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### **Advances in studies of behaviour and welfare in relation to animal production.**

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#### **Abstract**

An understanding of animal behaviour is important for animal production and for animal welfare. An example of an area where there is new information is domestic animal learning. A second example concerns social networks. The development of human-animal relationships has been found to be substantially affected by the early experiences that the animals have of humans. With careful handling when young, later handling during general management and loading becomes much easier. The welfare of an individual is its state as regards its attempts to cope with its environment. This definition refers to a characteristic of an individual and to the state of the individual on a scale varying from very good to very poor. Welfare concerns all of the mechanisms for coping: involving physiology, behaviour, feelings and pathological responses. Welfare is a wider term than health but health is an important part of welfare. In order to enforce laws and standards, animal welfare outcome indicators are useful.

Keywords: animal behaviour, learning, early experience, social network, animal welfare.

#### **Resumo**

##### **Nova informação acerca produção animal do comportamento e bem-estar.**

O comportamento animal é importante para a produção e para o bem-estar. Um exemplo da nova informação é do aprendizado dos animais domésticos. Um outro exemplo é a análise das redes sociais. O desenvolvimento das relações entre os humanos e os animais podem ser modificados de acordo com as experiências. Com

manejo cuidadoso durante o criando, o manejo durante embarca estava mais fácil. O bem-estar de um indivíduo é seu estado em relação às suas tentativas de se adaptar ao seu ambiente. Esta definição refere-se a uma característica do indivíduo e ao estado de um indivíduo em uma escala variando de muito adequado a muito ruim. Bem-estar se refere a tudo os mecanismos de enfrentar: fisiológico, comportamento, sentimento e as respostas á patologia. O bem-estar é um termo mais amplo que o saúde mas o saúde faz parte importante do bem-estar. Para fazer cumprir as leias e os códigos, os indicadores dos resultados de bem-estar estaram muito útil.

Palavras chave: comportamento animal, aprendizagem, experiências iniciais, redes sociais, bem-estar animal.

## **Introduction**

Animal behaviour is a discipline that has substantial relevance to those studying or practising animal production, with continuing development over the last 50 years, and hence is included in university animal science degree courses (Paranhos da Costa and de Assis Pinto 2003). It is also essential information for veterinarians. The many applications of behaviour study to these subjects are discussed by Broom and Fraser (2007, 2010) so only selected examples of some recent developments: learning in domestic animals, social network analysis and effects of early handling, will be presented here. The number of people involved in the scientific study of animal welfare has increased greatly in recent years. Studies that reduce disease are relevant to animal welfare and these have been carried out for many years but the development of the use of methods for the general assessment of animal welfare has occurred mainly in the last 20 years. The demands of the public for improved welfare in farmed animals are having a big impact on the animal production industry so a specific course on animal welfare is essential for those studying animal science and veterinary medicine. Brazil is one of the countries where the teaching of animal welfare as a scientific subject in universities has become widespread with at least 70 universities teaching such courses (Molento and Calderón 2009, Gallo et al 2010). The concepts and some of the methodology for assessment are discussed below.

## **Learning in domestic animals**

Early attempts to compare learning ability depended upon motor abilities that were easy for some species but were very difficult or impossible for other species. Hence no unbiased comparison of learning ability was possible. A set of studies that largely overcame this problem were those of Kilgour (1987) using modified Hebb-Williams mazes for domestic and other animals of different sizes. These mazes start with a decision point where there are two or more possible directions to take, one being towards a concealed target reached after two further turns. When the numbers of errors were measured, cows, sheep, goats and pigs performed less well than 5-year-old children but better than dogs, cats, rats, horses and several other mammals and birds. When speed of learning was compared in the same study, the sequence was very similar but dogs performed as well as the farm ungulates.

Learning in social situations has been described for many species of animals (Box and Gibson 1999). Can social animals like cows, pigs and dogs recognise individuals of their own or of other species? Pigs (Mendl et al 2002, McLeman et al 2005) and dogs (Sommerville et al 1993) are amongst the species that have been shown to be able to discriminate amongst and respond to conspecifics and other animals using olfaction. Cattle have been trained to go towards one conspecific rather than another in order to get a food reward (Hagen and Broom 2003). In a series of studies with sheep, Kendrick and colleagues demonstrated behavioural discrimination of individual sheep and humans and identified neurones in the medial temporal and prefrontal lobes of the cerebral cortex that fired only when particular individuals were seen. These discriminations of pairs of photographs could still be shown and the specific cells could still be found one to two years after the training period (Kendrick and Baldwin 1987, Kendrick et al 1995, 2001). When a ewe recognises her lamb between two and twelve hours after birth, changes in the brain are associated with the behavioural process. Production of brain-derived neurotrophic factor and its receptor *trk-B*, occurred at 4-5 hours after birth and there was mRNA expression in the olfactory and visual processing systems, temporal cortex, four other cortical regions, hippocampus and amygdala (Broad et al 2002).

Are domestic animals aware of objects or other resources? At one time it was thought that a chicken would lose any concept of an object if it were out of sight. However,

studies by Vallortigara and colleagues showed that, not only could young domestic chicks go to objects hidden behind screens but that when two or three objects were hidden behind screens, the chicks went to the screen with the larger number of objects (Rugani et al 2009). Other experimental studies show that domestic animals can use a visual or auditory symbol for objects. Langbein et al (2004) were able to train goats to respond by carrying out an operant in order to get water when they saw one particular picture rather than others. A second example is familiar to those who have trained dogs but has been studied in one female dog in a carefully controlled way by Rossi and Ades (2008). When a dog was given commands that required her to respond to one of several objects, such as a ball, a stick, a bottle, a key or a toy bear, and to carry out one of several actions, such as point to it or fetch it, she was successful. Similarly, Kaminski et al (2009) found that dogs shown replicas or photographs could use this information and fetch the objects that were thus iconically portrayed. When Rossi and Ades' dog was provided with a keyboard that had symbols on it that indicated water, food, stroke me, I go out, I get a toy, or I urinate, she could indicate what she detected or what she wanted to do next. A further example is of pigs studied by Held et al (2000). They were put in a room and allowed to find hidden food. On the next day they were returned to the room and they went immediately to the place where they had found food. These studies show that the animals, in one or more of these examples, had a concept of an object in the absence of that object, had a concept of a symbol or of a location, and had a concept that pressing the symbol or going to a particular place was linked in a causal way to obtaining the resource.

In some cases, animals have to learn that immediately detectable information about the location of a resource has to be modified in a specific way in order that the resource can be obtained. One example is that animals of several species have been able to learn how to make a detour around a fence in order to get to a resource. This has been shown for chickens (Regolin et al 1995) and dogs Pongrácz et al (2001). A second example is that an individual capable of assessment awareness may be able to learn about what it sees in a mirror in relation to itself and then to use the information at a later time. Broom et al (2009) found that 4-6-week-old pigs responded to a mirror initially as if to another pig but later appeared to look at the image as they moved. They made a movement and then stopped still, apparently looking at their image and its surroundings, oriented either with nose towards the mirror or with the head parallel

to it. After 5 hours spent with a mirror, the pigs were shown a familiar food bowl, visible in the mirror but hidden behind a solid barrier. Seven out of eight pigs found the food bowl by going away from the mirror and around the barrier. Naïve pigs shown the same, looked behind the mirror. To use information from a mirror and find a food bowl, each pig must have observed features of its surroundings, remembered these and its own actions, deduced relationships among observed and remembered features and acted accordingly.

Where one individual is aware that another individual has information, it may be possible for us to know this if the first copies what the second does. Held et al (2000) described an experiment in which a pig watched another pig that could see a food location. The observer pig then did what the other pig had done to get food. In a further pig study, Held et al (2002) described the feeding strategy of a pig that watched an informed but subordinate individual and robbed it when it found food.

Subordinate individuals who observed food being hidden by a person, although they went to the food if able to do so, refrained from going to it if a dominant pig was present. These pigs had a concept of the dominant pig taking the food from them if they went to it and hence delayed their action until there was a good chance that they could retain the food. Another example from pig research by Curtis (1983) was of young pigs that had learned to raise or lower environmental temperature by putting the nose in a hole where a light beam is broken. Many of the pigs were able to control the heaters by nudging other pigs to make them turn them on or off.

The effects of emotional states on cognition are described in humans and, recently, in farm species (Paul et al 2005, Mendl et al 2009). These and the other studies mentioned above provide evidence about domestic animal awareness. *Awareness is defined here as a state in which complex brain analysis is used to process sensory stimuli or constructs based on memory* (Broom, 1998). Animals vary in the extent to which they are aware of themselves (DeGrazia, 1996) and of their interactions with their environment, including their ability to experience pleasurable states such as happiness and aversive states such as pain, fear and grief (Panksepp, 1998). This capacity is an aspect of sentience. *A sentient being is one that has some ability: to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risk, to have some feelings and to*

*have some degree of awareness* (Broom, 2006c). All of this information about cognitive abilities of domestic animals changes views about these animals and also leads to possibilities for using the animals' abilities to control their environments, find resources and make the work of farmers easier.

### **Social network analysis**

Social network theory and analysis has been introduced and applied to fish behaviour (Croft et al. 2004; Croft 2005) and health studies in both humans (Bell et al. 1999) and other animals (Bohm et al. 2008; Drewe et al. 2009). Social network analysis addresses complex biological questions as it describes the direct and indirect relationships occurring amongst individuals within a group (Wasserman and Faust 1994) and quantifies the social ties and influences among connected individuals. Importantly, social network analysis has been used to identify the roles of key individuals in the group (Lusseau and Newman 2004) who possess higher number of contacts and interactions and thus the power to influence social relationships within and between groups (Wasserman and Faust 1994). The use of novel tools such as social network analysis to quantify relationships between aggression and fin damage in farmed fish has helped to identify the precise social role of key individuals and their social position within groups (Cañon Jones et al 2010). An understanding of social behaviour in farmed animals is of key value in animal management.

### **Benefits for animal handling of early social experience with humans**

Domestic animals can form social attachments to people but lack of contact with man is a much more important problem on farms. The most common relationship between a farm animal and the people whom it sees is that the animal is afraid of the people. This fear is extreme in poultry and may be extreme in sheep, pigs and other animals. Stockpersons sometimes treat animals roughly or inconsistently. When this occurs, there are effects on welfare and there may be effects on production. Milk production by dairy cows is much affected by the behaviour of the stockman towards the animals (Seabrook 1984, 1987). The milk yield is substantially lower in the herds where people treat the animals in the worst way.

The work of Hemsworth, Barnett and collaborators has shown that early handling of the pigs in a group can have effects on the later responses of the pigs to man. The pigs can be handled much more easily when older after short periods of gentle early handling and the reproductive performance of the animals was better (Hemsworth *et al.* 1981, 1986a, b, Hemsworth and Barnett 1987). Using a standard test of latency of and amount of approach to a person, it was found that sows on different farms varied greatly in their responses to man. The average level of fear of human beings was negatively correlated with the reproductive performance of the pigs on the farm. When pigs were either minimally handled, or stroked and patted when they approached (pleasant handling), or slapped or prodded with an electric goad when they approached (adverse handling), pleasant handling resulted in the smallest behavioural and adrenal cortex response to man, highest growth ratio, highest pregnancy rate in gilts and earliest mating responses in boars. It is clear from these results that the welfare and production of pigs is substantially affected by the extent of controlled human contact with the animals. The same must be true of all farm animals. This subject area is reviewed by Hemsworth and Coleman (1998).

A substantial improvement in ease of handling and reduced heart-rate and plasma cortisol responses to novel situations were shown if the heifers had been handled for a few minutes per month. Human contact prior to handling and transport is also important. If young cattle have been handled for a short period just after weaning they are much less disturbed by the procedures associated with handling and transport (Le Neindre and Sourd 1984). All animals can be prepared for later management and transport by appropriate previous treatment. Productivity and welfare can also be improved with appropriate early handling. The time invested may be a few minutes on three or four days but the advantages to the farmer can be substantial.

### **Animal welfare concepts**

Whilst the human concepts of what are and are not moral actions have probably changed little over many millennia, ideas about which individuals should be the subject of such actions have changed with: (i) increasing knowledge of the functioning of humans and other animals and (ii) improved communication in the world (Broom, 2003). We all have obligations towards other individuals, including

those of other species. If we keep or otherwise interact with animals, we then have obligations in relation to their welfare. Assertions of rights and freedoms can cause problems.

Animal welfare is a term which describes a potentially measurable quality of a living animal at a particular time and hence is a scientific concept. It requires strict definition if it is to be used effectively and consistently. A clearly defined concept of welfare is needed for use in precise scientific measurements, in legal documents and in public statements or discussion (Broom and Molento 2004). Welfare refers to a characteristic of the individual animal rather than something given to the animal by people (Duncan 1981).

Animals have an array of coping systems with components including organ physiology, cellular mechanisms such as the immune system, brain mechanisms and behaviour. If, at some particular time, an individual has no problems to deal with, that individual is likely to be in a good state, where that state includes physical condition, physiological functioning, good feelings, brain state and behaviour. However an individual may face challenges in life and be unable to cope with them or able to cope only with difficulty. *Coping implies having control of mental and bodily stability* and prolonged failure to cope results in failure to grow, failure to reproduce, or death (Broom 2001a). Failure to cope or difficulty in coping, are likely to be evident from signs associated with bad feelings. *The welfare of an individual is its state as regards its attempts to cope with its environment* (Broom 1986). The origin of the concept is how well the individual is faring or travelling through life and the definition refers to state at a particular time (Broom 1991, 2008b, Broom and Fraser 2007 2010, Broom and Johnson 2000). The concept refers to the state of the individual on a scale from very good to very poor (Curtis 1983, Duncan 1987). This is a measurable state and any measurement should be independent of ethical considerations. When considering how to assess the welfare of an individual, it is necessary to start with knowledge of the biology of the animal (Fraser 1993) including its ability to adapt (Broom 2006a). The state may be good or poor, however, in either case, attempts should be made to measure those feelings that are a part of the state of the individual. *A feeling is a brain construct involving at least perceptual awareness which is associated with a life regulating system, is recognisable by the individual when it recurs and may change*

*behaviour or act as a reinforcer in learning (Broom 1998). Suffering occurs when one or more negative, unpleasant feelings continue for more than a few seconds.*

Feelings, such as pain, fear and pleasure, are often a part of a coping strategy and they are a key part of welfare (Duncan and Petherick 1991, Broom 1991b, 1998). They are adaptive aspects of an individual's biology which must have evolved to help in survival just as aspects of anatomy, physiology and behaviour have evolved. Fear and pain can play an important role in the fastest acting urgent coping responses, such as avoidance of predator attack or risk of immediate injury. Positive and negative feelings, as well as other brain processes that involve no affect, are among the causal factors determining what decisions are taken in longer time-scale coping procedures, where various risks to the fitness of the individual are involved. Aspects of suffering also contribute significantly to how the individual tries to cope in attempts to deal with very long-term problems that may harm the individual. In the organisation of behaviour so as to achieve important objectives, pleasurable feelings and the expectation that these will occur have a substantial influence.

The pain system and responses to pain are part of the repertoire used by animals, including man, to help them to cope with adversity during life. Pain is clearly an important part of welfare. It can be an indicator that the environment outside the control systems in the brain is having an impact such that, the individual is having difficulty in coping. Pain may also indicate that there is likely to be a failure to cope in the long term. *Pain is defined here as an aversive sensation and a feeling associated with actual or potential tissue damage (Broom 2001a).* This is an improvement on a previous definition used by the International Association for the Study of Pain (Iggo 1985).

Coping with pathology is necessary if welfare is to be good so health is an important part of the broader concept of welfare, not something separate (Dawkins 1980, Webster 1994, Broom 2006, Broom and Fraser 2007). However, health is not all of welfare, as those with a medical or veterinary background have sometimes assumed.

Health refers to the state of body systems, including those in the brain, which combat pathogens, tissue damage or physiological disorder and *health may be defined as an animal's state as regards its attempts to cope with pathology.* In this statement, animals include humans. The meaning of pathology is discussed by Broom (2006b).

Welfare is a broader term than health, covering all aspects of coping with the environment and taking account of a wider range of feelings and other coping mechanisms than those which affect health, especially at the positive end of the scale. When an animal's health is poor, so is its welfare, but poor welfare does not always imply poor health. There are many circumstances where behavioural or physiological coping mechanisms are activated, indicating that welfare is poor, but the animal's health remains good. These include: situations where the coping mechanisms are successful, such as when body temperature is maintained despite extreme ambient temperatures; circumstances where failure to cope has consequences for psychological, but not physical, stability, such as in the development of non-injurious pathological behaviours; and where detrimental effects upon physical stability are compensated for by management practices, such as the routine use of antibiotics. There are some indicators of poor welfare which are classified as pathology and, as such, will also indicate poor health. These include body damage and infectious disease. The prevention of normal physiological processes and anatomical development will also indicate poor health, where these phenomena can be shown to be symptoms of an infectious, metabolic or nutritional disease. Mortality rate is usually also an indicator of welfare in general and health in particular in the individuals in a population. When animals are close to death, their welfare including their health will often be very poor.

When considering how to assess the welfare of animals it is necessary to start with knowledge of the biology of the animal and of all of its needs. It is important to be aware that needs have a biological basis but this does not mean that degree of naturalness is a part of the definition of welfare (Fraser 2008). Some events that occur in nature, such as starvation or predation, result in very poor welfare. The needs of individuals will vary according to genotype and will be affected by conditions during development. It is more useful to consider the needs of animals of a given species, using scientific information about them, than to use the vaguer concept of freedoms.

*A need can be defined as a requirement, which is part of the basic biology of an animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus.* These include needs for particular resources and needs to carry out

actions whose function is to obtain an objective (Broom and Fraser, 2007; Toates and Jensen, 1991). Needs can be identified by studies of motivation and by assessing the welfare of individuals whose needs are not satisfied (Broom and Johnson, 2000; Dawkins, 1990; Hughes and Duncan, 1988a; Hughes and Duncan, 1988b). Some needs are for particular resources, such as water or heat, but the animal may also need to perform a certain behaviour. It may be seriously affected in an adverse way if unable to carry out the activity, even in the presence of the ultimate objective of the activity. For example, pigs need to root in soil or some similar substratum (Hutson, 1989), hens need to dust-bathe (Vestergaard, 1980) and both of these species need to build a nest before giving birth or laying eggs (Arey 1992, Brantas 1980). In all of these different examples, the need itself is not physiological or behavioural but in the brain.

The word "stress" should be used for that part of poor welfare that involves failure to cope, as the common public use of the word refers to a deleterious effect on an individual (Broom and Johnson 2000) Reference to stress as just a stimulation that could be beneficial, or as just an event that elicits adrenal cortex activity, is of no scientific or practical value. One indicator of adversity is whether there is an effect on biological fitness. *Stress can be defined as an environmental effect on an individual which over-taxes its control systems and reduces its fitness or seems likely to do so.* Using this definition, the relationship between stress and welfare is very clear. Firstly, whilst welfare refers to a range in the state of the animal from very good to very poor, whenever there is stress, welfare is poor. Secondly, stress refers only to situations where there is failure to cope but poor welfare refers to the state of the animal, both when there is failure to cope and when the individual is having difficulty in coping.

Amongst those working with companion animals and carrying out veterinary treatment on them, many people express concern about the quality of life of the individual (Broom 2007b, Timmins et al 2007). 'Quality of life' is essentially the same in meaning as 'welfare'. However, whilst welfare can be considered over the short-term or the long-term, quality of life usually refers to a characteristic of an individual over a time-scale longer than a few days. It is a state of the individual that

will vary from good to bad.

### **Welfare assessment**

The assessment of welfare (Broom and Johnson 2000) should be carried out in an objective way, taking no account of any ethical questions about the systems, practices or conditions for individuals which are being compared. Once the scientific evidence about welfare has been obtained, ethical decisions can be taken.

Much of the evidence used in welfare assessment indicates the extent of the problems of individuals but it is also important to recognise and assess good welfare, i.e. happiness, contentment, control of interactions with the environment and possibilities to exploit abilities. We should try to assess the specific functioning of the brain when welfare is good in humans and other animals (Broom and Zanella 2004); the methods of recognising when welfare is, or is likely to be, good; and the factors which contribute to good welfare in man and other species. Good welfare in general, and a positive status in each of the various coping systems, should have effects which are a part of a positive reinforcement system, just as poor welfare is associated with various negative reinforcers. There should be various recognisable effects on individuals of good welfare. We need to identify these so that the assessment of welfare is as effective at the good end of the range as at the bad end.

Each assessment of welfare for a human or other animal will pertain to single individual and to a particular time range. In the overall assessment of the impact of a condition or treatment on an individual, a very brief period of a certain degree of good or poor welfare is not the same as a prolonged period. However, a simple multiplicative function of maximum degree and duration is often not sufficient because the most severe effect of poor welfare may be brief whilst there is a more prolonged milder effect. If the intensity of the good or poor welfare is plotted against time the best overall assessment of welfare for that individual animal is the area under the curve thus produced (Broom 2001c).

Effects on animal welfare which can be described include those of: disease, injury, starvation, beneficial stimulation, social interactions - positive or negative, other forms of success in actions, housing conditions - positive or negative, deliberate or accidental ill treatment, human handling - positive or negative, transport, laboratory procedures, various mutilations, veterinary treatment - positive or negative, genetic change by conventional or other breeding (Broom 2008a, 2010a).

Welfare indicators are described by Broom and Fraser (2007, 2010). There are differences between welfare indicators for short-term and long-term problems. Short-term measures like heart-rate and plasma cortisol concentration are appropriate for assessing welfare during handling or transport but not during long-term housing. Some measures of behaviour, immune system function and disease state are more appropriate for long-term problems.

The general methods for assessing welfare are summarised in Table 1 and a list of measures of welfare is presented in Table 2. Most indicators will help to pinpoint the state of the animal wherever it is on the scale from very good to very poor. Some measures are most relevant to short-term problems, such as those associated with human handling or a brief period of adverse physical conditions, whereas others are more appropriate to long-term problems. These measures of welfare are not “subjective” measures and it is possible to assess quality of life by the use of such measures and not just by asking the subject questions. Subjective measures in humans may be incorrect or inconsistently correct. However, those who use the methodology used in medical research on welfare/quality of life and those who assess the welfare of non-human animals have much to learn from one another (see Lutgendorf, 2001). For a detailed discussion of measures of welfare, see Broom and Johnson, (2000).

Table 1. Summary of Welfare Assessment

<u>General Methods</u>		<u>Assessment</u>
Direct indicators of poor welfare		How poor is it?
Tests of	(a) avoidance	(a) What is the extent to which animals have

	to live with avoided situations or stimuli?
and	
(b) positive preference	(b) To what extent is that which is strongly preferred available?
Measures of ability to carry out normal behaviour and other biological functions.	How much important normal behaviour or physiological or anatomical development cannot occur?
Other direct indicators of good welfare	How good is it? (modified after Broom 1999a)

Table 2. Measures of welfare

- Physiological indicators of pleasure
- Behavioural indicators of pleasure
- Extent to which strongly preferred behaviours can be shown
- Variety of normal behaviours shown or suppressed
- Extent to which normal physiological processes and anatomical development are possible.
- Extent of behavioural aversion shown
- Physiological attempts to cope
- Immunosuppression
- Disease prevalence
- Behavioural attempts to cope
- Behaviour pathology
- Brain changes
- Body damage prevalence
- Ability to grow or breed
- Life expectancy

(modified after Broom 2000)

Some signs of poor welfare arise from physiological measurements. For instance increased heart-rate, adrenal activity, adrenal activity following ACTH challenge, or

reduced immunological response following a challenge, can all indicate that welfare is poorer than in individuals that do not show such changes. Care must be taken when interpreting such results, as with many other measures described here. The impaired immune system function and some of the physiological changes can indicate what has been termed a pre-pathological state (Moberg 1985). As a consequence of the high proportion of coping mechanisms that involve the functioning of higher centres in the brain, some welfare assessment should involve brain function measures (Broom and Zanella 2004).

Behavioural measures are also of particular value in welfare assessment. The fact that an animal avoids an object or event, strongly gives information about its feelings and hence about its welfare. The stronger the avoidance the worse the welfare whilst the object is present or the event is occurring. An individual which is completely unable to adopt a preferred lying posture despite repeated attempts will be assessed as having poorer welfare than one which can adopt the preferred posture. Other abnormal behaviour such as stereotypies, self-mutilation, tail-biting in pigs, feather-pecking in hens, or excessively aggressive behaviour in dogs indicates that the perpetrator's welfare is poor.

In some of these physiological and behavioural measures it is clear that the individual is trying to cope with adversity and the extent of the attempts to cope can be measured. In other cases, however, some responses are solely pathological and the individual is failing to cope. In either case the measure indicates poor welfare.

Disease, injury, movement difficulties and growth abnormality all indicate poor welfare. If two housing systems are compared in a carefully controlled experiment and the incidence of any of the above is significantly increased in one of them, the welfare of the animals is worse in that system. The welfare of any diseased animal is worse than that of an animal that is not diseased but much remains to be discovered about the magnitude of the effects of disease on welfare. Little is known about how much suffering is associated with different diseases. A specific example of an effect on housing conditions that leads to poor welfare is the consequence of severely reduced exercise for bone strength. In studies of hens (Knowles and Broom, 1990, Norgaard Nielsen 1990) those birds that could not sufficiently exercise their wings and legs because they were housed in battery cages had considerably weaker bones than those birds in percheries where there was enough space to exercise. Similarly, Marchant and Broom (1996) found that sows in stalls had leg bones only 65% as

strong as sows in group-housing systems. The actual weakness of bones means that the animals are coping less well with their environment so welfare is poorer in the confined housing. If such an animal's bones are broken there will be considerable pain and the welfare will be worse. Pain may be assessed by aversion, physiological measures, the effects of analgesics (e.g. Duncan *et al.* 1991, Stilwell *et al.* 2009) or by the existence of neuromas (Gentle 1986). Whatever the measurement, data collected in studies of animal welfare gives information about the position of the animal on a scale of welfare from very good to very poor.

The majority of indicators of good welfare that we can use are obtained by studies demonstrating positive preferences by animals. In operant tests a cost is imposed upon access to the resource by requiring the subject to perform a task. Performance of the task requires time and effort, which could otherwise have been spent doing other things. The task may also be unpleasant to the subject. In choice tests, a cost is normally imposed instead upon consumption. The animal must divide time between consuming the resources.

How do we find out from animals what they need? What is preferred? How hard will the individual work for a resource? A rat can readily learn to lift a weighted door and the amount lifted gives an indication of its strength of preference for the resource. Manser *et al.* (1996), studying floor preferences of laboratory rats, found that rats would lift a heavier door to reach a solid floor on which they could rest than to reach a grid floor. Terminology used in motivational strength estimation includes the following (Kirkden *et al.* 2003). A resource is a commodity or an opportunity to perform an activity. The demand is a measured amount of action which enables resource to be obtained. The price is the amount of that action required for a unit of resource. Income is the amount of time or other variable limiting that action. The price elasticity of demand is the proportional rate at which consumption or demand changes with price. The consumer surplus is a measure of the largest amount which a subject is prepared to spend on a given quantity of the resource. It corresponds to an area beneath an inverse demand curve. Where the demand for a resource is measured at a range of prices, the importance of the resource is indicated better by the consumer surplus than by the price elasticity of demand (Kirkden *et al.* 2003).

An example of the use of this methodology is the work of Mason *et al.* (2001). The key question was to ascertain the strength of preference of mink, a partially aquatic

species, for various resources including water in which they could swim. The mink were trained to perform operants to reach: an extra nest, various objects, a raised platform, a tunnel, an empty cage and a water pool to swim in. The swimming water was given very high priority by the mink.

The third general method of welfare assessment listed in Table 2 involves measuring what behaviour and other functions cannot be carried out in particular living conditions. Hens prefer to flap their wings at intervals but cannot in a battery cage whilst veal calves and some caged laboratory animals try hard to groom themselves thoroughly but cannot in a small crate, cage or restraining apparatus.

In all welfare assessment it is necessary to take account of individual variation in attempts to cope with adversity and in the effects which adversity has on the animal. When pigs have been confined in stalls or tethers for some time, a proportion of individuals show high levels of stereotypies whilst others are very inactive and unresponsive (Broom 1987, Broom and Johnson 2000). There may also be a change with time spent in the condition in the amount and type of abnormal behaviour shown (Cronin and Wiepkema 1984). In rats, mice and tree shrews it is known that different physiological and behavioural responses are shown by an individual confined with an aggressor and these responses have been categorised as active and passive coping (Koolhaas *et al* 1983, von Holst 1986,). Active animals fight vigorously whereas passive animals submit. A study of the strategies adopted by gilts in a competitive social situation showed that some sows were aggressive and successful, a second category of animals defended vigorously if attacked whilst a third category of sows avoided social confrontation if possible. These categories of animals differed in their adrenal responses and in reproductive success (Mendl *et al* 1992). As a result of differences in the extent of different physiological and behavioural responses to problems it is necessary that any assessment of welfare should include a wide range of measures. Our knowledge of how the various measurements combine to indicate the severity of the problem must also be improved. It is also important to understand the strategies used by animals in various coping situations as these may be different from those used by humans. An example is the response to severe pain in sheep and some other prey species, in which it is not adaptive to show obvious behavioural responses (Broom and Johnson 2000).

There are factors that affect animal welfare greatly but are insufficiently studied. For example, animals supposedly cared for by people may starve (Agenäs et al 2006). *Starvation occurs when there is a shortage of nutrients or energy such that the animal starts to metabolise functional tissues rather than food reserves*, (Broom and Fraser 2007). More measurements of starvation are needed and management that animals starvation should be development. The effects of extreme temperatures and their effects on welfare also require study and changes in management practice.

As a result of these various areas of interest in the scientific study of animal welfare, courses on the subject for students of veterinary medicine, animal management, biology and psychology (Hewson et al 2005; Broom 2005) are now widely demanded.

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