

Assessing the Welfare of Farm Animals – A Review

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Executive Summary – Part 1

As with the treatment of domestic animals in other settings, there is increasing societal concern about the treatment of livestock on farms and their quality of life within production environments. Viable livestock farming requires practices that are not only productive, profitable and sustainable but that also fit with society's expectations on ethical dimensions such as animal welfare. Transparent demonstration of how these expectations have been met will be paramount in the future.

To establish whether an animal's physical and emotional needs are being met requires a detailed assessment of its welfare. Welfare assessment is a major challenge as the utility of any assessment methodology depends on the specific situation under examination and the ethical views held by the stakeholder group seeking the assessment. The purpose of this review is to explore the subject of welfare assessment further by examining the conceptual frameworks, complexities and methodologies applied to the task.

The specific aims of Part 1 of the review are to:

1. undertake a comprehensive analysis of the scientific literature on welfare measures and assessment methods to identify the most credible scientific measures that could be developed into a uniform field index and,
2. recommend where further research to validate welfare concepts and methodologies is required.

The review describes the historical and current contexts of animal welfare and the commonly used conceptual frameworks for its assessment. The broad categories of measures used in science and in welfare assessment and assurance systems used on-farm are then reviewed.

The key conclusions are:

- The pre-eminent concepts of good welfare employed today encompass biological functioning, affective states and naturalness.

- There is ongoing need to demonstrate the validity of welfare measures (i.e. show that measures accurately reflect an animal's welfare state or the definition of a good animal welfare state held by the stakeholder group(s) seeking the assessment .
- Welfare assessment is an evaluative process in which values influence the choice of the conceptual framework and consequently the measures, their interpretation and their weighting when the measures are combined in any legislative standard, QA assessment system, welfare management tool or research methodology.
- A better understanding of the emotional range and valence in livestock species is required, as is a better understanding of the consequences of injury and illness for animal emotions. To that end, the ongoing development and validation of behavioural and cognitive methodologies is essential. This goal could be greatly enhanced through the application of neuroscience disciplines to studies of livestock behaviour and emotions.
- There is no one comprehensive, fully-validated system for on-farm welfare assessment that accommodates the diversity of species, production environments and animal management systems practiced in Australia. However, research has shown that assessments based on combinations of health and production data together with observation of behaviour and physical appearance of animals within a group offer reliable and feasible tools for the assessment of welfare. The strategic combination of input or resource-based and outcome or animal-based measures will also be important, particularly in the context of welfare risk assessment and risk management (e.g. assessments of pasture/forage availability and body condition score in cattle and sheep).
- Efforts should be directed at improving the practicability of welfare assessment systems within the various livestock enterprises. Specifically, further effort is needed to find ways to improve the reliability whilst reducing the complexity and invasiveness of methodologies. The development and application of remote automated data capture systems could be valuable in both extensive and intensive animal production systems.

In conclusion, the development of appropriate welfare assessment methodologies that are credible to all stakeholders will be built on a better understanding of:

- changes in biological functioning and fitness including changes in physical health that correspond with different levels of welfare;
- the capacities of livestock to experience negative and positive mental states and associated levels of welfare;

- the ways that separate measures and welfare attributes can be weighted and integrated to give an overall index of welfare; and
- how these can be practically and reliably implemented in the production environment.

Part 2 of the review describes in detail current welfare assessment schemes and looks at the challenges faced in devising a comprehensive assessment program suitable for cross-sectional application. It proposes a new unified field index for implementation through a process of risk assessment, risk management and benchmarking to provide a welfare management and assessment tool for use across Australia's livestock industries.

1. Scope of the review

Increasing societal interest in the treatment of animals used in livestock production systems has led to recognition of the need for ongoing improvements in animal welfare. Concern about an animal's quality of life is placing an increasing onus on those who husband animals to provide for the animal's physical and emotional needs, and to provide information about husbandry practices to the public. To describe how adequately the needs of animals are met requires a detailed assessment of the animals in their environment. This is a major challenge on a number of levels as the utility of any welfare assessment methodology will depend on the specific situation being assessed and the ethical views held by the stakeholder group seeking the assessment. The purpose of this review is to explore the subject of welfare assessment by examining the conceptual frameworks, complexities and methodologies that are applied to the task of assessing welfare in farm animals.

The review will be presented in two parts. In the Part 1, the specific aims are to:

- (1) undertake a comprehensive review of the scientific literature on welfare measures and assessment methodologies in order to identify the most credible scientific measures that could be developed into a uniform field index and
- (2) recommend where further research to validate welfare concepts and methodologies is required.

Part 2 of the review examines novel methods for integrating these measures into a welfare index.

The review examines:

- **societal concerns about animal welfare**
- **conceptual frameworks for assessing welfare**
- **measures of welfare, and**
- **current methods for assessing welfare in research and on farm**

The second part of the review addresses approaches to integrating measures into a unified field index of farm animal welfare and proposes a unified field index for on-farm application across Australia's livestock sectors.

2. Setting the scene

Awareness and concern about animal welfare usually arise when the actions of humans intersect with the lives of animals, especially those animals born into our care and responsibility. When we approach the issue of animal welfare we do so from a number of perspectives that are influenced by evidence, by values and by attitudes about how animals ought to be treated. For each of us, these

viewpoints can be considered to be personal anchoring points or landmarks from which we attempt to triangulate and fix on animal welfare, just as a GPS unit uses satellites to fix a position on the ground.

If you have ever driven down a country road watching a rainbow dance across the landscape, then stopped to take a photo, you will have witnessed a surprising phenomenon. Without the motion of the car, the rainbow becomes dull and shallow, and from some vantage points is not visible at all. So it is with animal welfare that as we move between various values, attitudes and evidence, the depth, vividness and character of the issue changes and are envisioned in greater detail and complexity. Projections from the landmarks of evidence, values and attitudes create the construct we call animal welfare that, like a hologram, appears to differ from each new perspective. As we move between landmarks we can see suffering, happiness, utility, fitness, pain, health, disease, purpose, arousal, depression, anxiety, exploitation and so on in many depths and intensities. From a single viewpoint, we sometimes understand very little at all about animal welfare and the acceptability of animal use practices.

It follows then, that each 'sighting' of animal welfare, such as say the perception of suffering, can be disaggregated into its constitutive elements of evidence, values and attitudes. Conversely, a single piece of evidence, say a cortisol response, can project to multiple aspects of the animal welfare hologram. Thus when interpreted through differing ideas of biological function, of affective states, or of naturalness, the datum may map to differing places within the animal welfare construct. Without knowledge of how the perception of welfare deconstructs into its constitutive elements, we are ignorant of how the perception arose in the first place and of what it tells us about the whole of which it is a part.

The role of science in the assessment of animal welfare has been discussed in detail in the literature (Barnett and Hemsworth, 2009; Croney et al., 2012; Sandoe et al., 2004; Tannenbaum, 1991). While scientific methods provide an objective way of collecting evidence, it is well recognized that the interpretation of data is influenced by values, as indeed is the initial choice of measures used to make the welfare assessment. The fact that scientific processes are underpinned with values does not diminish their contribution to welfare assessment but, as noted by the above authors, highlights the importance for scientists, like other stakeholders involved in animal welfare assessment, to clearly enunciate the value framework underpinning the interpretation of evidence.

Perceptions, understanding and interpretations of animal welfare are influenced by:

- Evidence
- Values, and
- Attitudes to animals

Scientific approaches to animal welfare are also influenced by these factors

2.1 Brief historical overview

The most prominent development and indeed the primary foundation of animal welfare is the fundamental acceptance that animals are sentient beings that feel emotions and are aware of their world through subjective experience. While this may seem to be a modern concept, this is not the case, as there was recognition of animal sentience in the writings from the Renaissance period spanning the 14-17th centuries (Duncan, 2006). Unfortunately, a consideration of animal feelings was not always reflected in the treatment of animals during this period. Significant momentum occurred during the 18th century when influential philosophers and social reformers challenged contemporary attitudes to animals. Preeminent amongst these reformers was Jeremy Bentham who asserted that “The question is not, Can they reason? nor, Can they talk? but, Can they suffer?” Bentham’s seminal question suggested that the capacity to suffer might be a sufficient criterion to entitle animals to legal rights. In the present day, this basic question continues to lie at the heart of animal welfare science where our challenge is to determine how best to quantify emotional states of animals and to ascertain the significance of these welfare states in relation to our duty of care in animal management. The last three decades have seen a significant expansion in efforts to understand the emotional repertoire of farm animals (Duncan, 2006). Most emphasis has been on quantifying negative or unpleasant emotional states (eg. pain, fear, hunger). However, with an increasing community interest towards not merely minimising suffering in domestic animals, but also enhancing pleasure in these animals (Tannenbaum, 2001), there is now increasing attention on examining positive affective states and their importance within the lives of farm animals. We anticipate that an improved capacity to assess affective states of farm animals will change our biological understanding of the scope of animal experiences and have a significant bearing on future animal welfare policy and also lead to the development or refinement of some new or alternative animal production systems.

In terms of historical impact, two significant events occurred during the mid nineteen sixties. The first of these was the publication of *Animal Machines* by Ruth Harrison in 1964 which challenged the intensification of animal production and the concept of “factory farming”. Secondly, in response to the marked increase in public concerns about intensive animal farming that followed publication of the book, the UK government established the Brambell Committee in 1965. The terms of reference

of this committee were relatively simple; “To examine the conditions in which livestock are kept under systems of intensive husbandry and to advise whether standards ought to be set in the interests of their welfare, and if so what should they be?” (Brambell Committee, 1965). The full effects of the committee’s report and their recommendations on UK and European animal welfare policy and legislation were both profound and enduring (Veissier et al., 2008) with consequences in other industrialized countries, including Australia. Furthermore, the report also strongly influenced the subsequent direction of animal welfare science at the time (Keeling et al., 2011).

Recognition and indeed advocacy of animal sentience was prominent in the views of the Brambell Committee which stated that animal welfare should encompass both the physical and emotional well being of the animal. They went on to say; “Any attempt to evaluate welfare therefore must take into account the scientific evidence concerning the feelings of animals that can be derived from their structure and functions and also from their behaviour” (Brambell Committee, 1965). Whilst consensus about the definition of animal welfare remains somewhat elusive, there are signs of some convergence (refer Section 3). Notwithstanding this, one could argue that the Committee’s definition was certainly prescient.

- **Recognising the sentience of animals is central to appreciating that they can suffer**
- **The capacity of animals to suffer has been recognised since the renaissance period**
- **A moral responsibility on humans to minimize suffering in animals has been acknowledged since at least the later 1700s**
- There is increasing community interest towards not merely minimising suffering in domestic animals, but also enhancing pleasure in these animals

3. Conceptual frameworks for animal welfare

A lesson from the historical changes in concepts of animal welfare is that current perceptions of what constitutes animal welfare are likely to also change. A common strategy to address the dilemma of how to assess animal welfare is to start by strict definition of what animal welfare is. This strategy has utility in that it helps sets the boundaries for what needs to be considered. A contemporary example is the definition adopted by European Food Safety Authority Panel on Animal Health and Welfare.

“Welfare refers to the state of an individual as it attempts to cope with its environment. Effects on welfare include changes in health, mental functioning, positive and negative feelings, physiological and behavioural responses and injuries.”

The definition encompasses the range of states of the animal generally considered to be associated with its welfare. An obvious shortcoming of this type of definition is the absence of an explicit framework for interpreting evidence that falls within the parameters articulated in the definition. Three interpretive frameworks are commonly adopted and, even when used in combination tend to be weighted differently depending on the perspective of the assessor, the assessment methodology or the purpose for which the assessment is being undertaken. These three frameworks are:

- Biological functioning – normality as evidenced through measures of behaviour, physiology, health and productivity
- Affective states – as evidenced through measures of abnormal behaviours, affective states (positive and negative feelings) and cognitive function, and
- Naturalness – as evidence by attributes of the animal, or telos, in particular normal behavioural repertoires, and by attributes of its environment, in particular congruence between the extant production environment and a sometimes notional, preconceived ideal environment for the animal’s species

Schematically the 3 domains are typically depicted in a Venn diagram as overlapping circles in which good welfare occurs within the common area as shown in Figure 1. Some alignment of disciplinary expertise and personal experience with each of the interpretive frameworks can also be recognised, with farmers and veterinarians often emphasizing biological functioning, cognitive and behavioural scientists often emphasizing mental functioning, and philosophers and animal rights proponents often emphasizing naturalness and integrity. The importance of insights drawn from each perspective to the appraisal of animal welfare and to ethical judgements is also well recognised. The interpretive frameworks are not necessarily competing views vying for dominance but complementary understandings that can potentially contribute to a more sophisticated and nuanced appreciation of animal welfare.

Interpretive frameworks

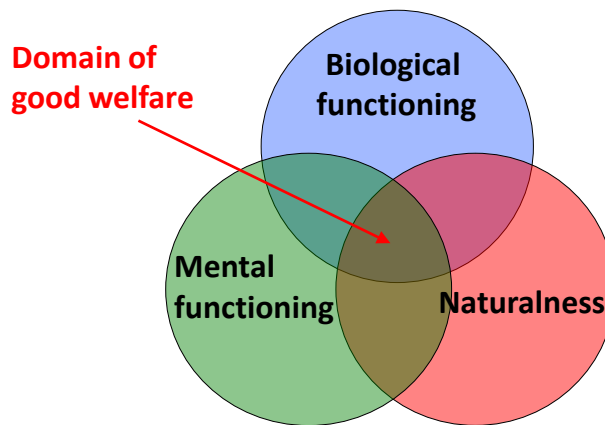


Figure 1. Schematic representation of three common conceptual frameworks for interpreting the welfare state of animals

The so-called 'Five Freedoms', that is:

1. Freedom from hunger and thirst,
2. Freedom from discomfort,
3. Freedom from pain, injury and disease,
4. Freedom to express normal behaviour, and
5. Freedom from fear and distress (FAWC, 1993)

are included to varying degrees in each of three animal welfare concepts. While most would accept that these freedoms are necessary to avoid a lack of suffering, in terms of a consensus on animal welfare assessment, there has been little attempt to define the levels of freedom that are desirable or the adverse consequences of not providing such freedoms. These different frameworks or concepts on animal welfare lead to the use of different methodologies to assess an animal's welfare and therefore it is useful to briefly consider these concepts and their rationale, before considering these methodologies.

Three conceptual frameworks dominate interpretation of animal welfare. These are

- **Biological functioning**
- **Mental functioning (or affective state) and**
- **Naturalness**

3.1. Biological functioning concept

The biological functioning concept, equates poor welfare to difficult or inadequate adaptation (Broom, 1986; Hemsworth and Coleman, 2011). Broom (1986) defines the welfare of an animal as “its state as regards its attempts to cope with its environment”. The “state as regards attempts to cope” refers to both (1) how much has to be done in order to cope with the environment and includes biological responses such as the functioning of body repair systems, immunological defences, physiological stress responses and a variety of behavioural responses and (2) the extent to which these coping attempts are succeeding. These behavioural and physiological responses include abnormal behaviours, such as stereotypies and redirected behaviours, and the stress response, respectively, while the success of the coping attempts are measured in terms of lack of biological costs, such as adverse effects on the animal's ability to grow, reproduce and remain healthy and injury-free (i.e., fitness effects). Thus the intensity of challenges from the animal's environment, including social and climatic stressors and environmental complexity, and challenges from disease including infections, traumatic injury, and poor nutrition, will be reflected in the magnitude of the biological responses utilised by the animal in its attempts to cope. As Broom (1986) recognises, there are two general types of indicators of poor welfare, one demonstrating that an individual has failed to cope with an environment, the other indicating the effort involved as the individual attempts to cope.

More detailed and recent accounts of the rationale of this concept are provided by Mellor et al. (2009) and Hemsworth and Coleman (2011).

This definition of Broom's (1986) is not dissimilar from the one recently endorsed by the 172 member countries of the OIE (2008): “Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal; the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment.”

Some have narrowly interpreted this biological functioning concept of animal welfare as one that equates an animal's welfare to attempts to cope with the environment, whether successful or not (Korte et al., 2007), however, others such as Moberg (2000) and Barnett (2003) emphasise that it is the consequences of these coping attempts that determine an animal's welfare rather than the

responses per se. A key precept in this concept is that animals use a range of behavioural and physiological responses to assist them in coping with environmental conditions, and while biological regulation in response to environmental change is constantly occurring, adaptation is not always possible. When homeostasis fails, there is damage, disease or even death (Broom, 1986; Moberg, 2000; Barnett, 2003). Therefore, difficult or inadequate adaptation generates animal welfare problems.

Others have criticised this concept of animal welfare on the basis that it does not adequately include emotions or feelings. However, this would only be valid if emotions are independent of other biological processes but this is unlikely since the mental state of an animal is an integral component of its biological state (Dantzer and Mormede, 1983). Emotional responses are produced in the limbic system, which projects to several parts of the brain, including those involved in the initiation and maintenance of the stress response, thus explaining why emotional insults activate a stress response (Kaltas and Chrousos, 2007). Emotions are part of the body's regulatory system and together with a range of learning processes function to assist animals in avoiding potentially harmful situations or recognizing potentially beneficial situations (Cabanac, 1979).

In conclusion, how well an animal is coping with the challenges it faces will be reflected in the normality of its biological functioning and fitness, and severe risks to welfare will be associated with the most extreme coping attempts. Difficult or inadequate adaptation will affect the fitness of the animal through a range of long-lasting behavioural and neuroendocrine responses and thus the rationale underpinning this animal welfare concept of biological fitness is that difficult or inadequate adaptation generates welfare problems for animals. These behavioural and physiological responses include abnormal behaviours, such as stereotypies and redirected behaviours, and the stress responses including those involving both the sympathetic-adrenal-medullary and the hypothalamic-pituitary-adrenal axes, respectively, while the biological cost includes adverse effects on the animal's ability to grow, reproduce and remain healthy and injury-free.

A focus on biological functions during welfare assessment emphasizes

- **Behaviour**
- **Homeostasis in the animal's physiology**
- **Health and disease**
- **Genetics, and**
- **The concept of interrelated costs and benefits between biological functions that influence adaptation, fitness and failure of the animal to cope with stressors that leads to pathology**

3.2. Affective state concept

The affective state or feelings-based concept, defines animal welfare in terms of emotions and emphasizes reductions in negative emotions, such as pain and fear and frustration, and increases in positive emotions such as comfort and pleasure (Duncan and Fraser, 1997). It should be recognized that there are numerous definitions of emotions in the literature often representing several disciplines. Denton et al. (2009) view primordial emotions as the subjective element of the instinctive behavioural patterns. These primordial emotions include thirst, hunger for air, hunger for food, pain, hunger for specific minerals, sexual arousal and orgasm, sensations accompanying impediment of visceral function (e.g., for micturition or defecation), desire for sleep after severe deprivation, and avoidance of change of body core temperatures, etc. (Denton, 2006). Denton et al. (2009) contrast the primordial emotions with another class of emotions which are most often fired by the distance receptors (exteroceptors)—the eyes, ears and the nose. These distance receptor evoked emotions, like rage, fear, hate, envy, happiness, playfulness, affection, anxiety, depression and disgust, are those to which the term emotion is most commonly applied.

Duncan (2004; 2005) has argued that animal welfare ultimately concerns animal feelings or emotions as follows. All living organisms have certain needs that have to be satisfied for the organism to survive, grow and reproduce and if these needs are not met, the organism will show symptoms of atrophy, ill-health and stress and may even die. Higher organisms (vertebrates and higher invertebrates) have evolved 'feelings' or subjective affective states that provide more flexible means for motivating behaviour to meet these needs. Thus the central argument is that although natural selection has shaped animals to maximize their reproductive success, this is achieved by proximate mechanisms involving affective states (pain, fear, separation distress, etc.) which motivate behaviours that can ultimately enhance fitness (Fraser, 2003).

Animal emotions have in the past been considered inaccessible to scientific investigation because they have been described as human subjective experiences or even as illusory concepts outside the realm of scientific inquiry (Panksepp, 1998). The difficulties in studying emotions as though they were objective states of bodily arousal are well recognized in the literature (Cacioppo et al., 1993). While each emotion may reflect a different pattern of arousal, the visceral response to many emotions is reasonably uniform in animals. Most animals react physiologically, at least in the short term, in essentially the same way whether the arousal is sexual, fear provoking or if there is the anticipation of play or food. It is obviously a major challenge to study and understand emotions in animals, although there have been some promising recent developments in the comparative study of emotions that show that there are many homologous neural systems involved in similar

emotional functions in both humans and other mammals, and perhaps other vertebrates (LeDoux, 1996; Panksepp, 1998, 2005).

It is widely accepted in animal welfare science that good welfare is not simply the absence of negative experiences, but rather also requires the presence of positive experiences such as pleasure (Boissy et al., 2007; Mellor et al., 2009). While methods to assess pain and suffering have been developed, there is still no agreement on how to assess positive experiences (Boissy et al., 2007). However, preference tests have been used to identify resources and behaviour that might be important to hens (Cooper and Albentosa, 2003). Furthermore, measuring preferences of animals, using preference tests, aversion learning and behavioural demand testing (Dawkins 1980; Matthews and Ladewig 1994; Kirkdon and Pajor, 2006) has been used by scientists to assess animal welfare predominantly on the basis that these preferences are influenced by the animal's emotions.

A focus on how the animal feels (mental functioning/affective state) during welfare assessment recognizes that animals feel emotions; that emotional states are important to an animal's well being and that environmental, social and infectious conditions can induce negative emotional states that compromise welfare.

3.3. Natural or normal behaviour concept

The third main concept of animal welfare, which is not often well-enunciated, promotes the principle that animals should be allowed to express their normal behaviour. For some this also implies that animals should be raised in 'natural' environments and allowed to behave in 'natural' ways.

The term abnormal behaviour in domestic animals invariably raises questions about what is normal (Mills, 2010), particularly when most behavioural differences between wild and domestic animals appear to be quantitative rather than qualitative in character, and best explained in differences in response thresholds (Price 2003). When considered as an aspect of the behaviour of an animal, abnormal behaviour is frequently defined as behaviour that is either atypical for the species, outside the normal behavioural pattern that has evolved in the natural habitats of the species or outside the range usually observed in the species in non-captive situations (Keeling and Jensen, 2005). In the early literature, the view that animals should perform their full 'repertoire' of behaviour was very common, however there is broad agreement within science that it is often difficult to attribute actual suffering when the expression of certain behaviours is prevented or is absent when it would be expected to be present (Dawkins, 2003). Furthermore, as Fraser (2003a) notes, "Few scientists today would support the simple view that animal welfare depends on the animal carrying out all its

natural behaviour in a natural environment because natural environments contain many hardships (harsh weather, predators), and natural behaviour includes many means of dealing with hardship (shivering, fleeing).”

The difficulty of deciding what constitutes the natural environment for domestic animals is brought in to focus when reviewing the history of the domestic hen as described by Appleby *et al.* (1992). The progenitor of the domestic fowl was the Red Jungle Fowl (*Gallus gallus*). It is a tropical species confined to forested areas and to thick vegetation. There are now two modern hybrids, the egg laying bird that reaches point of lay at 16-18 weeks of age at a body weight around 1.8-2.0 kg and that lays close to an egg a day, and the meat bird which reaches slaughter weight of about 2.0 kg as quickly as 5 weeks of age. What is the ‘natural environment’ of a young bird selected for meat production or an adult hen selected for egg laying, both of which are the same species, and following about 8000 years of selection for fighting capabilities and a hundred years of intense selection for production attributes? Is an outdoor area with relatively little structural diversity, except perhaps for some grass, a natural environment for a tropical species?

Thus the concept of ‘natural’ would need to be more specific before it could give guidance in assessing animal welfare, since generalizations may lead us astray and achieve the opposite of what is intended. Similarly, the ‘natural behaviours’ that are desirable or undesirable in terms of animal welfare require definition together with the rationale for their inclusion or exclusion. More recently the emphasis has been on behavioural indicators of poor coping such as fearfulness, aggression and stereotypies (EFSA, 2005), responses that are also utilized in the biological functioning-based concept of animal welfare.

Related to this notion of the importance of displaying normal behaviour is that of 'behavioural (or ethological) need'. The term 'behavioural need' appears to have been introduced into the scientific literature without any scientific evidence (Duncan, 1998). Dawkins (1990) and Fraser and Duncan (1998) suggested that the term 'behavioural need' refers to situations that elicit intense negative emotions and likely evolved for those behaviours in which an immediate action is necessary to cope with a threat to survival (e.g., escape from a predator) or reproductive fitness (e.g., nesting). In contrast other types of behaviour that can be performed when the opportunity arises (e.g., play, grooming) are more likely to be associated with positive emotional states. Duncan (1998) defined “behavioural needs” as behaviour patterns that are very strongly motivated, and, if they are not allowed expression, the animal’s welfare may be jeopardized. However, any argument for impaired welfare due to restriction of these behaviours would be strengthened by supporting physiological

measurement of frustration (Cooper and Albentosa, 2003), or evidence of decreased health or increased physiological stress (Duncan (2005).

A focus on natural behaviours in welfare assessment has been more strongly driven by philosophical precepts than by biological evidence. Defining natural behaviour and understanding the impact of the inability to perform them remains a major unanswered question in the assessment of animal welfare from the perspectives of biological function and affective states.

3.4. Scientific uncertainty

These different concepts or views on animal welfare can lead scientists to use different criteria or methodology in assessing an animal's welfare. For short term animal welfare issues involving acute stress, such as painful husbandry procedures, there is considerable agreement on the need to assess animal welfare from a perspective of biological functioning (Mellor et al., 2000). However, for longer term issues, disagreement over these welfare concepts, especially when consequent interpretations conflict, often lead to debates concerning animal welfare and the varying interpretations (Fraser, 2003a,b).

This so-called 'scientific uncertainty' does not necessarily diminish the robustness of the research utilising methodologies or measurements arising from these views or concepts, but it does raise the question of the relatedness of these concepts (Barnett and Hemsworth, 2009). In other words, are situations in which an animal has to resort to the extreme coping attempts (i.e., challenges that may overwhelm an animal's capacity to adapt) associated with, or do they lead to, negative affective states and vice versa? In a similar context, is an inability to perform normal or 'natural' behaviours associated with extreme coping attempts and/or negative affective states? Therefore, if these concepts are related, are the resultant methodologies measuring the same adverse physiological and mental state(s) in the animal? Indeed many authors have raised the commonalities in these concepts (e.g., Fraser, 2003^b, 2008).

As suggested by Barnett and Hemsworth (2009), this conceptual convergence suggests a way forward in developing a broader consensus on the study of animal welfare by reducing both conceptual differences and consequently methodological differences in animal welfare science. The validity of the welfare criteria can be tested in several ways: first, with the finding that there are correlations between independent measures of different concepts of animal welfare; and second, with the finding that an intuitively aversive condition reduces animal welfare on the basis of the measures of different concepts of animal welfare. Therefore, research examining the validity of these concepts—and, in turn, methodologies—is necessary to understand the relationships between

the concepts and indeed minimize the conceptual and methodological differences as discussed here. The development of a broader scientific consensus on welfare measures arising from this research should lead to the development of credible measures that can be incorporated into welfare assessment and screening tools in the field. It should be noted that there is indeed some evidence to support this conceptual convergence (Nicol et al., 2009; Stevens et al., 2009; Arnold and Matthews, 2010; Matthews and Bryant, 2011).

In the meantime, until science can broadly agree on the best methodology or methodologies to evaluate animal welfare, these approaches should guide current welfare research methodology. Using several of these approaches where the opportunity arises should also be utilised: for example as Widowski and Hemsworth (2008) recommend that, while studies of motivation can provide compelling evidence that the performance of some behaviour (or preference) may be important to the animal, additional evidence, particularly on occurrence of abnormal behaviour, stress physiology and health, are necessary to provide a more comprehensive assessment of the impact on animal welfare. Furthermore, the basis of the methodology used by scientists to assess animal welfare should routinely be provided so that individuals using science in their decision-making appreciate both the rationale for the methodology and its limitations (Fraser, 2003b; Sandoe et al., 2004).

There is evidence of a convergence of the three conceptual frameworks for assessment of animal welfare. Nonetheless, intrinsic scientific uncertainty remains in these approaches. This uncertainty does not diminish the value of scientific approaches to the assessment of animal welfare.

3.5. Interplay between welfare and ethics

We can see from the above discussion that animal welfare is at least, in part, a conceptual construct developed by humans to protect animals within our care and responsibility. No doubt it has also been developed to protect some of the moral sensibilities of humans. Importantly, animal welfare does not stand independent of ethics. The boundaries to what is considered to lie within the domain of animal welfare are influenced by religious and traditional understandings and change with emerging philosophical and biological knowledge. Interpretations of what within these boundaries constitutes good welfare come under similar influences.

Whilst there are some (Broom, 1996) who suggest the welfare assessment and ethics are juxtaposed, others (Sandoe et al., 2003) would argue they are inextricably linked and this should be made more transparent by the scientific community. According to Sandoe (2011), the application of ethics occurs at two levels. Firstly, it occurs during the derivation or establishment of the scientific conclusions. For example, in the investigation of a specific welfare issue (eg. stocking density,

transport duration), the outcomes are rarely black and white. Quite often this occurs because there aren't clearly defined thresholds indicative of acceptable and unacceptable welfare in the measured responses. Therefore, when drawing a conclusion about a minimum stocking density for example, it is ultimately a subjective decision based on the consideration of the facts and an ethical context. The second level occurs during the evaluation and processing of scientific evidence. Any judgement about whether to accept or not accept scientific evidence pertaining to the welfare status of an animal or a production system or practice will depend on the individual's ethical perspectives and values. What may be deemed reasonable by scientists may not be to others simply because of their different ethical points of view.

Ethicists recognise many concepts that can be used to help judge what is right and wrong conduct. These concepts such as duty, rights, utilitarianism, and consequentialism provide additional influences on the interpretation of welfare states. Most participants, including scientists, engaged in assessment and interpretation of welfare are not schooled in ethics and do not knowingly bring formal ethical principals into their consideration of welfare (Mather, 2011; Veissier et al., 2011). Nonetheless, the nascent or unformulated ethical viewpoints of those participating in discussions on welfare can engage values that lead to divergent and strongly contested conclusions. No simple means to reconcile these divergent viewpoints is apparent, although procedures such as the Ethical Matrix and the ethical assessment process of Campbell are being developed for application in animal welfare (Croney and Anthony, 2010). A more detailed discussion of ethics is beyond the scope of this review.

Ethical values influence the choice of measures used during the assessment of animal welfare and the interpretation of data. Progression from collection of data to its interpretation and subsequent deliberation of ethical questions is usually a multistep, iterative process.

4. Welfare assessment measures used in science

In science, a broad range of measures have been applied to assess the welfare of experimental animals. The actual choice of measures or methodologies will vary depending on the experimental design, type of experimental challenge/treatment and livestock species. The measurement categories, and examples of specific measures within each, are shown in Table 1.

In addition to the application of existing welfare measures in livestock production research, considerable research effort has also been expended developing novel measures and approaches to

assessing changes in biological function and affective state. The latter has received significant attention over the last 20-30 years and this is discussed in more detail below.

A broad range of measures have been applied to assess the welfare of animals. Choice of measures or methodologies will be influenced by the type of experimental challenge/treatment and livestock species. Measurements can be broadly categorised as those relating to the animal's behaviour, productivity, health, physiology, affective state, environment/resources and genetics/genotype.

Table 1: A selection of commonly used measures from which welfare status of animals is inferred. See notes for explanation of terms. The quantification of the value and interpretation of these measures shown in the table is quite subjective and is intended to provide a guide to the challenges faced with using the measures

Category	Examples	Extent to which measure integrates impact of multiple stressors over an extended period	Validity as a welfare measure: strength of association with welfare issues and sensitivity to non welfare effects	Technical robustness of measure – repeatability across operators	Is the measure an indicator of good welfare, poor welfare or both?		Practical application				Limitations	Knowledge gaps
					Good welfare	Poor welfare	On-farm	QA audit	Vet-clinic	R&D		
Explanatory notes	1	2	3	4	5		6					
Behaviour												
Ethograms	Behavioural schedules, “natural behaviours”	+	+	++	+	++	?			✓	Absence of expression doesn’t mean welfare is compromised	Impacts of lack of opportunity to express behaviours
Normal/abnormal	Pain related Injurious behavior, thermoregulation	+	+++	++		+++	✓	✓	✓	✓	Can vary with type of pain. Species specific	Comparisons across types of pain within species and between species
		+++	+++	+++		+++	✓	✓	✓	✓		
		++	+++	+++	+++	+++	✓		✓	✓	Species specific, influenced by age structure, gender	Impacts of lack of opportunity to express behaviours
Human-animal relationship?	Fear of humans, habituation to management,	++	+++	++	+	+++			✓	✓	Negative experience prior to	Non-genetic methods for modifying

	temperament traits											purchase not necessarily remediable, genetic influences	temperament
Productivity													
Growth/Composition	ADG, growth targets, body condition score, feed conversion efficiency	+++	++	+++		+	✓	✓	✓	✓		Genetic variation (within species) influences target values multiple influences	
Reproduction	Fertility, fecundity, age at puberty, Days open, return to service, parity number success failure	+++	++	++		+	++	✓	✓	✓	✓	Genetic variation (within species) influences target values More difficult to measure in extensive systems, multiple influences	
Product yield	Milk Wool Egg Meat	+ +++ + +++	++ + + +	+++			++	✓	✓	✓	✓	Genetic effects, species specific multiple influences	
Product quality	Milk Wool strength Egg Meat	+ + + +	+ +++ + ++	+++			++	✓	✓	✓	✓	Genetic effects, species specific multiple influences	
Culling variables	Percentage, age, reason for culling	+++	++	+++		+	++	✓	✓	✓		Genetics influences,	

											enterprise objectives multiple influences	
Health												
Infectious disease status	Mastitis, footrot, bovine respiratory disease complex, parasites	+	+++	+++	++	++	✓	✓	✓	✓		
Metabolic disease status	Ketosis, acidosis	+	+++	+++		+	✓		✓	✓		
Developmental disease status	Joint and long bone deformities	+++	+++	+++	++	++	✓	✓	✓	✓		
Physical state of animal	Clinical signs including: coat (pelage), demeanor, eyes, reflexes food intake, faeces, urine	+	++	+++	++	+++	✓	✓	✓	✓		
Physical injury	Lameness, canabilism	+++	+++	+++	+	+	✓	✓	✓	✓		
Mortality		+++	+++	+++	+	+	✓	✓	✓	✓		
Physiology												
Sympatho/ adrenomedullary system	Catecholamines, Heart function variables, vagal tone	+	+	++	+	+			✓	✓	Most samples need lab analysis	
Neuroendocrine	CRH, ACTH, Cortisteroids, prolactin, oxytocin, vasopressin, etc	+	+	++		+				✓		
Immune function	Hematology, antigen responsiveness, acute phase proteins	+	+	++		+			✓	✓		
Metabolic status	Ketosis, acidosis, mineral (micronutrient) status	+	++	+++		+			✓	✓		
Neurotransmitters	Dopamine, glutamic acid, endorphins, neuropeptides	+	+	++	+	+				✓		
Affective state												
Behavioural demand		+	++	+		+				✓	Importance of	
Cognitive bias	Judgement bias,	+	++ or +?	+	+?	+				✓		

	Attention bias												opportunity to experience negative affective states
Preferences		+	++	++		+				✓			
Qualitative behavioural assessment		+	++	+++		+++				✓			
Environment/resource													
Social	Enforced isolation, group size and structure	++	+++	+		+	✓	✓		✓			
Climatic	Temp, humidity, atmospheric pressure	+	+	+++		+	✓		✓	✓			
Physical	Housing, sun shade, wind, bedding, room to move, cleanliness predation	+++	+++	+++		+++	✓	✓	✓	✓			
Nutrition	Quality, abundance,	+	+	++		+	✓		✓	✓			
Stockmanship	Attitude to animals, use of goads, husbandry skills, records and review processes, participation in QA systems	+++	+++	++	+++	+++	✓	✓	✓	✓			
Genetic variables													
Breeding values	Birth weight Disease resistance Flight time	na	++	++			✓			✓			Genetic and phenotypic costs and benefits with other welfare and production traits Multiple influences?
Molecular markers	Polledness Disease resistance Fear?	na	++	++			✓			✓			

Notes

1. A non-exhaustive list of examples of each category of measures. Individual measurements can inform welfare interpretations in more than one of the 3 major domains: biological functioning, mental states, and naturalness discussed above.

2. Some measures are highly labile and change quickly with the circumstance of the animal, whereas others represent the cumulative effect of extended exposure to stressors. Measures which integrate extended exposure to stressors have more + signs
3. Validity as a welfare measure scores the strength of association of the measure with compromised welfare (+++). Measures with a low score are more susceptible to perturbation by events that don't necessarily compromise welfare can perturb.
4. Technical robustness scores the extent of standardization of the measure and ease of repeatability across operators
5. Some measures can indicate that welfare of the animal is compromised but absence of the measure does not necessarily indicate that the animal is in a good welfare state. An example is lameness. These types of measures are scored under the column as indicators of poor welfare but are not scored as indicators of good welfare. Scores tend to be low in the good welfare column because few measures have amplitude in the direction of good welfare to indicate degrees of very good, or extremely good welfare.
6. Practicality for use by farmers (on-farm) in QA audit systems, in veterinary investigations of animal health, and in research settings.

4. 1. Changes in biological functioning

As discussed in Section 3.1, this approach to assessing the welfare of an animal focuses on the normality of its biological functioning and consequent fitness. Difficult or inadequate adaptation will affect the fitness of the animal through a range of long-lasting behavioural and neuroendocrine responses. This approach has been used by scientists to assess the effects of housing, husbandry and handling on animal welfare. For example, a broad examination of the behavioural, physiological, health and fitness responses in handling studies, particularly in pigs and poultry, have generally shown that negative or aversive handling, imposed briefly but regularly, will increase fear of humans and reduce growth, feed conversion efficiency, reproduction and health of these animals (see Waiblinger et al., 2006; Hemsworth and Coleman, 2011). A chronic stress response has been implicated in these effects on productivity since in many of the pig handling studies (see Hemsworth and Coleman, 2011), handling treatments which resulted in high fear levels also produced either a sustained elevation in the basal free cortisol concentrations or an enlargement of the adrenal glands. Studies examining surgical husbandry procedures have also used a broad examination of the behavioural, physiological, health and fitness responses to study animal welfare (Mellor et al., 2000; Hemsworth et al., 2009; Colditz et al., 2010).

Studying biological function thus provides the opportunity to identify disturbances arising both internally (deviations from internal functional states, e.g., deviation from homeostasis) and externally deviations from expectations, e.g., emotions) but appear to provide little opportunity to identify positive experiences.

There are a large number of parameters that can be measured that reflect changes in biological functioning in response to challenges that can arise during animal production processes. These have been reviewed elsewhere (e.g. Moberg and Mench 2000) and continue to evolve as new understandings of physiological and behavioural responses develops. For example, Wang *et al.* (2004) discovered a new nociceptive signalling pathway, and suggest that the chemical mediator superoxide could be used as a novel indicator of pain. Nonetheless, much remains to be discovered by research on molecular markers of stress (Gornati *et al.* 2005). In addition, considerable efforts are under way investigating the potential for measures of biological functioning to reflect mental health in animals (e.g. Yeates and Main 2007); and new technical developments such as infra-red thermography will enable increasingly sophisticated measurement on animals without the confounding effects of stress arising from the measurement process itself (Stokes et al., 2012). The main methodological issues with the measurement of biological functioning are:

- The lack of an agreed procedure for amalgamating different measures into a global welfare index, and
- Determining the levels of biological functioning that match with different levels of welfare.

Notwithstanding the different ethical viewpoints amongst the various stakeholders on the acceptability of specific husbandry practices, the lack of clear scientific guidelines for integrating measures and rating practices (Fraser 1995) has led to divergent recommendations from within the scientific community on the acceptability of various procedures. For example, two different reviews of the available scientific evidence on the housing of sows came to different conclusions. Barnett *et al.* (2001) emphasised biological functioning and corresponding decreases in fitness in assessing animal welfare (e.g., criteria such as behaviour (aggression), stress (cortisol), health, immunology, reproduction, injuries, growth rate and nitrogen balance) and concluded that “On balance, it would appear that both individual and group housing can meet the welfare requirements of pigs.” The second review, by von Borell *et al.* (1997), emphasised the importance of both affective states and the opportunity to carry out natural behaviour in assessing animal welfare (e.g., high levels of abnormal behaviour and inability to perform some natural behaviours) and concluded that “Since overall welfare appears to be better when sows are not confined throughout gestation, sows should preferably be kept in groups.” Underlying differences in ethical values brought to bear by the authors during interpretation of the results appear to have led, at least in part, to these divergent conclusions.

Extending Broom’s definition of animal welfare (Broom, 1986), Moberg (2000) has proposed, in our view correctly, that the key to the development of an index of welfare based on biological functioning is the measurement of the biological cost of challenges (at least for harmful challenges). Such an index will be underpinned by measures of endocrine, or other physiological and behavioural responses to challenges, but as none of these provide definitive endpoints that reflect the biological cost to the animal, nor are easily integrated (Fraser 1995), the index is unlikely to be based on them alone. Further, different constellations of responses are seen depending on the nature of the challenge and other genetic and life history experiences (Jarvis *et al.* 2006). Thus, Moberg (2000) has proposed a model based on pre-pathological conditions as quantifiable measures of biological cost. Such conditions include disruption of ovulation, abnormal growth and abnormal behaviours as well as sub-clinical or clinical disease. While measures are more quantifiable and more integrated than individual responses, such as changes in adrenal output of endocrine hormones, this proposition has the disadvantages that:

- there is no common index to rate different practices but this challenge is common to many other approaches ;

- it restricts concern about welfare issues to insults; and,
- there is little possibility for detecting positive experiences.

There are a range of alternative possibilities for developing an overall index for welfare assessment and these are presented below.

Numerous measures have been successfully applied to assess changes in biological function. Key limitations include:

- **The lack of an agreed methodology for amalgamating different measures into a global welfare index, and**
- **Determining the levels of biological functioning that match with different levels of welfare.**

4.2. Assessment of negative and positive mental states in livestock

While the subjective experiences of animals cannot be measured directly, there is a consensus, as embodied in the Five Freedoms, that animals have the capacity to suffer and experience negative affective states. Further, there is a common belief amongst many citizens that animals have the ability to experience positive affective states (Kjaernes *et al.* 2007). Animals respond peripherally to challenges with a wide variety of responses that result in activation of some or all of the following biological process: immune system, hypothalamic-pituitary-adrenal axis, motor and other behavioural activities (e.g. Appleby 2011). Interacting with these peripheral responses is a range of neurophysiological changes, which influence both peripheral physiological responses and mental/cognitive processes. Cognitive elements include the animal's perception of its own state (e.g. the aversiveness of the events/feelings). Most of the scientific research on animal welfare has aimed at assessing the effects of putatively stressful or harmful events on animals' wellbeing, although there is increasing interest in understanding if other aspects of the production environment can contribute to positive welfare (Boissy *et al.* 2007; Yeates and Main 2007). Measurement of the harmful effects has focussed on understanding the physiological (peripheral, and to a lesser degree, central) and behavioural responses to stressors.

There is growing recognition by the scientific community of the relevance of an animal's subjective experiences to key stakeholders and there has been steady progress in the development of techniques to more directly access the perceptions and feelings of animals (reviewed by Dawkins, 2006). These will be discussed in detail as they present the major opportunity to align scientific methodologies with community views (Hogan and Fisher).

Preference testing

One of the initial methodologies to be applied in this context was based on preference testing. The best example is the use of a Y-maze that allows a choice between access to two different resources. This approach has been used extensively to provide information about specific features in the animal environment such as flooring (Hughes and Black, 1973; Hutson, 1981), restraint methods (e.g. Pollard et al., 1994), handling treatments (Rushen, 1986) and ramp design (Phillips et al., 1988), with the overriding objective of optimising the environment for animals.

While the consistent choice or preference of one resource over another or others indicates the animal's relative preference, some have argued that in addition to establishing what an animal prefers, it is important to understand the strength of the preference (Dawkins, 1983; Matthews and Ladewig, 1994). To address the question of the strength of an animal's preference, experiments have incorporated varying levels of cost (e.g., work effort, time and relinquishing a desirable resource) associated with gaining access to a resource or avoiding aversive stimulation (refer to the subsequent section on Behavioural demand). For example, Dawkins (1983) varied the price paid for access to litter by increasing the duration of feed withdrawal before the test. She found that although hens preferred litter to wire floors, their preference was not strong enough to outweigh the attraction of food and concluded that in both experiments there was no evidence that hens regarded litter as a necessity.

These initial preference studies stimulated considerable debate on conceptual and methodological difficulties (Dawkins, 1977; Duncan, 1978) and Fraser and Matthews (1997) concluded that the usefulness of preference tests to answer questions about animal welfare is limited by three main issues. First, these tests should adequately reflect the animal's preference, second, they need to establish how strongly an animal prefers a chosen option, avoids a non preferred one or is motivated to perform a behaviour, and third, preferences may not correspond to welfare if the choices fall outside the animal's sensory, cognitive and affective capacity or if the animal is required to choose between short- and long-term benefits.

Expanding on these limitations, firstly, preference tests measure an animal's choice behaviour at a point in time and such measurements run the risk of failing to account for interactions of different motivational states which may influence the behaviour of the animal over time (Hutson, 1984). Furthermore, this short term choice may reflect the animal's proximate (immediate or present) requirements, rather than the animal's ultimate requirements or those necessary for survival, growth and reproduction (Lawrence and Illius, 1997). Clearly preference tests therefore need to be comprehensive enough to identify these sources of variation (Fraser and Matthews, 1997).

Secondly, preferences may vary with familiarity (Phillips et al., 1991, 1996) and thus prior experience can be controlled in preference tests by using naïve animals, familiarizing the animals with the resources prior to testing or, as Fraser and Matthews (1997) suggest, prolonged testing. Furthermore, since preferences for specific resources may also be affected by the context in which the animals are tested (e.g., the social environment at the time of testing), the context in which the animals are studied therefore should relate to the commercial conditions in which the experimental question is directed (Dawkins, 2003).

Thirdly, Fraser and Matthews (1997) recognize that limitations in using preference tests arise when animals are exposed to potential dangers or benefits that are beyond their sensory or affective capacity or if the choice requires a level or type of cognitive ability that the animal does not possess. They suggest that the best safeguard is to base preference tests on the types of choices that the species arguably evolved the capacity to make and that the individual animals are accustomed to making.

In concluding on animal preferences, clarifying the conceptual link between animal preferences and animal welfare is an issue for some. The individual's concept of animal welfare clearly underscores the methodology used to judge or measure animal welfare. However, as commented by a number of authors (e.g. Fraser and Matthews, 1997), preference research should be integrated with other measures used in animal welfare research. Furthermore, Widowski and Hemsworth (2008) recommend that, while studies of motivation can provide compelling evidence that the performance of some behaviour (or preference) may be important to the animal, additional evidence, particularly on occurrence of abnormal behaviour, stress physiology and health, are necessary to provide a more comprehensive assessment of the impact of restriction on animal welfare.

Behavioural demand

The importance of resources for animals can also be derived from measures of demand elasticity (Dawkins 1983). Consequently, 'behavioural demand' studies, using operant conditioning techniques in which the animal must learn to perform a response, such as pecking at a key or pushing through a weighted door, to gain access to a resource, have been used to study the animal's level of motivation to access or avoid the situation being tested. The strength of the motivation provides a quantitative measure of how much it matters to the animal. One methodology, derived from the theory of behavioural economics has proved helpful in identifying appropriate quantitative measures (Dawkins 1990; Lea 1978). Typically, in a behavioural economic framework animals are required to work for a resource, and the quantity of the resource obtained as the work requirement ('price') is increased is

measured. The generic function (demand curve) describing the change in total quantity of the resource acquired as the price increases is positively decelerating (Hursh and Winger 1995) and takes the form:

$$\ln Q = \ln(L) + b[\ln(P)] - a(P)$$

where,

Q is the measured consumption of the resource,

P is the price for a unit of the resource, and

L, b and a are parameters characterising the initial level of the curve at minimal price, the corresponding slope at minimal price, and the acceleration or increase in slope with increases in price, respectively.

ln natural logarithm

Elasticity ($b - a(P)$) is the point slope of this function and is a linear function of price. The price at maximal work (P_{max}) is calculated as $(1+b)/a$ and occurs when elasticity takes the value -1. P_{max} can be conceptualised as the sensitivity of work output to environmental constraints and costs. The maximal work at P_{max} is O_{max} . O_{max} can be conceptualised as the level of resource seeking. The various curve parameters have been used in different ways to quantify animal perception, and there is some debate about which is the most useful (Kirkden et al., 2003; Kirkden and Pajor 2006a). Recent evidence presented by Verbeek et al (2012b) and Madden *et al.* (2007) suggest that O_{max} may be the best measure for quantifying the subjective experiences of animals. They reported that those resources (e.g. food or pharmacological agents) sustaining higher O_{max} values were the ones that more effectively met the animal's needs. O_{max} is equivalent to the area under the demand curve bounded by P_{max} and the corresponding level of consumption (Hursh and Winger 1995). In economic terms, O_{max} belongs to a class of measures known as consumer surplus, which Kirkden et al (2003) argue is the best measure of motivational strength or resource value. Resources with inelastic demand (elasticity values less than -1) have also been reported to reflect a strong need (Matthews and Ladewig 1994).

The validity of the behavioural economic approach is supported by other studies demonstrating that biological functioning is impaired in animals that are not able to access resources that are subjectively rated as very important. Mason et al. (2001) identified food and access to a water bath as needs, and that preventing access to one or other resulted in similar and elevated levels of stress hormone (cortisol) concentrations in the urine. Further, rest is rated as highly as food by dairy cattle (Munksgaard et al.

2005; Matthews et al., 2006), and reducing the amount of rest obtained each day by about 50% adversely effects the physical functioning of the animal in a variety of ways (e.g. altered hypothalamic-pituitary-adrenal axis regulation, Fisher et al., 2001; reduced growth, Fisher et al., 2003).

Cognitive bias testing

Measures of cognitive bias are another way that has been proposed to assess affective state (both positive and negative) in animals (Harding et al., 2004). This methodology has been developed in human studies, where anxious or depressed individuals typically interpret ambiguous stimuli more pessimistically compared with non-depressed controls (Mathews et al., 1995). In the animal studies, the subjects are exposed to different treatments presumed to induce different affective states. By analogy with the human studies, animals are trained to respond to cues differentially associated with rewarded and unrewarded (or punishing) events. Typically, the rewarded and unrewarded cues are selected from a single sensory modality e.g. visual, auditory, tactile, and spatial. During testing for cognitive bias, stimuli intermediate to the training cues are presented and the animals' responses are measured. If the responses to the ambiguous stimuli are inhibited (e.g. slower) than the controls, then this is called a negative cognitive bias and is said to reflect a negative mood state induced by the treatment. Alternatively, if the animal's responses are, for example, quicker to the ambiguous stimuli, then this is called a positive cognitive bias and said to reflect a positive mood as a result of the treatment. There are growing number of studies, with several different species including rats, dogs, pigs, sheep and starlings, where a negative cognitive bias has been reported (see Mendl et al., 2009 for a review; Doyle et al., 2011a) and a number of studies beginning to report evidence of positive cognitive biases (e.g. sheep, Doyle et al., 2010; pigs, Douglas et al., 2012). However, there are a number of findings in cognitive bias studies which suggest that the interpretation of the data is not straightforward, at least in terms of ascribing states of positive and negative mood to the animals utilised. For example, treatments designed to induce different mood states sometimes produce no differences in cognitive bias (e.g. Burman et al., (2011) for supposedly positive states; Weichman et al. (2012) for supposedly negative states). Further, mismatches between the expected effect of treatment and the measures of cognitive bias have been reported. For example, positive bias has been reported following imposition of supposedly negative treatments like restraint and isolation in sheep (Doyle et al., 2010), and negative bias has been reported even though independent measures showed that there was no difference between treatments in the emotional state of the animals (Doyle et al., 2011b). As yet, the methodology is primarily a tool for understanding mental experiences of animals in experimental settings; if/when it becomes fully validated as a measure of affective state then practical measures for use in the field will be required.

Qualitative behavioural assessment (QBA)

Recent research has demonstrated the potential of the qualitative assessment of animal behavioural expressions as a valid scientific tool for the integration of different approaches to animal welfare (Rousing & Wemelsfelder, 2006; Defra, 2006; Stockman 2010; Rutherford 2012; Wickham 2012).

Qualitative Behavioural Assessment (QBA) is a whole animal approach that relies on the ability of human observers to integrate subtle information about animals' behaviour and body language and the animals' context to provide a valid measure of the animals' affective state. In other words, it describes not 'what' the animals do, but 'how' they do what they do.

These studies apply Free-Choice-Profiling methodology (FCP), and the associated statistical approach of Generalised Procrustes Analysis (GPA), to the qualitative assessment of animal behaviour. FCP elicits spontaneous descriptors of animal behaviour (e.g. "calm", "confident", "anxious"), and the level of consensus in those assessments among a group of observers can be calculated with GPA. Such descriptors have an expressive connotation that is relevant to how the animal perceives its immediate environment. This is preferred over other methods that focus on separate demarcated aspects of an animal's response such as when observers may be directed to make judgements based on pre-determined lists of indicators or body postures thought to reflect an animal's experience (e.g. flattened ears signal fear).

A number of QBA studies in pigs and other species have shown good internal validity (i.e. high levels of inter- and intra-observer reliability and repeatability) (Wemelsfelder 2001, 2009, Rousing and Wemelsfelder 2006, Walker 2010). Furthermore, external validity of QBA has been shown through correlations with quantitative behavioural measures (Napolitano et al., 2008; Minero et al., 2009 Rutherford 2012) and physiological indicators of stress in cattle (Stockman 2011) and sheep (Wickham 2012). Importantly, a recent paper further strengthens the biological validity of QBA as observer judgements were shown to be sensitive to the altered emotional state in pigs achieved through pharmacological intervention with an anti-anxiety drug (Rutherford 2012). Thus, this strongly supports the notion that QBA can be used as an outcome measure of emotionality (the affective state) in animals. A recent review of methodologies that might be used to assess positive welfare states in cattle concluded that QBA was 'the most promising assessment methodology' (Napolitano et al 2009). The UK Farm Animal Welfare Council report (FAWC 2009) has similarly indicated the important role that QBA could play in assessing the consideration of positive welfare states in animals.

A strong point of qualitative methodologies is that, given their integrative nature, they are sensitive to the context in which the observation is made. As many animal welfare studies seek to compare how animals cope in various contexts, there is a risk that contextual bias may occur if observers were to

compare an environment they considered morally 'good' with one considered 'poor' (e.g. an enriched versus a barren environment). Wemelsfelder (2009) investigated how the perceived environmental background affects observers' assessments of pigs by comparing observers' judgements when the same subjects were viewed against an indoor and outdoor background by digital modification. High correlations were found between the pig scores viewed in both settings indicating that QBA is sensitive to context but this sensitivity does not weaken the reliability of such assessment.

Some concern for qualitative methodologies remains as to whether cultural backgrounds of observers and different levels of experience with animal behaviour observations may affect the reliability of observers. Napolitano et al (2012) supports previous QBA studies that have compared assessments from groups of observers with different nationalities and cultural and experiential backgrounds and shows reliable, high levels of inter-observer agreement between groups.

QBA represents a component of the multi-criteria Welfare Quality Project, a program designed to develop reliable on farm monitoring systems across the European Union. Further discussion of the Welfare Quality Project occurs in a subsequent section of this review. Hence, the studies described above suggest that QBA has the potential to integrate other scientific measurements of animal welfare and to be used as a practical tool for on-farm welfare assessment and surveillance.

Assessment of positive states

Consideration of positive welfare implies that good welfare is not just about the elimination of poor welfare but also includes aspects such as positive affective state (Yeates and Main 2007). While positive welfare has long been viewed by many citizens as an important aspect of good livestock husbandry, it has only recently become subject to critical scientific analysis. Methodologies to assess the capacity of livestock to experience positive mental states have been reviewed (e.g. Boissy et al. 2007; Yeates and Main, 2007; Mendl et al., 2010). While there are no unambiguous measures of positive states in livestock, there are a number of promising avenues under development. Fundamental neurobiological studies of feeding indicate that there are distinctive neural systems (and neurotransmitters) associated with the affective states (e.g. pleasure of having attained a reward, called "liking") and the motivation to obtain the reward ("wanting") (Berridge 1996; Berridge 2003). Wanting and liking are functionally and neurologically inter-related (Berridge and Robinson 2003). Thus, behavioural and physiological indicators of the states of liking and wanting would be useful candidates for measures of positive states. The demand function methodologies outlined earlier, and positive anticipatory behaviour (van der Harst et al 2003) are useful procedures for quantifying wanting. Methods for measuring "liking" include behaviours such as facial expressions and vocalisations, changes in cognitive functioning, immune and sympathetic nervous system parameters, and brain imaging techniques (for more detail see reviews by Boissy et al.

(2007) and Yeates and Main (2007)). Interestingly, approach-avoidance behaviour (rather than the more usual measures of heart rate variability and high frequency vocalisations) has been identified as one of the best ways to assess the emotional valence of a situation in pigs (Imfeld-Mueller et al., 2011).

Indicators for positive welfare states that are suitable for on farm assessment have not been described; however appropriate environmental stimulation would favour good welfare and allow animals the opportunity to exhibit certain behaviours. Promising measures of positive indicators of cattle welfare include play behaviour which in calves is mainly expressed as locomotor (bucking and trotting) and social activities (rubbing and butting heads, play fighting), and social licking behaviour (Napolitano 2007^b). A prominent aspect of the social behaviour of cattle is that these animals are gregarious and under semi natural or extensive conditions, their behaviour is highly synchronised. Thus a high degree of synchronisation of behaviours within the herd may indicate a positive welfare state (Metz 1983). As such behaviour may only occur at specific times of the day and between certain sub groups, making an instantaneous scan sampling technique is problematic (Napolitano 2007^b). Hence the low feasibility (time consuming) and a lack of research into the reliability of play and social behaviours, means these types of measures, are not suitable for easy implementation into an assessment scheme.

Self administration of analgesics

A novel approach based on the measures of an animal's readiness to self-medicate analgesics, is particularly applicable to quantifying an animal's subjective experience of painful events. Danbury et al. (2000) trained broilers to discriminate between different sources of feed (with or without an analgesic). Lameness increased, lame birds selected significantly more analgesic feed than sound birds, and as the severity of the lameness increased, lame birds consumed a significantly higher proportion of the drugged feed. Thus, the severity of pain can be assessed from the measures of the amount of analgesic an animal will consume. This approach provides the most direct method for quantifying subjective experiences of pain and should be used much more widely in welfare assessment.

The combination of the behavioural economic and analgesic consumption methodologies, in which demand functions for access to analgesics by lame animals are determined, could provide additional explanatory power regarding chronic pain. This "treatment demand" methodology would provide a more quantitative framework, and allow assessment of the animal's experiences without the potential confounding effects of large differences in drug/food consumption between treatments.

A variation on the treatment-demand methodology could be developed for quantifying other potentially unpleasant health conditions e.g. gastro-intestinal malaise, where animals could work for access to antacids or other treatments. With this range of methodologies it should be possible to extend the

analysis of animals' experiences to a much wider range of potentially unpleasant challenges that has hitherto been possible or undertaken.

There has been steady progress in the development of experimental methods to assess affective states in animals. Preference testing and behavioural demand have been applied most frequently in this context. There are a number of promising behavioural and neurophysiological methodologies currently being evaluated. The ultimate utility of these new methods will be underpinned by their external validity (ie. correlations with other independent measures of welfare state). QBA offers the most promise for the assessment of affective states on-farm.

4.3. Integration of response measures - biological function and affective state

There are a number of different generic approaches that can be applied across species for integrating and linking the various societal/scientific aspects of the animal welfare debate, and which can be used to establish valid, practical indicators of welfare.

Using a cold challenge model with dairy cattle, Matthews and Bryant (2011) have demonstrated there is a good match between measures of affective state (as revealed by the animal making trade-offs between two highly valued but mutually-exclusive choices (shelter and rest)) and the level of biological functioning (as assessed by the energetic requirements to maintain thermal balance). Further, it was demonstrated that a practical measure, which reflects the degree of welfare challenge experienced on both the affective state and biological function dimensions, can be predicted from the degrees of cold below thermo-neutrality. A similar methodology has been used to assess the convergence between affective state and biological function in a heat stress model with dairy cattle (Arnold and Matthews, 2010). Similarly, Nicol et al. (2011) have shown that hens choose environments associated with lower stress (i.e. lower corticosterone levels and lower faecal water content). Preferred environments were also associated with behaviours such as less head shaking, self-scratching, standing alert and feeding, and more foraging, suggesting that responses such as these responses are indicators of good affective and physical states. With sheep and using a slightly different measure of affective state, a similar convergence between an animal's subjective experience of hunger and its requirements for energy has been demonstrated, both of which can be assessed practically with measures of body condition score (Verbeek et al., 2010, 2012^a, 2012^b.) There is, thus, good evidence that this general approach can be used to establish and validate a

range of quantitative, practical measures of welfare that reflect both the physical and emotional challenges faced by livestock.

Lateralisation

There is increasing evidence that degree of lateralisation (or handedness) can be used as a measure of both the affective and biological responses of animals to challenge (Matthews et al., 2012).

Typically, animals show a preference to use one of a pair of bodily organs, or asymmetry in the use of medial organs, such as the tail (Quaranta et al., 2007). Strength of 'handedness' reflects (normal) right brain hemispheric specialisation for processing aversive emotional experiences (Kendrick, 2006) and a more responsive HPA axis (Westergaard et al., 2003). In sheep (Hernandez et al., 2009^{a,b}, 2010) and other animals (Westergaard et al., 2003) stress inhibits handedness and emotionality. Measures of lateralisation have the advantage of perhaps being a relatively practical measure of welfare: the emotional and physiological responsiveness to an event can be assessed from such measures as the proportion of animals using their left versus right eye to evaluate the situation (Lippolis et al., 2005)

Chronobiological measures

There is strong temporal (chronobiological) organisation of essential behavioural and physiological functions of animals and disruption to the patterning of activities can be used as a generic indicator of welfare status, for both health/disease diagnosis and non-health related conditions (Bergen, 2011). For diagnostic or welfare assessment purposes, the patterning of behaviour can be described quantitatively with a variety of mathematical functions (e.g. fractals, Rutherford et al., 2004) and compared with species-typical norms. While chronobiological measures require frequent monitoring of behaviour or physiology, recent developments in automated and remote monitoring technology, especially when combined with GIS

https://online.tugraz.at/tug_online/fdb_detail.ansicht?cvfanr=F28667&cvorgnr=37&sprache=2

offer unprecedented opportunities for practical animal welfare assessment.

Methodologies based on the integration between biological function and affective state measures have been successfully applied in livestock studies. They offer a more robust and compelling determination of welfare. Emerging methods such as the assessment of lateralisation offers promise in the context of unifying biological and affective responses in animals.

4.4. Can welfare measures function as diagnostic tests?

Standardised measures or diagnostic tests are widely used for establishing the disease status of farm animals and humans. The tests are usually accredited for their diagnostic performance against standardised criteria including specificity, sensitivity, predictive value of a positive and predictive value of a negative as outlined in the figures below (Greiner and Gardner, 2000).

Diagnostic test	Gold Standard	
	Positive	Negative
Positive	True Positive	False Positive
Negative	False negative	True negative

Sensitivity and Specificity

- Sensitivity
 - the likelihood that a positive test result detects an animal that is positive for the gold standard $(TP/(TP+FP)) \times 100$
- Specificity
 - the likelihood that a negative test result detects an animal that is negative for the gold standard $(TN/(TN + FP)) \times 100$
- Predictive value of a positive
 - the likelihood that a positive test result comes from an animal that is positive for the gold standard $(TP/(TP + FP)) \times 100$
- Predictive value of a negative
 - the likelihood that a negative test result comes from an animal that is negative for the gold standard $(TN/(TN + FN)) \times 100$

For definitions see: Greiner and Gardner, Prev Vet Med 45:3

While diagnostic tests are typically used to identify infected versus not infected animals, some tests are also used to quantify the severity of an infection or a disease state (e.g. (Colditz and Le Jambre, 2008). In Australia, diagnostic tests for infectious disease are accredited through SCAHLS (<http://www.scahls.org.au/>) while best practice accreditation of laboratory standards for using diagnostic tests is provided through NATA (<http://www.nata.asn.au/>). In analogy with diagnostic tests of the severity of infection, measures of animal welfare can be considered to be tests aimed at detecting both the disease state of compromised welfare and the severity of that compromise. However, no individual measure described above (Table 1) approaches the level of sensitivity or specificity required for a reliable diagnostic test of compromised welfare. This shortcoming arises both from the diversity of physiological, behavioural and affective states that are considered either individually or in combination to constitute compromised welfare and the diversity of environmental, social, infectious and traumatic challenges that can perturb the individual measures without necessarily being considered to compromise welfare. Thus individual welfare measures fail in the standard performance criteria of sensitivity and specificity to diagnose compromised welfare. As a result, a suite of measures is routinely adopted for assessing welfare states. The aspiration for tests of animal welfare that achieve the sensitivity and specificity of diagnostic tests of infectious disease is unlikely to be met while ever the multiple dimensions in which welfare can be compromised remain clustered within the single common descriptor, animal welfare. A substantial challenge for measures of welfare is to define cut off points between positive and negative, good and bad, or acceptable and compromised welfare.

Two scientific approaches to define the boundaries between normal and abnormal are commonly employed. The first uses reference values for the species, or for a subgroup of the species such as a breed when this differs from the species values (Lepherd et al., 2009). Reference values are established through measurement of a large sample of normal individuals from the population and the distribution of normal values described by statistical parameters such as mean and 95% confidence intervals. Reference values permit interpretation of measures made on a single subject to determine whether the individual is clinically normal or abnormal. The second method uses statistical analysis of variables measured on the experimental or study groups under investigation. When animals within two or more groups are housed or managed in a way that lets contrasts be performed between the groups, statistical tests permit comparison to be made between the groups using the data from those groups in isolation of reference values for the species or breed. The important feature of the second approach is that statistical differences between values measured in the different groups or treatments can be detected that lie within the reference values for that

variable within “normal” animals. Ascertaining the impact on welfare of treatments or management procedures that lie within the normal range remains a challenge for animal welfare science.

One approach to this challenge would be to establish a set of reference values for combinations of variables, taking into account interrelatedness of variables and the impact on the animal of having multiple variables simultaneously deviating from the mean.

Individual measures fail in the standard performance criteria of sensitivity and specificity to diagnose compromised welfare which is why a battery of measures is routinely employed. A key constraint is the lack of suitable reference values or critical thresholds for measures.

5. On-farm welfare assessment measures and systems

There are a number of key drivers underpinning the need for welfare assessment systems on-farm.

These include:

- (i) Increasing societal concern about the treatment of animals and the need to further improve aspects of livestock production and to demonstrate these improvements to consumers.
- (ii) Profitability in key markets will be influenced increasingly by the growing global trend of ‘ethical consumerism’ (Clarke *et al.* 2007) in which attributes such as animal welfare are becoming seen as components of food quality and hence influence consumer purchasing choices. Concomitantly, there will be an expansion in the demand for so-called “ethical foods” that satisfy the expectations of (relatively affluent) consumers seeking products that exceed regulated standards for animal welfare. This in-turn will require the establishment of a regulatory or accreditation framework that provides confidence to all stakeholders in the “truth in labelling” of the animal welfare and other ethical claims made for products.
- (iii) The future growth in the human population will require an estimated 60% global increase in agricultural productivity by 2050 (OECD/FAO, 2012). To service this growth, there will need to be an intensification of animal production and farming, which is likely

to occur at least in part through an expansion in the number and activity of large corporate and sovereign business entities. Furthermore, there will need to be further gains in the efficiencies of animal production. Collectively, these trends will continue to invoke societal and consumer concerns. Therefore, there will be a strong imperative to demonstrate that the welfare of livestock is optimised in future farming systems.

Despite the compelling need, no accepted comprehensive fully-validated system of welfare evaluation currently exists. Finding an acceptable welfare assessment system that is acceptable to all stakeholders is problematic. Various stakeholder groups tend to differ in the value frameworks under which they operate, although there are also differences within stakeholder groups depending on factors such as culture and experience with farming practices (e.g. Evans and Miele 2007). Nevertheless, citizens/consumers are more likely to emphasise natural living, mental/emotional wellbeing and quality of life, while producers are more likely to align with the concept of physical fitness and biological functioning (e.g. Kjaernes et al., 2007; Matthews et al., 1994).

Further, it is obvious that different stakeholders will have different requirements for measurement methodologies and systems. Producers are primarily interested in indicators that will give them an early warning of impending conditions that will adversely affect the biological functioning and fitness of their livestock (Manning *et al.* 2007), regulatory agencies have a prime interest in compliance with minimum legal standards (related to the Five Freedoms in Australia), and marketing/retailers wish to see compliance with a comprehensive set of standards that reflect the views of their customers. Surveys undertaken in developed world markets indicate that consumers place high importance on emotional wellbeing, a state which is not currently readily assessable in animals (Kjaernes *et al.* 2007). Animal welfare advocacy groups/NGOs vary greatly in their needs for scientific assessment of welfare status. The moderate groups such as the Royal Society for the Protection of Animals (RSPCA) and Compassion in World Farming (CIWF) seek information to support their own welfare assurance schemes or campaigns along the lines of the Five Freedoms but with increasing emphasis on animal feelings. The more radical groups are heavily influenced by their beliefs and their actions may not take account of scientific information about welfare status. In practice, there is a mutual dependency between the key stakeholders (producers, marketers, consumers, advocates), so the information needs will need to reflect this.

Societal concerns, ethical consumerism and global food security are just some of the key drivers behind the need for farm animal welfare assessment systems. Despite a clear need, no one ideal system exists and this is highly unlikely given the diverse needs and interests of stakeholders.

5.1. An ideal welfare assessment system

While the various stakeholders may, historically, have had different motives for developing and implementing welfare monitoring systems, the inter-dependencies between the different parts of the supply chain is leading to a convergence in the characteristics, requirements and application of welfare assessment. Simply stated, the assessment system must provide information that: enables producers to predict and maintain good standards of physical and mental wellbeing in their livestock; provides evidence that these standards have been achieved; and, demonstrates that the welfare outcomes are consistent with all three ethical frameworks.

Implicit in welfare assessment systems is the notion that it is possible to compare welfare standards between different production processes and systems, and rate each of them against some desired standard (e.g. Laywel, 2006). In other words, assessment procedures will require the application of methodologies to measure and rank the overall standards of welfare in different farming systems. It has been argued by some (e.g. Fraser 1995; Fraser et al 1997) that it is technically not possible to reduce welfare measurement to a single dimension and, therefore, it is not possible to compare overall standards of welfare. It is acknowledged that there are several major hurdles to be overcome in the development of overall welfare measurement systems e.g. ways to weight and integrate different welfare domains, but several research teams around the world are making progress in this area and alternative ways forward are detailed below.

Thus, an ideal assessment system would have the following features:

- The measures must be underpinned by scientific evidence demonstrating their validity (i.e. directly reflect the welfare states relevant to stakeholders). The measures will most likely be outcome-based, although some input measures (resources or management procedures) may also be relevant
- A framework for assessing the trade-offs or weightings between different welfare domains (e.g. nutrition, health)
- A methodology for integrating the weighted domains to develop an overall welfare index
- A method for identifying biologically relevant thresholds corresponding to different levels of welfare (e.g. minimum standard, gold standard)
- From a practical perspective, the measures must be technically feasible and implementable, reliable, reproducible, provide an early indication of impending welfare concerns so that

livestock managers can take preventative action, and reflect the animal's welfare state over the assessment period.

For welfare monitoring on farms, the aim is to find feasible measures of proven validity and reliability that can be taken from a large sample of animals. The measuring tool or system must be simple, easily operated by trained people and require minimal time and handling of the animal. Non-invasive ratings by human observers to assess a range of animal welfare variables offer some practical advantages as they are inexpensive, can be used to integrate multimodal information across time and context and have been shown to be reliable and valid (reviewed by Meagher 2009). However, if observers are required to use complex check lists at each farm visit, the inspection may be too time consuming and discourage producer adoption. Some measures are regarded as less objective than others and have the potential to be affected by the attitudes and experience of the assessor. Thus, whatever measure is chosen, and irrespective of how many observers are required, tools to check for consistency and objectivity between observers are required to ensure robustness.

The ideal welfare assessment system would have the following features:

- Measures underpinned by scientific evidence demonstrating their validity
- A framework for assessing the trade-offs or weightings between different welfare domains
- Integration of the weighted domains to develop an overall welfare index
- Biologically relevant measurement thresholds corresponding to different levels of welfare
- Practical, repeatable and reliable measures that provide an early indication of impending welfare concerns.

5.2. On farm assessment

A number of different welfare assessment systems have been developed and implemented throughout the world - though none meet the requirements for an ideal system (see above). Several examples are discussed below in order to illustrate some of the methodological issues with animal welfare assessment, and the implications for development of practical welfare assessment protocols. One major observation is that most welfare assurance/assessment schemes focus on how well the farms comply with the given standards and do not make a scientific evaluation of welfare.

Five freedoms

Traditionally, the Five Freedoms (Farm Animal Welfare Council (FAWC) 1993), or variations of them, have been used as an aspirational framework to guide welfare assessment. The Five Freedoms have been modified to reflect a more pragmatic approach to animal welfare assessment in recent legislation in the UK (Animal Welfare Act, 2006) and include the following needs:

- for a suitable environment (place to live)
- for a suitable diet
- to exhibit normal behaviour patterns
- to be housed with, or apart from, other animals (if applicable)
- to be protected from pain, injury, suffering and disease.

As discussed, the adequacy of this wording for covering the diversity of ethical views is questionable.

Input and output measures

Traditionally farm animal welfare assessment has focused on the environmental observation of resources, or inputs provided to the animals on commercial farms. These are indirect measures that typically assess the quality of the management and stockmanship (e.g. space, food) and are attractive because their measurement is quick, simple and reliable. However, direct animal-based measures or outputs which include measures of animals' response to what is provided are thought to more accurately reflect how an animal is coping within its environment. For example, the animals' physical fitness, health or behaviour (e.g. mortality, reproductive performance, and injuries) may give a better indication of the long term adequacy of a production system.

A key advantage of output or animal-based indicators is that variation in conditions within and between geographical regions, production systems and other features can be accommodated with different management practices and yet remain consistent with legislative requirements. For example, variation in climate conditions may result in different demands for the quality of resting area or space allowance. Such differences are difficult to resolve if only defined by resource-based indicators. It might be easier, for instance, to use animal-based indicators to assess the degree of resting comfort under differing management conditions. However, one concern is that is that many animal-based indicators have yet to be demonstrated as valid measures of animal welfare. To date, most of the research on animal-based indicators has been on reliability issues rather than the validity of the measures.

Even the most widely-applied animal-based measures have not been scientifically-validated.

Scandinavian and EU legislation provides for the compulsory evaluation of foot health in meat chickens.

Foot health is typically achieved by scoring the incidence and severity of foot pad dermatitis (Berg & Algers, 2004), yet until recently there had been no scientific research on the implications of foot (or hock) burn in terms of pain and changes in behaviour. Gait scoring for lameness in meat chickens is another widely-used animal-based indicator of welfare. Some authors (Knowles et al., 2008) have stated that a Gait Score of 3 and above is a sign of poor welfare yet the validity of this measure, too, has only been recently been properly evaluated (Defra, 2012).

Fortunately, progress has been made validating some output measures. The best recent example is the scientific validation of body condition score (as an indicator of chronic hunger) in sheep, (Verbeek et al., 2011, 2012^{ab}), dairy cattle (Matthews et al., 2012) and beef cattle (Ferguson et al., 2012). However, there is an ongoing need to continue validating animal-based measures as indicators of animal welfare.

Another important issue in this context is that collecting animal-based indicators typically requires greater effort in comparison with that required for resource-based or management-based indicators, particularly for animal-based indicators collected on-farm. This has been one of the important criticisms of the Welfare Quality® protocol especially amongst practitioners (veterinarians and farmers). One way to make collection of animal-based measures less onerous is to take the measures in the abattoir post-slaughter using automated recording systems (Valros et al., 2004). Although post-slaughter indicators are not able to be used to manage welfare during the animals' life time, the information can be used to identify issues that can be fed back to the farmer or can be used for risk-oriented control of the farms in question.

The collection of animal-based measures is particularly problematic in extensive grazing systems. Typically, livestock are generally only mustered a few times a year for management and husbandry procedures, with additional inspections occurring with the monitoring of water supplies and fencing. This infrequent monitoring therefore creates major challenges with respect to welfare assessment. Furthermore, the significance of this is further accentuated when considering the profound production challenges that occur in extensive grazing systems such as seasonal variations in food supply, climatic extremes and variability, parasitism and predation (Petherick and Edge 2008). The development of remote animal measurement and monitoring technologies will provide producers with increased capacity to monitor animal movement and possibly health in these extensive environments. Several research studies have shown wireless sensor networks can monitor animal location and health indicators (e.g. rumen temperature) (Mayer et al., 2004) and can estimate behaviour such as landscape avoidance and selection behaviours (Swain et al., 2011).

As stated, most of the welfare monitoring systems that have been developed are based on input or resource measures. They offer practical advantages as it is easier to collect objective observations of resource provision compared with the more subjective assessment of the outcomes (Main & Webster 2011). These resources are presumed to affect animal welfare but links between specific measures of them and the animal welfare status are not clearly understood (Blokhuis et al., 2006). Furthermore, unless there is close correspondence between input variables (e.g. climatic parameters) and output measures (e.g. heat stress), welfare standards based on input measures will not always guarantee good welfare (Main et al 2003; Offner et al 2003).

Stocking density has been a widely-used input parameter in legislation, government-approved welfare codes and in industry, NGO and corporate welfare assurance schemes aimed at protecting animal welfare during intensive-rearing practices. Yet, there has been a paucity of scientifically-credible evidence to determine the appropriateness of stocking density as an indicator of welfare under commercial production conditions. Its shortcomings were amply demonstrated by Dawkin's and colleagues (Dawkin's et al., 2004; Jones et al., 2005), who examined the effects of stocking density on meat chicken welfare. Contrary to several other studies conducted under laboratory conditions, it was shown that stocking density had no effect on a broad range of welfare measures (e.g. mortality, gait score, pododermatitis) at densities used in typical commercial practice. Variation in other input measures (such as environmental temperature and humidity) have been associated with some chicken welfare problems, but as the relationships were weak, they too would not be ideal welfare indicators.

Given there is no agreed gold standard for the determination of welfare for animals, careful interpretation of data collected from a range of parameters is required. The relative weighting assigned to each parameter selected is critical for effective outcomes and comparisons between enterprises. Further discussion on the different approaches to the integration and weighting of parameters into a practical index is required before assessments of welfare taken in the field can be truly effective (part 2 of this review). Once these welfare indices have been scientifically proven, there will be a need to inform retailers and consumers alike so that consumers can make informed decisions on animal products.

Another good example of using a combination of input and output measures is that used in commercial cattle feedlots in Australia to predict and manage heat stress events. By using a combination of observed local climatic conditions and animal responses to the heat (panting scores), feedlot managers can manage risks and implement strategies to reduce the impact of severe hot

weather (Gaughan et al., 2008). Additional indices, namely the heat load index (HLI) and the accumulated heat load (AHL) determine the animal's heat load balance taking into account the duration of daily heat exposure and the availability of natural cooling at night (Gaughan et al., 2008). Using the new HLI and AHL indices that have been incorporated in to a Web-based model, feedlot managers can determine specific heat risk assessments for different cattle genotypes on a daily, pen by pen basis if required. Although the physiological impact of heat stress on beef cattle has been well quantified and provides sufficient evidence to merit intervention, the impact of heat stress on the animal's experience and its affective state remain unknown (Matthews 2008).

The utility of input and output measures is perhaps best summarised by the European Food Safety Authority (EFSA, 2012). The EFSA view is that input measures are more suited to identifying situations that pose a potential hazard to welfare and that output or animal based measures are more appropriate for assessing welfare and evaluating the effects of management procedures to improve welfare. We support this position.

Welfare quality[®]

By comparing the assessment systems currently in place with the set of ideal requirements outlined earlier, the limitations of the current measure methodologies are readily apparent. These limitations are becoming more widely acknowledged (e.g. Farm Animal Welfare Council, 2005) and research is underway around the world to address them. The largest research project of this kind in the world is Welfare Quality (Veissier *et al.* 2007) based in the European Union (EU). A unique feature of this project is the linking of an understanding of societal values and concerns about animal welfare in production processes with the development of appropriate measures. Twelve key elements of animal welfare (Table 2) have been identified and these have been shown to encompass all aspects of welfare underlying the value frameworks of a majority of EU citizens (Kjaernes *et al.* 2007). The protocol covers a slightly wider range of animal attributes than the Five Freedoms by including specific categories including good human-animal relationship and a positive emotional state (even though definitions and assessment criteria remain questionable for emotional status). For example, in the Welfare Quality protocol used to assess the welfare of pigs at slaughter (Velarde and Dalmau, 2012), positive emotional state is measured by recording the incidence of 'reluctance to move' or 'turning back' activities. Clearly, these behaviours reflect aversive experiences of the animals and the absence of these behaviours does not necessarily imply a positive emotional state.

Currently, Welfare Quality is focussing more on the practical aspects of measurement (i.e. feasibility, reliability) than on validity. While these are important issues that need addressing, there is also a clear requirement to address the remaining deficiencies in welfare assessment methodologies.

TABLE 2: Welfare principles, criteria and some examples of potential measures for each welfare criterion

Principle	Welfare criteria	Examples of potential measures
Good feeding	1. Absence of prolonged hunger	Body condition score
	2. Absence of prolonged thirst	Access to water
Good housing	3. Comfort around resting	Frequencies of different lying positions, standing up and lying down behaviour
	4. Thermal comfort	Panting, shivering
	5. Ease of Movement	Slipping or falling
Good health	6. Absence of injuries	Clinical scoring of integument, carcass damage, lameness
	7. Absence of disease	Enteric problems, downgrades at slaughter
	8. Absence of pain induced by management procedures	Evidence of routine mutilations such as tail docking and dehorning, stunning effectiveness at slaughter
Appropriate behaviour	9. Expression of social behaviours	Social licking, aggression
	10. Expression of other behaviours	Play, abnormal behaviour
	11. Good human-animal relationship	Approach and/or avoidance tests
	12. Positive emotional state	Qualitative Behavioural Assessment (QBA)

A number of different welfare assessment systems have been developed and applied on-farm - though none meet the requirements for an ideal system. Traditionally these systems are input-based focusing on assessments of the animals' environment and resources. Whilst useful, these assessments have limitations and there has been increased emphasis on developing and applying animal-based or output measures. Systems based on the integration of input- and output-based measures are starting to be applied – EU Welfare Quality®. Although more comprehensive, on-going demonstration of validity and practicability is required.

On-farm welfare quality assurance schemes

Formal welfare assessment and audits of animals on farms may be required for voluntary farm assurance schemes or to ensure relevant welfare legislation and industry standards are enforced. Farm assurance can affect the welfare of animals through encouraging improvements in welfare by setting good standards of provisions for animals and encouraging continuous improvement. If farm produce is to be certified with a label that implies the produce is derived from farms meeting certain conditions, including welfare, consumers and trading partners must be assured that such farms are monitored and audited against an agreed set of welfare indices. Farm assurance bodies claim to offer whole chain assurance from the farm to the consumer – farm to fork- encompassing farmer, haulers, abattoirs and suppliers (Whay, 2008). Quality Assurance (QA) is defined as ‘a planned and systematic set of activities to ensure that requirements are clearly established and the defined process complies with these requirements’ (Isixsigma 2012). Farm QA schemes were first developed in the UK in the early 1990’s and currently, there are 12 voluntary schemes assuring consumers that the food is of high quality while upholding good animal welfare and environmental standards (Hubbard 2012). The longest standing assurance scheme is the UK based RSPCA’s Freedom Foods which covers a range of species.

Farm assessment is an increasingly valuable component of the agri-food industry for creating quality driven food markets (Buller and Roe 2012) yet the success of such markets will rely heavily on the integrity of the assessment and auditing process. These assurance schemes are recognised as the key tool for assessing on-farm welfare (Veissier et al., 2008) and allow consumers ‘buying power’ as they can make better informed choices when purchasing animal products. The bodies that set the standards have sometimes been linked to large retailers and employed inspectors to check compliance with rules laid out in the standards (Whay 2008). Different QA schemes place different emphasis on food safety, animal welfare and the environment. For example, the RSPCA Freedom Foods is primarily designed to ensure high standards of animal welfare, but the Red Tractor Scheme is designed to ensure compliance with food safety, sustainability and environmental protection, in addition to animal welfare standards. Hence the development of robust monitoring protocols for welfare and husbandry underpins the effectiveness of any welfare-based quality assurance.

In Australia there has been considerable effort towards the development of standards and/or QA programs that incorporate animal welfare, both nationally (e.g. Barnett and Glatz, 2004; Edge et al., 2008) and internationally (e.g. Blokhuis et al., 2003; Main et al., 2003). A major challenge is for QA programs is the interpretation of data within a variety of production systems.

On farm assurance requires an inspector to visit farms to gather evidence in terms of records and health data, to observe management and to assess of a number of individuals on each farm audited as a representative sample. The RSPCA Freedom Foods scheme has laid out standards of animal management, based around the Five Freedoms that if complied with, are believed to inevitably lead to good animal welfare. The Freedom Food scheme covers every stage of a farm animal's life; each stage governed by strict and compulsory RSPCA welfare standards covering handling, transport and slaughter and now exists in Europe and Australasia. Products labelled with Freedom Food logo are available for purchase for customers shopping with an ethical agenda including animal welfare. These products are sold at a higher price and it was initially thought that farmers who joined the schemes would be able to command a premium price, but with the exception of beef products, the premium payment has not yet filtered through to the producer (Whay 2008). Many farmers now perceive farm assurance as a costly time consuming exercise with which they have no choice but to comply (Whay 2008). Freedom Foods and other schemes including those used by McDonald's continue to implement animal-based welfare assessments within its scheme using protocols based on the Bristol Welfare Assurance Program. These schemes include those applied to animals in abattoirs which appear to have been effective in improving welfare (Grandin 2007).

The Austrian Animal Needs Index (ANI) is an example of an on-farm assessment program which has been used in Europe (Bartussek et al., 1999) and Asia (Seo et al., 2007). The current version for cattle is called ANI35L/2000-cattle and has been widely used for certification and legislative purposed for many years. The ANI system has been in use for dairy and beef cattle, laying hens and pigs. This index has the following five components (sheets) to assess animal welfare:

- sheet 1, affording movement and locomotion (Locomotion),
- sheet 2, affording social interaction (Social interaction),
- sheet 3, type and condition of flooring (Flooring),
- sheet 4, light and air conditions (Light and Air) and
- sheet 5, stockmanship (Stockmanship).

This system assesses the welfare level on farms based on environmental parameters, not the actual state of the animals. These categories are assessed and recorded on each evaluation sheet by the assessor, each visit taking one hour. Points are assigned to several parameters within each of the five categories. The total of the points in all sheets is the ANI score with high ANi scores indicating better welfare levels. Correlations between the ANI score and behaviour and health parameters have provided some validity of the index (Ofner 2003). However, it remains unsuitable for assessing

restricted housing such as battery cages for layer hens or sow crates because the scoring system requires minimum standards to be fulfilled. Certain assessment parameters have proven to be difficult to judge especially in the stockmanship category, as they included subjective criteria for scoring items such as cleanliness, floor slipperiness and animal health (Seo et al, 2007). Thus, much more detailed information about evaluating such criteria and the relevance of the criteria to animal well being is needed.

The Bristol Welfare Assurance Programme is a good example of a more comprehensive animal-based assessment scheme (www.vetschool.bris.ac.uk/animalwelfare). The protocols for monitoring farm welfare here are very detailed, species specific and based on the principles of the Five Freedoms. These operational welfare assessment protocols are primarily based on animal parameters that have been developed, initially for dairy cows (Whay et al., 2003). For example, for dairy cattle under the principle of freedom from hunger, a body condition assessment is made. Under the provision of freedom from discomfort, a measure of the number of painful conditions such as swollen hocks, and swollen udders are noted. The methodology of how each indicator should be measured is provided. The information gathered from the comprehensive indices of welfare from each farm assessed is circulated to 50 experts who are asked to indicate the herd prevalence which would indicate a welfare problem. For example, what incidence of lameness or percentage of thin cows on dairy farms would the experts recommend intervention at the herd level? Thus, the interpretation of the significance of any health criteria is paramount.

Quality assurance programs can have a role in influencing animal welfare through the standards they set and by providing incentives for good animal welfare. Although there is no evidence in the UK yet, a farm that shows an unacceptably high cost to animal welfare could lose its certification status (Whay 2008). For a scheme to succeed it must operate both on the farm and at the retail end so any added-value is passed on at every link in the food chain, to reward the farmers by informed consumers. Programs must not only incorporate a means to identify the prevalence of a welfare problem but must ensure effective intervention for continuous improvement. Webster and Main (2011) state that many of the assurance schemes are still young and as yet there is little evidence from which to truly assess their impact.

In addition, farm assurance could act as a route for information and knowledge transfer to the consumer, and back to farmers to engender pride in good achievements. Buller and Roe (2012) describe the increasing trend for animal welfare to be commodified, that is for welfare to be a 'value-added' component. However, few retailers believe that 'welfare sells' and reject the notion

of a standalone 'welfare label'. Increasing support for free range systems for egg production, which is a system- or input-based measure of welfare and one that may not always represent high welfare for the birds, questions the role for the new range of output-based measures in the minds of consumers. Thus, there will be an additional need to convey messages to consumers, perhaps through labelling, regarding the importance of using animal outcomes as measures of welfare.

Welfare auditing introduces an additional layer of independent monitoring. Inspection for farm assurance involves measuring or testing parameters on the day of the visit and then comparing data to a standard. However, welfare auditing involves providing assurance that the practices observed on the day of the inspection are likely to be sustained in the future. This involves ensuring problems are prevented, re-evaluating inspection outcomes and involves herd health planning (Whay 2008). Finally, an effective assessment system involves a means of integrating the weighted input- and output-based components into an overall index and concurrently determining relevant thresholds for at risk animals. Does farm welfare assurance deliver good animal welfare?

Just how effective these assurance schemes are on ensuring high animal welfare standards is unclear. A recent UK report showed an association between farm assurance scheme membership and increased compliance with welfare codes and legislation from 2003-2008 (KilBride et al., 2011). However, there were differences between countries and associations varied across enterprise types and there was insufficient evidence to analyse the effect of schemes standards that exceed welfare codes.

The impact of the RSPCA Freedom Food scheme on the welfare of dairy cattle was studied and outcomes of measures compared between farms belonging to the Freedom Food scheme or other schemes (Main et al., 2003). The Freedom Food farms performed less well for welfare indicators including hock injuries, lameness and restrictions in rising behaviour, but Freedom Food farms performed better in terms of indicators of mastitis, cleanliness and body condition. However, regardless of the scheme, welfare problems remained prevalent indicating that setting standards of provision alone is insufficient to ensure good welfare (Whay 2008). The Scottish Agricultural College (2007) compared the welfare of dairy cows in organic milk production systems and showed that levels of lameness and hock damage were lower on organic farms as a result of shorter winter housing periods and a higher age of first calving heifers which are both elements of the more extensive housing approach described in organic standards. Whay (2008) concludes that with the exception of Freedom Foods and Soil Association Certification there is little evidence of a genuine

effort among farm assurance schemes in the UK to use their role to push for animal welfare improvement on farms.

Another important question when assessing the welfare status of livestock on farms is: how many animals should be sampled in the assessment procedure? The answer is not simple as it depends on finding a balance between time constraints in conducting the assessment and the level of accuracy required at the individual or farm level. There have been several recent studies exploring this question. Main et al. (2010) reported that, for larger herds, a sample size of 100 cows is required. However, if the goal is to detect farms, rather than individual animals, with a lameness problem, then focussing on the numbers of cows with severe lameness at the end of milking is an efficient strategy. Alternatively, concentrating assessments on the middle third of the milking order gives an accurate estimate of the prevalence of lameness in a herd. Vasseur et al. (2012) have shown that to estimate lying time in dairy cattle accurately requires four days of continuous (automated) data collection and that parity and stage of lactation need to be taken into account when selecting animals.

Finally, all systems of scoring animals (farm, abattoir, or research) for welfare outcomes are underpinned by value-based decisions. The evaluative nature of scoring animals does not mean they should be rejected but that we are required to make the ethical judgements clear (Veissier et al., 2011). Ethical values influence both the choice of measures to record and their interpretation. A model for the overall measurement of livestock welfare is needed where the assessment will rely on indicators that cover multiple dimensions including health, physical comfort and expression of behaviours etc. Furthermore, the importance, or weighting, of each dimension in the model is inherently a value-based decision. Thus consultations between social scientists and animal scientists are recommended as demonstrated in the Welfare Quality Project (reviewed by Veissier et al., 2011). Value-based decisions are required in determining whether the assessment is made at the individual or farm level, and whether the condition of the average or the worse-off animal(s) is considered. In general, welfare is a concept that applies to the individual as it is regarded as a subjective experience, but when we rate welfare at a farm level we typically mean the welfare of all animals on that enterprise collectively. Thus one option is to make an aggregate score based on information at the individual level, so that the proportion of animals in a good versus bad state is measured. Alternatively, the farm may be evaluated at the criterion level, so that the performance of farms against set criterion (presence of disease, milk yield) can be compared. A further consideration is whether aggregation within a criterion is more important than the range from better off and worse off animals. Decisions must be made as to whether a farm that has a low

percentage of animals suffering from a severe condition (disease) is rated above or below one that has all animals suffering equally from a mild welfare problem (poor nutrition).

The emergence of ethical consumerism has been a driving factor behind the development of welfare assurance systems. Such schemes are typically based on independent audits of animal resources or of both resource and animal-based variables. There is still a question over whether such systems genuinely facilitate improved animal welfare.

5.3. Legislative regulations in Australia

In Australia, animal welfare legislation is state or territory based and is primarily concerned about the protection of animals from cruelty. Under Australian law, the stockperson or person responsible for animals is designated as the person in charge and they have a “duty of care” to the animal(s). Thus, livestock producers have a legal obligation to prevent harm and be aware of the welfare state of animals in their care both in intensive and extensive production systems. In addition, national guidelines exist which underpin the legislation and detail expected practices described in the Model Codes of Practice for the Welfare of Animals and are adopted by each state or territory. The existence of these Codes provides a form of welfare regulation and all Australian states and territories have agreed to work on enforcing national minimum standards for livestock. Although a limitation with these codes is that they are voluntary. A new initiative under the auspices of Australian Animal Welfare Strategy (AAWS 2005) involves the translation of existing codes into legislated national standards. An additional option currently being discussed is to legislate for key animal welfare requirements to be delivered via Quality Assurance (QA) programs or a licence using a co-regulatory approach (Edge et al., 2008). This would imply the government then oversees a guarantee that the legislation delivers the required outcomes. Currently, in most states and territories of Australia producers are not subject to routine government welfare inspections. However, state based assessments made against the animal welfare Codes of Practice (which are primarily resource-based guidelines) have been recently proposed. For example in Tasmania, unannounced animal welfare inspection now occurs on all commercial poultry farms and pig farms with 50 or more pigs, for the purpose of assessing animal welfare. Under this program, farms are subject to inspection about once every 1-2 years to check for compliance with the relevant Code of Practice for Pigs or Poultry (Department of Primary Industries Parks Water and Environment, Tasmania 2012). The development of a national QA system would reduce the need for multiple

state regulatory enforcements of standards and provide an opportunity to consolidate legislative and commercial requirements (Edge 2008).

In Australia, all model codes of practice for farm animal welfare are being replaced with national standards and guidelines. Standards will be enforceable under law and these represent the minimum level of animal welfare required.

6. Conclusions

Animal welfare is a complex human construct. There are three conceptual frameworks that have been applied for assessing farm animal welfare:

- Biological functioning – normality as evidenced through measures of behaviour, physiology, health and productivity
- Affective states – as evidenced through measures of abnormal behaviours, affective states (positive and negative feelings) and cognitive function, and
- Naturalness – as evidence by attributes of the animal, in particular normal behavioural repertoires, and by attributes of its environment

These conceptual frameworks are not mutually exclusive but are complementary in our fundamental understandings of animal welfare.

The viability of livestock farming requires practices that are not only productive, profitable and sustainable but fit with society's expectations on ethical dimensions such as animal welfare.

Transparent demonstration of how these expectations have been met will be paramount in the future.

Society comprises a range of stakeholders including: governmental regulatory and policy making bodies, producers, marketers, citizens/consumers, scientists, retailers/service providers, non-Governmental organisations (NGOs) and animal advocacy groups. Given this diversity, it is extremely challenging to develop a common welfare assessment framework that meets the requirements of all stakeholders.

A useful first step for undertaking a welfare assessment is to define the purpose or reason the assessment is being undertaken. Four broad categories of reasons for undertaking assessments are:

1. To inform the development and implementation of policies and regulations
2. For assessment and quality assurance of farm animal practices
3. For research purposes
4. To enable better on-going welfare management on farm

A second valuable step in welfare assessment that is not currently practiced would be articulation of the values and ethical frameworks used for selection of assessment criteria and for interpretation of data. This step acknowledges that welfare assessment is an evaluative process in which values influence the choice of measures, their interpretation and their weighting when the measures are combined in any legislative standard, QA assessment system or research methodology. Thus engagement and improvement in the quality of dialogue amongst stakeholders is needed so that the reasons for the choice of assessment measures are more clearly understood.

For on-farm welfare assessment it is evident that there is no one comprehensive, fully-validated system for evaluating the welfare of the diversity of species, production environments and management systems used in livestock enterprises. This does not imply that we are starting from a zero base, as research has shown that assessments combining health and production data, observation of behaviour and physical appearance of animals within a group offer reliable and feasible tools for welfare assessment. The strategic combination of input or resource and output or animal-based measures is important, particularly for welfare risk assessment (e.g. assessments of pasture/forage availability + body condition score in cattle or sheep). In addition to the requirement to demonstrate the validity of these measures or systems, efforts should also be directed to improving the interpretation and applicability of assessment systems within the various livestock enterprises. Priority should be given to exploring avenues to improve the reliability whilst reducing the complexity and invasiveness of methodologies. The development and application of remote automated data capture systems is central here in both extensive and intensive animal production systems.

Preeminent in welfare science is the development of a better understanding of the emotional range and valence in livestock species. To that end, the ongoing development and validation of behavioural and cognitive methodologies is essential. This could be greatly enhanced through the integration of neuroscience disciplines particularly with respect to the validation of these methodologies and the development of novel measures (e.g. lateralisation). The capacity to assess

affective states in production environments is a current limitation. However, Qualitative Behavioural Assessment (QBA) would appear to offer most promise to date and further investigation is warranted. The convergence between affective state and biological function, as demonstrated in recent research, represents an important development in welfare science. Indeed, this approach based on the integration of biological function and affective state measures provides a more robust methodology to examine the welfare impacts of a particular production or husbandry issue. Such an approach should be encouraged in future welfare research.

In summary, the development of appropriate welfare assessment methodologies that are credible to all stakeholders will be built on a better understanding of:

- changes in physical health and biological functioning that correspond with different levels of welfare;
- the capacities of livestock to experience negative and positive mental states and associated levels of welfare;
- the ways that separate measures and welfare attributes can be weighted and integrated to give an overall index of welfare;
- how these can be practically implemented in the production environment.

7. References

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