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ASSESSING STRESS IN FARM ANIMALS

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Summary

The prevention of poor welfare in the animals that we use is one of our moral obligations. Systems for producing farm animals are not sustainable unless people accept the system and its effects and one of the criteria for this is the welfare of the animals. The welfare of an animal is its state as regards its attempts to cope with its environment. In order that welfare can be good, the needs of the animal have to be met and the coping systems help to ensure this. When environmental effects on an animal overtax its control systems and result in adverse consequences, eventually reduced fitness, the individual is stressed. Measures of poor welfare include those that are physiological, some being associated with behavioural and pathological changes. Heart-rate and plasma glucose give information about short-term changes. Hormones, proteins and metabolites in the blood also allow the assessment of the extent of poor welfare, for example during handling and transport. Somewhat longer periods of poor welfare may be identified by measuring behaviour or faecal cortisol. The concentration of oxytocin can sometimes be used as a physiological measure of good welfare. When welfare studies are carried out, it is important that the scientific assessment is considered separately from the ethical judgement.

Key words: Animal welfare, welfare indicators, stress, needs, pain, health, sentience.

Introduction

Animals have always had welfare but what humans know of it has changed. 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 (12).

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.

In Europe, one of the big pressures for laws has been the view that it is uncivilised to: allow people to become sick, animals to be treated badly, or the environment to be damaged. A system or procedure is sustainable if (i) it and its effects are acceptable now and (ii) its future effects are acceptable and are expected to continue to be acceptable, in particular in relation to: resource availability, consequences of functioning and morality of action. Animal welfare is one of the criteria used by the public when deciding whether a procedure or system is acceptable so it is a necessary consideration for sustainability.

Welfare definition

The welfare of animals is regarded as particularly important by many people and is a key factor when determining whether or not a system or procedure involving animals is sustainable. However, the term welfare 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. If animal welfare is to be compared in different situations or evaluated in a specific situation, it must be assessed in an objective way.

A useful definition of animal welfare must refer to a characteristic of the individual animal rather than something given to the animal by man. Effects on welfare which can be described include those of disease, injury, starvation, beneficial stimulation, social interactions, housing conditions, deliberate or accidental ill treatment, human handling, transport, laboratory procedures, various mutilations,

veterinary treatment or genetic change by conventional breeding or genetic engineering.

We have to define welfare in such a way that it can be readily related to other concepts such as: needs, freedoms, happiness, coping, control, predictability, feelings, suffering, pain, anxiety, fear, boredom, stress and health. Animals vary in the extent to which they are aware of themselves (22) 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 (33). This capacity may be referred to as their degree 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 (15). Awareness is defined here as a state in which complex brain analysis is used to process sensory stimuli or constructs based on memory (9).*

Insert Table I

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 (see Table I) 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 (10). 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 (6).* This definition refers to a characteristic of the individual living animal at the time. 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 (8, 16, 17). The concept refers to the state of the individual on a scale from very good to very poor (20, 23). 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 (25) including its ability to adapt (13). The state may be good or

poor, however, in either case, attempts should be made to measure those feelings which 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* (9). *Suffering occurs when one or more negative, unpleasant feelings continue for more than a few seconds.*

Needs

Most scientists involved in welfare research would agree with Appleby (1) that a range of components of that environment, each of which is to some extent variable, should be considered when attempting to determine what is an appropriate environment for an animal. The environment is appropriate if it allows the animal to satisfy its needs. Animals have a range of functional systems controlling body temperature, nutritional state, social interactions etc. (4). Together, these functional systems allow the individual to control its interactions with its environment and hence to keep each aspect of its state within a tolerable range. The allocation of time and resources to different physiological or behavioural activities, either within a functional system or between systems, is controlled by motivational mechanisms. When an animal is actually or potentially homeostatically maladjusted, or when it must carry out an action because of some environmental situation, we say that it has a need. *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 (16, 36). Needs can be identified by studies of motivation and by assessing the welfare of individuals whose needs are not satisfied (17, 21, 26, 27).

Control systems have evolved in animals in such a way that the means of obtaining a particular objective have become important to the individual animal. Some needs are for particular resources, such as water or heat; 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, rats and ostriches will work, in the sense of carrying out actions

which result in food presentation, even in the presence of food. In the same way, pigs need to root in soil or some similar substratum (28), hens need to dust-bathe (37) and both of these species need to build a nest before giving birth or laying eggs (2, 3). In all of these different examples, the need itself is not physiological or behavioural but in the brain. It is the fulfilment of needs which requires physiological change or certain behaviour to be shown, and this has led to the use of “biological needs” or just “needs”.

Feelings

The feelings of an animal are an extremely important part of its welfare (8, 12). However, whilst we have many measures that give us some information about injury, disease and both behavioural and physiological attempts to cope with the individual's environment, fewer studies tell us about the feelings of the animal. Information can be obtained about feelings using preference studies and other information giving indirect information about feelings can be obtained from studies of physiological and behavioural responses of animals.

Feelings are aspects of an individual's biology which must have evolved to help in survival (9), just as aspects of anatomy, physiology and behaviour have evolved. They are used in order to maximise its fitness, often by helping it to cope with its environment. It is also possible, as with any other aspect of the biology of an individual, that some feelings do not confer any advantage on the animal but are epiphenomena of neural activity (17). The coping systems used by animals operate on different time scales. Some must operate during a few seconds in order to be effectual, others take hours or months. Optimal decision-making depends not only on an evaluation of energetic costs and benefits but on the urgency of action, in other words the costs associated with injury, death or failure to find a mate (4). In the fastest acting urgent coping responses, such as avoidance of predator attack or risk of immediate injury, fear plays an important role in the immediate response and both fear and pain may facilitate future learning if such situations are encountered again. In longer time-scale coping procedures, where various risks to the fitness of the individual are involved, feelings rather than just cognitive processes are amongst the causal factors affecting what decisions are taken. In attempts to deal with very long-

term problems which may harm the individual, aspects of suffering contribute significantly to how the individual tries to cope. In the organisation of behaviour so as to achieve important objectives, pleasurable feelings and the expectation that these will occur have a substantial influence. For example, the taste of a preferred food may lead to pleasure and this may increase the likelihood that a particular route is taken to allow a visit to the source of that food. The general hypothesis advanced is that whenever a situation exists where decisions are taken which have a big effect on the survival or potential reproductive output of the individual, it is likely that feelings will be involved. This argument applies to all animals with complex nervous systems, such as vertebrates and cephalopods, and not just to humans. Feelings are not just a minor influence on coping systems, they are a very important part of them.

In circumstances where individuals are starting to lose control and fail to cope, there may be unpleasant feelings. These feelings might have a role in damage limitation that is functional. However they might also occur when the individual is not coping at all and the feelings have no survival function then. Extreme suffering or despair are probably not adaptive feelings but an observer of the same species might benefit and a scientist might use indications of such feelings, such as certain postures and absence of responses to stimuli that would normally elicit a response, to deduce that the animal is not coping.

If the definition of welfare were limited to the feelings of the individual as has been proposed by Duncan and Petherick (24), it would not be possible to refer to the welfare of a person or an individual of another species that had no feelings because it was asleep, or anaesthetised, or drugged, or suffering from a disease which affects awareness. A further problem, if only feelings were considered, is that a great deal of evidence about welfare like the presence of neuromas, extreme physiological responses or various abnormalities of behaviour, immunosuppression, disease, inability to grow and reproduce, or reduced life expectancy would not be taken as evidence of poor welfare unless bad feelings could be demonstrated to be associated with them. Evidence about feelings and about other welfare measures must be considered in welfare assessment.

Stress

The word stress is best used for that part of poor welfare which involves failure to cope. If the control systems regulating body state and responding to dangers are not able to prevent displacement of state outside the tolerable range, a situation of different biological importance is reached. The common public use of the word stress refers to a deleterious effect on an individual (17). The usage of the term stress to refer to an environmental change which affects an organism, a process affecting the organism or the consequences of effects on the organism (34, 35) has been confusing. Stress has been limited to one kind of physiological response mechanism, or to mental rather than physiological responses or has been regarded as a much more wide ranging phenomenon. A definition of stress as just a stimulation or an event which elicits adrenal cortex activity is of no scientific or practical value (11, 31). A precise criterion for what is adverse for an animal is difficult to find but one indicator is whether there is, or is likely to be, an effect on biological fitness. *Stress can be defined as an environmental effect on an individual that over-taxes its control systems and reduces its fitness or seems likely to do so (5, 17).* 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. It is very important that this latter kind of poor welfare, as well as the occasions when an animal is stressed, is included as part of poor welfare. For instance, if a person is severely depressed or if an individual has a debilitating disease but there is complete recovery with no long term effects on fitness then it would still be appropriate to say that the welfare of the individuals was poor at the time of the depression or disease.

Health

The word "health", like "welfare", can be qualified by "good" or "poor" and varies over a range. However, health refers to the state of body systems, including those in the brain, which combat pathogens, tissue damage or physiological disorder. *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 (14).

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. Although people regularly refer to poor health, they sometimes use the word to mean absence of illness or injury in the same way that people refer to welfare when they mean good welfare. However the precise and scientific use of both health and welfare must refer to states varying from very good to very poor. "Health" is encompassed within the term "welfare", and indeed is a very important part of welfare.

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.

Pain

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 (10). This is an improvement on a previous definition used by the International Association for the Study of Pain (29).

In order to feel pain, animals need to have receptor cells in appropriate places in the body, peripheral and central neural pathways with neuro-transmitters and adequate processing centres in the brain. The pain system would be expected to have links between these brain centres and an output system which can initiate a behavioural or other response. Acute pain could result in behavioural avoidance, repeated risk of acute pain could result in learning so that potential damage could be avoided and chronic pain could result in suppression of activity and behaviour which ameliorates adverse effects. A mechanism for switching off the feeling of pain such as that mediated by endorphins and other opioids would also be expected because if pain has a great effect on behaviour, such an effect would sometimes be dangerous.

Welfare concepts in relation to assessment

Most welfare 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. Tests of avoidance and positive preference help in the design of better conditions and procedures.

In all welfare assessment it is necessary to take account of individual variation in attempts to cope with adversity (30, 32) 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 (7). There may also be a change with time spent in the condition in the amount and type of abnormal behaviour shown (19) and different sympathetic and para-sympathetic physiological responses. 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.

The general methods for assessing welfare are summarised in Table II and a list of measures of poor welfare is presented in Table III.

Insert Table II

Insert Table III

Some signs of stress and 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 which do not show such changes.

Short-term problems, such as those that occur during handling and transport of farm animals, can be assessed using a range of physiological indicators (Table IV).

Insert Table IV

Where blood samples cannot easily be taken without disturbance to the animal, physiological measurement in urine or faeces can be useful. For example, faecal cortisol can be assayed and

provides information about responses over a period of hours. There are also physiological indicators of good welfare, for example measures of oxytocin. Oxytocin, whose concentration is higher during some pleasurable events, is synthesised in the paraventricular nucleus (PVN) of the hypothalamus and in the supraoptic nucleus. Oxytocin increase is associated with: ACTH and glucocorticoid decrease, lymphocyte proliferation, brain GABA increase, and cardiac vagal tone increase.

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 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 which is not diseased but much remains to be discovered about the magnitude of the effects of disease on welfare.

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. 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. We should try to assess the specific functioning of the brain when welfare is good (18); 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.

Each assessment of welfare for a human or other animal will pertain to a 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 there is a net effect of poor welfare and the severity of the poor welfare is plotted against time the best overall assessment of welfare for that individual animal is the area under the curve thus produced (11).

References

1. Appleby M.C. (1997). - Life in a variable world: behaviour, welfare and environmental design. *Appl. Anim. Behav. Sci.*, 54, 1-19.
2. Arey D.S. (1992). - Straw and food as reinforcers for prepartal sows. *Appl. Anim. Behav. Sci.*, 33, 217-226.
3. Brantas G.C. (1980). - The pre-laying behaviour of laying hens in cages with and without laying nests. In *The Laying Hen and its Environment. Current Topics in Veterinary Medicine and Animal Science*, Vol. 42 (R. Moss, ed). Martinus Nijhoff, The Hague, The Netherlands, 129-132.
4. Broom D.M. (1981). - *Biology of Behaviour*. Cambridge University Press, Cambridge, UK.
5. Broom D.M. (1983). - The stress concept and ways of assessing the effects of stress in farm animals. *Appl. Anim. Ethol.*, 1, 79.
6. Broom D.M. (1986). - Indicators of poor welfare. *Brit. Vet. J.*, (142): 524-526.

7. Broom D.M. (1987). - Applications of neurobiological studies to farm animal welfare. In *Biology of Stress in Farm Animals: an Integrated Approach* (P.R. Wiepkema & P.W.M. van Adrichem, eds). Martinus Nijhoff, Dordrecht, The Netherlands, 101-110.
8. Broom D.M. (1991). - Assessing welfare and suffering. *Behav. Process.*, 25, 117-123.
9. Broom D.M. (1998). - Welfare, stress and the evolution of feelings. *Adv. Stud. Behav.*, 27, 371-403.
10. Broom D.M. (2001). - Evolution of pain. In *Pain: its Nature and Management in Man and Animals. International Congress and Symposium Series, Royal Society of Medicine*, 246, 17-25.
11. Broom D.M. (2001). - Coping, stress and welfare. In *Coping with Challenge: Welfare in Animals Including Humans* (D.M. Broom, ed). Dahlem University Press, Berlin, Germany, 1-9.
12. Broom D.M. (2003). - *The Evolution of Morality and Religion*. Cambridge University Press, Cambridge, UK.
13. Broom D.M. (2006). - Adaptation. *Berl. Münch. Tierärztl. Wochenschr.*, 119, 1-6.
14. Broom D.M. (2006). - Behaviour and welfare in relation to pathology. *Appl. Anim. Behav. Sci.*, 97, 71-83.
15. Broom D.M. (2006). - The evolution of morality. *Appl. Anim. Behav. Sci.*, 100, 20-28.
16. Broom D.M. & Fraser A.F. (2007). - *Domestic Animal Behaviour and Welfare*. CABI, Wallingford, UK.
17. Broom D.M. & Johnson K.G. (2000). - *Stress and Animal Welfare*. Kluwer, Dordrecht, The Netherlands.
18. Broom D.M. & Zanella A.J. (2004). - Brain measures which tell us about animal welfare. *Anim. Welfare*, 13, S41-S45.
19. Cronin G.M. & Wiepkema P.R. (1984). - An analysis of stereotyped behaviours in tethered sows. *Ann. Rech. Vet*, 15, 263-270.
20. Curtis S.E. (1986). - Perception of thermal comfort by farm animals. In *Farm Animal Housing and Welfare* (Baxter S.H., Baxter M.R. & MacCormack J.A.C., eds). Martinus Nijhoff, The Hague, The Netherlands, 59-66.
21. Dawkins M.S. (1990). - From an animal's point of view: motivation, fitness, and animal welfare. *Behav. Brain Sci.*, 13, 1-61.

22. DeGrazia D. (1996). - Taking Animals Seriously: Mental Life and Moral Status. Cambridge University Press, New York, USA.
23. Duncan I.J.H. (1987). - The welfare of farm animals: An ethological approach. *Sci. Prog.*, 71, 317.
24. Duncan I.J.H. & Petherick J.C. (1991). - The implications of cognitive processes for animal welfare. *J. Anim. Sci.*, 69, 5017-5022.
25. Fraser D. (1993). - Assessing animal well-being: common sense, uncommon science. In *Food Animal Well-Being*. USDA and Purdue University, West Lafayette, USA, 37-54.
26. Hughes B.O. & Duncan I.J.H. (1988a). - Behavioural needs: can they be explained in terms of motivational models? *Appl. Anim. Behav. Sci.*, 20, 352-355.
27. Hughes B.O. & Duncan I.J.H. (1988b). - The notion of ethological 'need', models of motivation and animal welfare. *Anim. Behav.*, 36, 1696-1707.
28. Hutson G.D. (1989). - Operant tests of access to earth as a reinforcement for weaner piglets. *Anim. Prod.*, 48, 561-569.
29. Iggo A. (1985). - Pain in Animals. Universities Federation for Animal Welfare, Potters Bar, UK.
30. Koolhaas J.M., Schuurmann T. & Fokema, D.S. (1983). - Social behaviour of rats as a model for the psychophysiology of hypertension. In *Biobehavioural Bases of Coronary Heart Disease* (T.M. Dembrowski, T.H. Schmidt & G. Blumchen, eds). Karger, Basel, Switzerland, 391-400.
31. Mason J.W. (1971). - A re-evaluation of the concept of 'non-specificity' in stress theory. *J. Psychiat. Res.*, 8, 323-33.
32. Mendl M., Zanella A.J. & Broom D.M. (1992). - Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Anim. Behav.*, 44, 1107-1121.
33. Panksepp J. (1998). - *Affective Neuroscience: The Foundatoin of Human and Animal Emotions*. Oxford University Press, Oxford, UK.
34. Selye H. (1950). - *The Physiology and Pathology of Exposure to Stress*. MD Publ., Montreal.
35. Selye H. (1956). *The Stress of Life*. McGraw-Hill, New York, USA.
36. Toates F. & Jensen P. (1991). - Ethological and psychological models of motivation: towards a synthesis. In *Farm Animals to Animals* (J.A. Meyer & S. Wilson, eds). MIT Press, Cambridge, UK, 194-205.

37. Vestergaard K. (1980). - The regulation of dustbathing and other behaviour patterns in the laying hen: a Lorenzian approach. In *The Laying Hen and its Environment. Current Topics in Veterinary Medicine and Animal Science*, Vol. 42 (R. Moss, ed). Martinus Nijhoff, The Hague, The Netherlands, 101-113.

Table I - Examples of challenges to animals from their environment.

Pathogens
Tissue damage
Attack or threat of attack by a conspecific or predator
Other social competition
Complexity of information processing in a situation where an individual receives excessive stimulation
Lack of key stimuli such as a teat for a young mammal or lack of social contact for a social animal
In general, lack of ability to control interactions with the environment

Table II - Summary of Welfare Assessment (from Broom and Fraser (16))

General Methods	Assessment
Direct indicators of poor welfare	How poor
Tests of (a) avoidance and (b) positive preference	(a) Extent to which animals have to live with avoided situations or stimuli (b) Extent to which that which is strongly preferred is 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

Table III - Measures of welfare (from Broom and Fraser (16))

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
Reduced ability to grow or breed
Reduced life expectancy

Table IV - Physiological indicators of short-term problems (from Broom and Fraser (16))

Stressor	Physiological variable
Food deprivation	↑ FFA, ↑ β-OHB, ↓ glucose, ↑ urea
Dehydration	↑ osmolality, ↑ total protein, ↑ albumin, ↑ PCV
High exertion bruising	↑ CK, ↑ LDH5, ↑ lactate
Fear	↑ cortisol, ↑ PCV ↑ heart rate, ↑ h r variability, ↑ resp, ↑ LDH5
Motion sickness	↑ vasopressin
Inflammation	acute phase proteins, e.g. haptoglobin, C-reactive protein, serum amyloid-A
Immune responses	
Hypothermia / Hyperthermia	change in body and skin temperature, prolactin