, have become much choosier in their food selection and buying habits. Those who continue to buy milk (omnivores and lacto-vegetarians) may select low-fat, lactose-free, or organic options for reasons usually related to anxiety about personal health. Many consumers, including vegans, express concerns about cow welfare and the impact of cattle production on the living environment. These are valid concerns and it is in the interest of both dairy cows and dairy farmers that they are given proper attention. Part V considers environmental issues: environmental challenges and factors relating to sustainability and quality of life in intensive and pastoral systems. It examines what is meant by good husbandry in the context of practical ethics and public opinion then explores how these aims may be achieved through the establishment, validation and promotion of systems that best reconcile the occasionally conflicting demands of biological and economic efficiency with the need to ensure healthy and reasonably happy lives for both the cows and the farmers.

I say again, this is a book about cows. It is not a treatise on dairy farming. The success or otherwise of dairy farming in general and individual systems in particular is heavily influenced by non-biological issues of economics, politics, market forces and fashion. Predictably, these things are unpredictable. However, the yield of nutrients from the land and their conversion by cattle into milk and meat are governed by fundamental, logical and essentially invariant laws of biology. In this book I shall devote little space to the economics of dairy farming because they are so variable and subject to so many factors outside the scope of my argument. The processes that define the biology and behaviour of the dairy cow are complex, and we do not yet fully comprehend any of them, but the more that we who are interested in dairy cows and dairy farming can understand them the better we shall preserve and develop our craft to meet the needs of the age and our long-term responsibilities as custodians of the land and the animals.

Milk as Food

The four essential qualities of a good diet are to:

1) Provide a correct balance of nutrients to meet our metabolic needs at all stages of life
2) Ensure healthy digestion
3) Satisfy taste and appetite
4) Do no harm.

Nutrient Supply

The most important nutrient for all animals is energy. We tend to get more excited by essential but quantitatively minor components of food such as minerals and vitamins but our greatest need by far is for fuel to sustain the fire of life. The energy value of food is measured in joules or calories (1 kcal = 4.2 kJ). This describes the amount of heat liberated when that food is combusted completely in a bomb calorimeter. One gram of wheat, for example, generates about 16.6 kJ of heat on combustion. Animals extract energy from food by the processes of digestion and absorption, use it to meet metabolic needs for maintenance, exercise and synthetic processes like growth and lactation and produce heat in the process. After energy, the principal nutrients required, in decreasing amounts, are amino acids from proteins, minerals and vitamins.

Table 1.1 lists the principal nutrient requirements for an adult doing moderate exercise and a growing four-year-old child, and illustrates the extent to which these can be met from whole milk alone. Table 1.2 illustrates how these requirements would be met if man and boy were to subsist on a daily diet of 500 g of whole milk and breakfast cereal. These tables make some important points that are too frequently overlooked in many popular articles on human nutrition and dietetics. The adult and child require, respectively, 12.6 and 6.4 MJ/day. The adult can meet this need by consuming 800 g cereal plus 60 g of milk solids (total 860 g), the child needs to consume 350 g cereal plus 60 g milk solids (total 410 g). Requirements for protein, the second most important nutrient, are 87 g/day and 56 g/day, i.e. only 10% and 14% of the diet respectively. Absolute daily requirements for minerals and vitamins are much smaller still. In other words, an adult requires about 90% of digestible food as a source of energy (fuel), the child about 85%. The affluent are inclined to

Table 1.1 Contribution of 0.5 L cow's milk per day to the daily nutrient requirements of a four-year-old child and an adult doing moderate work.

	Four-year-old child		Adult	
	Requirement	% from milk	Requirement	% from milk
Energy (kJ)	6400	25	12600	13
Protein (g)	56.0	30	87	20
Calcium (g)	1.0	60	0.8	75
Iron (mg)	7.5	2	12.0	1
Vitamin A (iu)	3000	30	5000	15
Vitamin D (iu)	400	2	–	–
Vitamin C (mg)	15	70	20	50
Vitamin B				
nicotinic acid (mg)	6.0	7	12	3
riboflavin (mg)	0.9	85	1.8	45

Table 1.2 Meeting the energy and protein requirements of an adult and a four-year-old child from a diet of milk and breakfast cereal.

	Adult	Child
Daily requirement: energy (kJ)	12600	6400
Protein (g)	87	56
Energy supplied by milk (60 g solids, kJ)	1600	1600
Energy required from cereal (kJ)	11000	4800
Cereal intake (g/day)	800	350
Protein yield from milk and cereal (g/day)	120	62
Protein balance (g/day)	+33	+6

paranoia about calories but this is because we eat too much. For the hungry, calories are the biggest need by far.

A balanced diet is one in which the nutrients match the specific requirements of the consumer. Humans cannot live on a diet of bread and milk alone (not quite) because it lacks some of the minor nutrients. However, as indicated above, milk and cereal can meet not only energy but also protein requirements, even for growing children. When one looks at the minor nutrients, milk becomes even more impressive (Table 1.1). Relative to its capacity to provide energy, milk is rich in high quality protein, calcium, vitamin A and vitamin C. The nutrients it lacks are iron, vitamin D and some of the B vitamins, e.g. nicotinic acid. In practice this only constitutes a problem for animals such as veal calves reared on milk alone. As a food for human consumption therefore, cow's milk is rich in almost all the nutrients essential for life, especially essential nutrients such as high-quality protein (well balanced with respect to essential amino acids), calcium and vitamin A, so can provide an excellent balancer for low-cost, high energy foods such as cereals.

Healthy Digestion

Most people who drink milk on a regular basis can digest it without difficulty. Some individuals can suffer the consequences of lactose intolerance manifest by abdominal pain, bloating and diarrhoea. This is caused by a deficiency in the enzyme *lactase* that divides the disaccharide, lactose into its constituent monosaccharides, glucose and lactose. All healthy mammals must have lactase at birth to digest their mother's milk. If, after weaning, they drink no more milk the lactase enzyme is down-regulated so that if they suddenly consume milk as adults, they may experience discomfort. The real prevalence of lactose intolerance is difficult to gauge, being confounded by individual differences in severity of symptoms, real and imagined. It is certain that the prevalence of lactose intolerance is much higher some Asian and African communities than in Western communities accustomed to consuming dairy products throughout life. What is not certain is the extent to which this is genetic or environmental (i.e. no milk after weaning). In my youth, I was taught that the reason Chinese and other oriental races were unable to tolerate milk was genetic. This is clearly not the whole story. With increasing affluence, the Chinese have developed a taste for milk products and lactose intolerance does not appear to be a major problem. Maybe they just worry less. Those for whom lactose intolerance is real can, of course, buy lactose-free milk.

Taste and Appetite

Milk is the basis for a wide range of highly attractive products: butter, cream, ice cream, yoghurt and an amazing array of cheeses, to appeal to the palate of the consumer and increase the value of milk to the producer (and especially the middle-man). To these we may add products such as spreadable butter and anti-cholesterol spreads in which milk products are mixed with vegetable oils. There has been some interest among animal scientists (if no one else) in manipulating the nutrition or genetics of cows to produce healthier milk, e.g. richer in omega 3 fatty acids. This seems to me to be a pointless exercise. The versatility of milk (as distinct from meat) derives from the fact that so many tasty (and healthy) things can be done to it after it leaves the cow. As to concerns about appetite, we do have a problem. Milk products, butter, cheese, ice cream, are just too nice.

Do no Harm

For many years our main concerns about milk and health were driven by medical claims of associations between the consumption of animal fats and ill-health, especially obesity, cardiovascular diseases (CVDs), and to a lesser extent, cancers. Animal products containing significant amounts of fats can undoubtedly contribute to obesity, because fats are energy rich and these products are tasty. Moreover, obesity is a confirmed risk factor for many cancers. The problem here is one of quantity, not quality. There is good evidence that increasing the ratio of unsaturated to saturated fatty acids in the diet reduces the risk of CVD. The composition of milk fat is approximately 60% saturated, 30% monounsaturated, 10% polyunsaturated. In oily fish such as trout, the composition is 30% saturated, 40% monounsaturated, 30% polyunsaturated. We must conclude that for those at risk of CVD, it is wise to reduce the amount of saturated fat in the diet. However, new evidence makes it even more clear that those who select low fat diets and, in compensation, increase their sugar intake are putting themselves at greater risk of obesity and diabetes.

There are some differences between the composition of the milk protein casein in cows and humans that may have consequences for human health. There are, in fact, several milk caseins, as-1, as-2, β and K casein. Beta casein exists in two forms, A1 and A2 beta casein. Most Holstein and Friesian cows secrete A1 and A2 in roughly equal proportion. Some cattle, most notably Guernseys (and most goats) secrete milk that is about 80% A2, which is similar to human milk. There are some claims that A2 casein may be healthier, although this has not yet been substantiated by meta-analysis. There is no evidence to suggest a link between differences in A1:A2 ratios and milk allergies. However, if there was significant evidence of health benefit from the consumption of A2 milk, it would be possible to select from the high A2 cows within the Holstein breed.

Biological Efficiency of Milk Production

The primary source of energy for all food production is, of course, the Sun. The theoretical maximum efficiency of capture of solar energy by plants is about 3%. Actual efficiencies of capture by plants range from about, 0.3 to 0.7%. These efficiencies are very low but that is not too serious a problem as solar energy is plentiful and will be around for a very long time. Grasslands (a collective term to include clovers and other grazed herbs) are potentially the most efficient of the feed crops because they can be grazed and cropped many times per year and the whole crop gets eaten.

Food production from animals is inevitably less efficient than that from plants because much of the food eaten by animals is required to meet their own needs. Animals consume feeds from a variety of sources. Figure 1.2 illustrates very simply a typical cow diet consisting mainly of forage, cereal and a protein supplement, soya. In ruminants, the two-stage processes of digestion in the rumen and downstream

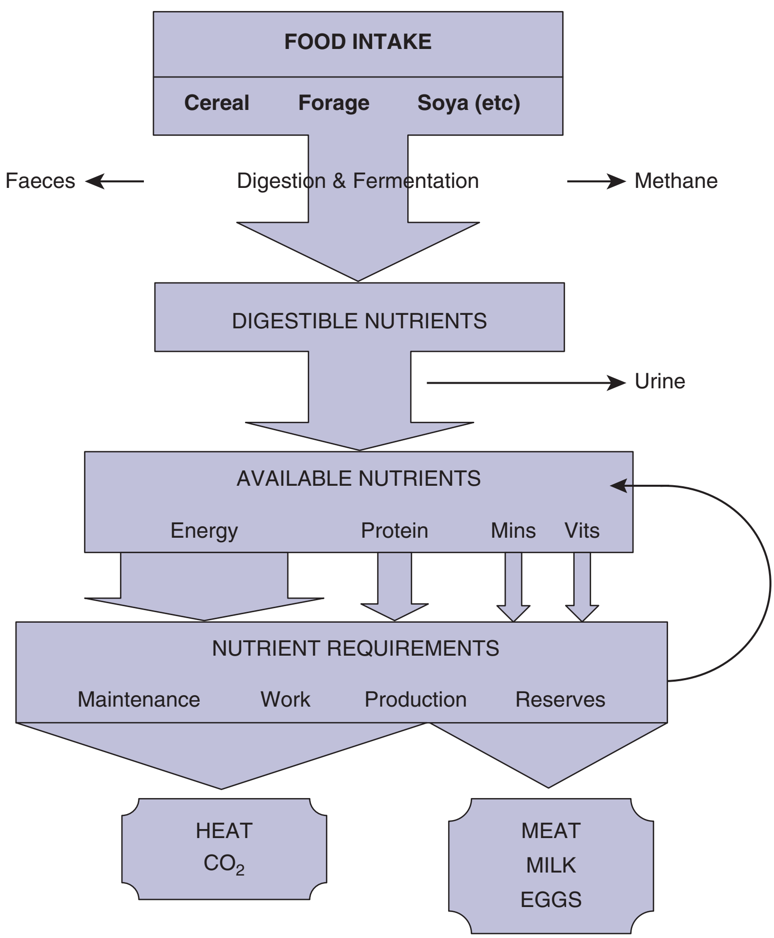

Figure 1.2 Nutrient supply and requirement (from Webster 2013).

yield digestible nutrients after losses as faeces and methane (see Chapter 2). The metabolism of digestible nutrients to meet specific demands for available nutrients to meet maintenance and production needs incurs further losses in the urine (especially nitrogen).

The amount of available energy is termed metabolizable energy (ME) usually measured in MJ where:

> Metabolizable energy (MJ) = gross energy of feed – energy in faeces, urine and methane.

The primary need for available nutrients is to support maintenance, the energy and materials needed to support life in an animal neither gaining nor losing body weight. Feed consumed in amounts greater than maintenance requirement is available for conversion into animal products (milk, meat and eggs). At maintenance, nearly all nutrients are used to provide ME and oxidised to produce heat and CO_2. For the farm animal reared to produce milk, eggs or meat, the requirements for protein, minerals and vitamins increase in relation to energy in proportion to the level of production, usually expressed in relation to maintenance. At the maintenance level of feeding the *gross* efficiency of conversion of animal feed into animal product (food for humans) is zero. The greater the capacity of a farm animal to ingest, digest and metabolizable feed into the synthesis of milk, eggs or meat, relative to the demands of maintenance, the greater will be the overall biological efficiency of production. All other things being equal, it follows that the way to maximise the biological efficiency of a dairy enterprise will be to breed and feed individual cows to produce as much milk as possible. However, as we shall see, all other things are not equal.

Milk Production: Species and Breed Comparisons

Table 1.3 compares the yields and composition of milk from Holstein and Jersey cows, a sow giving birth to fourteen piglets, a Labrador bitch with eight puppies and a human mother with one child. The figures for cows have changed substantially since the previous edition was published in 1993. Then I gave the example of a typical Friesian cow giving 31 L/day. The figure for a typical Holstein of today in an intensive unit is 60 L. The classic approach to making comparisons between species differing greatly in size is to express inputs and outputs in terms of 'metabolic body size', body weight to the power 0.75 (W $kg^{0.75}$). This exponent of body weight is universally accepted as that which confers proportionality on measurements of energy exchanges. In more simple language, the maintenance requirements of homeotherms for energy, when expressed per $kg^{0.75}$ are, as a first approximation, the same.

There are interesting differences between species in milk composition. The milk of sows and bitches is especially rich in nutrients. This reflects the fact that they give birth to large litters of small, immature offspring who need to grow quickly. Human milk is low in protein and fat, high in lactose. While human babies are extremely immature at birth compared with (say) a calf, they grow slowly. In the

Table 1.3 Yield and composition of milk from different mammals.

	Holstein cow	Jersey cow	Sow	Bitch	Woman
Body weight (kg)	700	420	240	26	60
Metabolic weight ($kg^{0.75}$)	135	93	60	11.5	21.5
Number of offspring	1	1	14	8	1
Peak milk yield (L)	60	35	8.5	1.3	1.0
Composition of milk (g/L)					
Protein	33	37	60	83	12
Fat	37	49	83	97	38
Lactose	45	46	52	41	70
Calcium	1.2	1.4	2.7	3.0	0.3
Phosphorus	0.9	1.0	1.6	2.0	0.2
Nutrient yield ($kg^{0.75}$/day)					
Energy (kJ)	1300	1180	770	715	132
Protein (g)	11.0	12.5	8.4	9.4	0.6

second edition (1993) I calculated the milk energy yield of the Friesian cow producing 31 L milk/day to be 745 kJ/$kg^{0.75}$ per day, not significantly different from that of the sow or bitch. Today it has risen to 1300 kJ/$kg^{0.75}$ per day. At that time, I wrote that the peak metabolic demands of lactation for the dairy cow were not significantly greater than for the sow, or bitch and that the stress of lactation was related more to the duration – nine months at least as against eight weeks or less. Today the physiological demands on the high yielding dairy cow are in a class of their own. I shall have much more to say about the metabolic and welfare implications of this in later chapters.

Efficiency of Feed Conversion to Milk, Eggs and Meat: Competitive and Complementary Feeds

Milk and egg production appeal to vegetarians and to thrifty souls like myself because they do not involve killing the animal to get at the food. Moreover, milk and (unfertilised) eggs are not bits of animals, they are simply foods of the highest nutritional value: the former to feed the growing calf from the time of its birth, the latter to feed the fertilised embryo up to the time of hatching. Table 1.4 compares the efficiency of conversion of feed energy (ME) and protein into hens' eggs, cows' milk, pork meat from the offspring of sows giving birth to 22 piglets/year and beef from extensively reared cow-calf systems where the contribution of the breeding beef cow is but one calf/year plus her own carcass at eventual slaughter.

Table 1.4 Efficiency of energy and protein conversion in meat, milk and egg production (from Webster 2013). For each system, efficiency is described by the ratio of output to input, where output is defined by energy and protein in food for humans; inputs are described in terms of total and 'competitive' intake of ME and protein, where 'competitive' describes energy and protein from feed sources that could be fed directly to humans.

	Eggs	Pork	Milk	Beef
Production unit	1 hen	22 pigs	1 cow	1 calf
Support unit	0.05 hens	1 sow	0.33 heifers	1 cow
Output/year (kg food)	15	1300	8000	200
MJ food energy	130	13000	28000	2500
kg protein	1.65	208	264	32
Input/year (MJ ME in total)	389	67038	67089	29850
MJ 'competitive' ME	351	53630	20127	10268
Input/year (kg protein in total)	5.2	818	946	361
kg 'competitive' protein	5.0	736	236	108
Efficiency				
Food energy/total feed ME	0.33	0.19	0.42	0.08
Food energy/'competitive' feed ME	0.35	0.24	1.39	0.24
Food protein/total feed protein	0.32	0.25	0.28	0.09
Food protein/'competitive' feed protein	0.33	0.28	1.12	0.30

In each column the efficiency of conversion of feed energy and protein is expressed in two ways:

- Overall efficiency: food energy and protein (for human consumption) relative to total feed energy and protein consumed by the animals (both the breeding and slaughter generations).
- Competitive efficiency: food energy and protein (for human consumption) relative to animal consumption of ME and protein from 'competitive' feed sources (e.g. feeds such as cereals that could have been fed directly to humans) as distinct from 'complementary' feeds (grazing, forages and by-products remaining after preparation of food and drink for human consumption (e.g. maize gluten, brewers' grains).

The *overall efficiencies* of ME conversion into eggs, pork, milk and beef are 0.33, 0.19, 0.42 and 0.08 respectively; for protein conversion they are 0.32, 0.25, 0.28 and 0.09. The reason why the efficiency of energy conversion to milk is greater than that for egg production can be attributed to the fact that there has, to date, been no limit to the ability of breeders to select cows to produce more and more milk per day, whereas hens are still restricted to the production of one egg per day. Both milk and egg production are more efficient than the intensive production of pork meat: beef production (by these measures) fails to achieve an efficiency of 10%.

When energy conversion is examined in terms of *competitive efficiency* the picture changes. Here beef becomes as efficient as pork (or no less inefficient) and dairy farming becomes very efficient indeed. In this example, based on a typical diet fed to the cows amongst whom I live in the pasture-rich South West of England approximately 65% ME is complementary and the output of food energy for human consumption is 39% greater than their demand for feed that we could eat ourselves. This impressive performance is not necessarily restricted to pasture-based systems. High competitive efficiencies can be achieved in fully housed systems though proper selection of complementary feeds.

Table 1.4 provides a powerful illustration of the danger of leaping to simplistic conclusions as to the profligacy of feeding our limited resources to farm animals. Even within these limited parameters of feed conversion, there is no simple answer. When other factors such as environmental sustainability, fuel costs, pollution, animal welfare and ethics are taken into account, our view of what's best becomes decidedly fuzzy.

Behaviour and Welfare

Cows are sentient animals. By my definition this means that they have 'feelings that matter'. They are motivated to behave in ways intended to meet their emotional need to seek satisfaction and avoid suffering. Many of these emotions are primitive, such as hunger, thirst, pain and fear. However, there is now convincing evidence that cows, in common with other farm animals, can experience (and are motivated by) 'higher' sensations within the spectra of confidence–anxiety, hope–depression, pleasure–grief. The sentient animal can interpret its physical and emotional state when under challenge, choose an action within the range of options available to its phenotype and remember how effective it was. Its memory of the success or otherwise of its response will affect how it feels when next presented with a similar challenge. If it learns that it can cope it will become less alarmed; it will *habituate*. If it learns that it cannot cope with the stress, or the anticipation of stress, then it is likely to suffer.

Stress and suffering are not the same. Sentient animals are well equipped to respond to environmental challenges (stress) in circumstances that permit them to make an effective response. Animals suffer when they fail to cope (or have extreme difficulty in coping) with stress. This can occur when:

- The stress is too severe, too complex or too prolonged
- The animal is prevented from taking effective action to relieve the stress.

A prime example of the first source of suffering is the dairy cow that fails to cope with the intense, multiple, prolonged physiological demands of lactation. This problem will be considered in depth in subsequent chapters. A classic example of the second is the sow in the extreme confinement of a pregnancy stall.

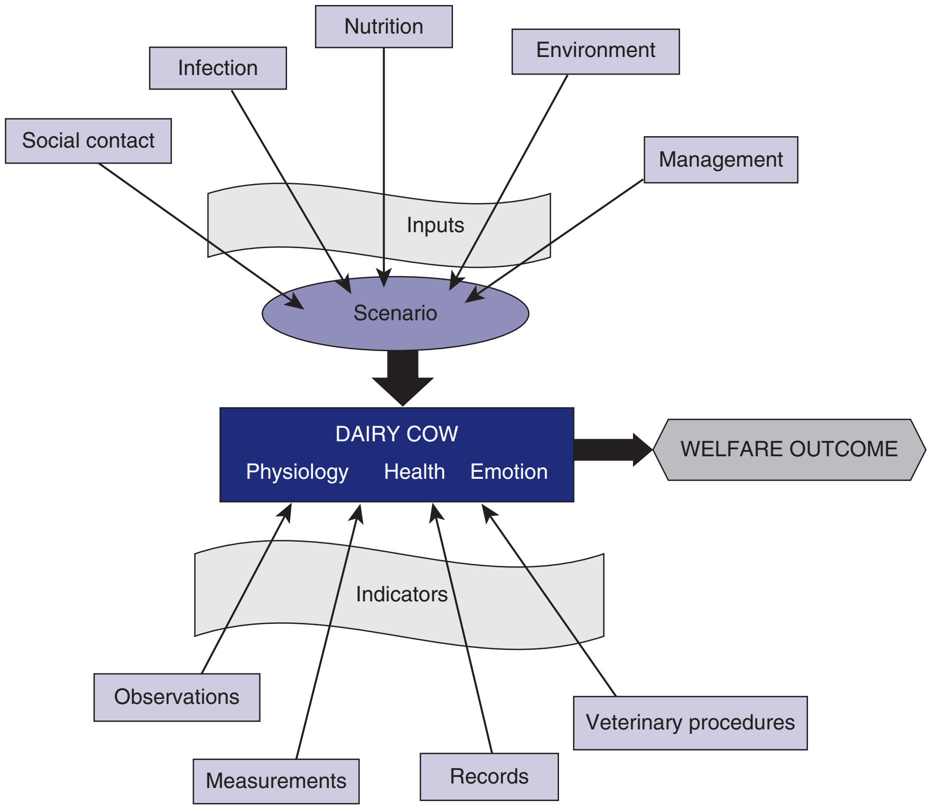

Figure 1.3 Dairy cow welfare and the environment: inputs and indicators.

The welfare of a sentient animal may be considered as an integral measure of its overall emotional state within a range from very good, through satisfactory, to very bad. The owner of any domestic animal, whether farmed or pet, has a responsibility to provide conditions that promote a sense of *wellbeing,* defined by a satisfactory (at least) quality of life considered in terms of the multiplicity of factors that can affect its welfare. This presents us with a problem. Our interpretation of the emotional state of others can only be subjective. Since I can never be sure how they are feeling, I am reluctant to speak with authority on the mental state of the dairy cow. Nevertheless, we have no option but to try. Figure 1.3 illustrates the complexity of the challenges that determine the welfare state of a sentient animal (here a cow) and the indicators by which we attempt to assess it. The inputs are nutrition, the physical environment, management, social contact and the potential for infection and disease. These, together, constitute a scenario that affects its welfare through impact on its physiology, health and emotional state. We can build up a picture of the welfare of individual cows, or the whole herd, by an appropriate choice of indicators. These should include the following, all of which will be considered at greater length.

- Welfare outcomes: observations and measurements of physical state (e.g. body condition, lameness) and emotional state (e.g. abnormal behaviour patterns)

- Husbandry provisions: nutrition, housing, herd health programmes
- Records: fertility, mastitis, lameness control (etc.).

In the minds of the general public, and even some scientists, the biggest welfare problems for farm animals are directly linked to the industrialisation and intensification of livestock farming, mainly because these systems deny them the free expression of natural behaviour. This was highlighted by the publication in 1965 of 'Animal Machines' by Ruth Harrison, that drew public attention to the conditions of pigs, laying hens and veal calves kept in the most extreme conditions of confinement. For these animals, denial of natural behaviour was a paramount cause of bad welfare. The impact of her book led to the establishment of the Brambell Committee (1965), who concluded that all farm animals should be provided with conditions that allowed them, without difficulty, to 'stand up, lie down, turn around, groom themselves and stretch their limbs'. These became known as the 'five freedoms' and were undoubtedly a high priority recommendation for the animals in these extreme systems. However, it should be clear from Figure 1.3 that they left an awful lot out.

In 1963 the UK Farm Animal Welfare Council produced a much more comprehensive set of Five Freedoms and Provisions. These are:

- Freedom from hunger and thirst – achieved by readily accessible fresh water and a diet to maintain full health and vigour.
- Freedom from discomfort – achieved by appropriate shelter with a dry, restful lying area and temperature within an acceptable range of tolerance.
- Freedom from pain, injury and disease – achieved by prevention or rapid diagnosis and treatment.
- Freedom from fear – achieved by conditioning animals to their surroundings and avoiding situations that cause stress.

Table 1.5 Abuses of the five freedoms that can arise through systematic failures in the provision of good husbandry (from Webster 2010).

Hunger	Nutrition fails to meet the metabolic demands of lactation
Chronic discomfort	Poorly designed cubicles, inadequate bedding
Pain and injury	Claw disorders (sole ulcer, white line disease)
	Damaged knees and hocks
	Mastitis
Infectious disease	Mastitis, digital dermatitis
Fear and stress	Rough handling, bullying, separation from calf
Suppressed behaviour	Zero grazing, inadequate rest time
Exhaustion	Emaciation, infertility, forced culling

- Freedom to express normal patterns of behaviour – achieved by the provision of room to move, things to do and the company of their own kind.

These recommendations have stood the test of time. For a start, they are measures of *outcome,* now recognised as the most direct approach to the assessment of animal welfare. They are, moreover, not intended as a counsel of perfection but as a guide to good husbandry: simple enough to be memorable but comprehensive enough to be effective. Four of these five freedoms are freedoms *from:* something that meets with general approval. The final freedom: 'to express normal patterns of behaviour' does arouse some concern. What, for example, is normal behaviour and when does normal behaviour become unacceptable? Isaac Stern expressed this well in a human context by pointing out that your freedom to swing your fist stops at the point of my nose. If I could persuade FAWC to rewrite the fifth freedom, I would reduce it simply to 'freedom of choice'. Applying this principle to a dairy system would imply (e.g.) freedom to select a preferred environment for rest and recreation, freedom to select, and avoid, contact with certain individuals in their social environment.

When we consider the welfare of the dairy cow, it becomes clear that her most severe problems are likely to be associated with physical stresses to her health and physiology, rather than denial of behavioural expression (Table 1.5). Relative to most farm animals she is most unlikely to suffer in consequence of having nothing to do all day. On the contrary she is worked quite extraordinarily hard. The modern dairy cow can cope in the short term with the intense metabolic demands involved in the production of 60 L milk/day (or more), coupled with the demands of consuming and digesting enough food to meet these demands. It is an inescapable fact, however, that too many succumb too soon to the long-term stresses of lactation, in particular, the *production diseases* such as rumen acidosis, ketosis, environmental mastitis and lameness that are, by definition, linked to the methods employed in the breeding, feeding and housing of cows to produce large quantities of milk (i.e. our fault).

Table 1.5 introduces a problem not addressed by the five freedoms, namely that of *exhaustion* arising from failure to cope, in the long term, with the exacting physical demands of lactation. For the dairy cow, exhaustion is probably the biggest problem of all. It describes a cow broken down in body, and possibly in spirit, through a combination of stresses associated with nutrition, housing, hygiene and management, exacerbated in many cases by breeding programmes that have overemphasised productivity at the expense of robust good health. Too many infertile, emaciated or chronically lame cows are culled prematurely because they are no longer making a productive contribution to the enterprise. This is not only an abuse of welfare but also a terrible waste since a dairy cow needs to complete at least four lactations to recoup the cost of rearing her as a heifer until she delivers her first calf and enters the milking herd. We cannot escape the fact that while some welfare problems for dairy cows may arise from bad luck, most may be attributed to systematic failures of provision. Later chapters will look in detail at how the individual production diseases affect the health and welfare of the individual cows, and how these may best be addressed at the herd level through the implementation of a herd health and welfare strategy.