ENRICHING THE LIVES OF ZOO ANIMALS, AND THEIR WELFARE: WHERE RESEARCH CAN BE FUNDAMENTAL

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Final acceptance: 10 July 1997

Abstract *Animal Welfare 1998, 7:* 151-175

As zoos have evolved, conservation and conservation education have become primary tasks. To achieve the maximum educational impact, zoos are enriching animal habitats so that their occupants display a wide range of activities that are attractive to the visitor, and unattractive activities are eliminated and reduced. Because public perceptions of the attractiveness of animal behaviour may not coincide with welfare realities, there can be a tension between the requirements of desirable exhibits and those of maximally promoting animal welfare. Zoo animals differ from domesticated animals in human care in several respects. These differences are discussed and set in the context of the sometimes competing aims of enhancing welfare and promoting educational exhibits. An outline history of zoo enrichment programmes suggests that the subject is in need of systematization. The range of data available for improving zoo exhibit designs, and the lives of zoo animals, is reviewed. It is concluded that fundamental data on the environmental needs of many of the wild animals maintained in zoos are deficient in many important areas. Consequently, there is an urgent need to increase such research. Zoo habitats could be excellent places for such fundamental studies, which would feed back into field studies. At the same time, habitat enrichment in zoos cannot await such research and must proceed pragmatically using the range of insights described in this paper. In particular, functional substitution is advocated as a means of enrichment wherever this can be made acceptable to the broad public; its educational value in combatting naive anthropomorphism is stressed. Naturalism in enrichment is criticized as reinforcing anthropomorhisms, but is desirable for promoting global habitat conservation.

Keywords: *animal welfare, enrichment, exhibit design, research, zoos*

Introduction

The twentieth century has seen a rapid evolution of zoos resulting in a widespread recognition of their role both in conservation and in conservation education. Thus in 1993, The World Zoo Association (also known as the International Union of Directors of Zoological Gardens or IUDZG) issued *The World Zoo Conservation Strategy*, heavily emphasizing education and *ex situ* breeding programmes as fundamental aspects of zoo conservation policies. It stressed that: 'effective education requires maintenance, husbandry and behavioural management techniques that guarantee the well-being of zoo animals. *Animals that appear to suffer from physical and psychological restraint are counter-*

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https://doi.org/10.1017/S0962728600020479 Published online by Cambridge University Press

productive to education and will spoil the conservation message. Conversely, people are attracted to animals that are enabled to explore and display a full variety of natural behaviour.' (IUDZG/CBSG [IUCN/SSC] 1993 p25, my emphasis). Education, now stated as an essential function of zoos, clearly involves removing negative messages. Some of the negative messages are fuelled by ignorant preconceptions or naive anthropomorphisms. Others are based on behaviours assumed to be aberrant by untrained observers, or on real aberrant behaviours. Both the perceived and the real have been lumped together under the term 'zoochosis', described as, 'a term used by behaviourists to describe mental illness in animals caused by the stress of captivity' (PETA 1993). If zoos are to function as important vehicles of education, the real aberrations have to be mitigated and the perceived ones explained and thereby eliminated. The aim of simultaneously enhancing the attractiveness of exhibits and the welfare of the animals they contain is apparently simple. Promoting natural behaviours that are interesting and educational, and trying to eliminate aberrant and unnatural behaviours can be conceptually equated with promoting welfare, but is it?

Welfare concerns about animals in human care have largely concentrated on farm and companion animals. (I avoid the term 'captive' to describe animals maintained by human intervention, away from their original surroundings, because it contains the implication that other so-called wild animals are 'free'. I think that the term 'free' is inapplicable to wild animals (Robinson 1991; 1992a,b.) There are very important differences between the biology and ecology of zoo animals and those of other animals in human care. These differences underlie differences in welfare problems. Among the differences between companion and farm animals on the one hand, and zoo animals on the other, are the following:

i) Zoo animals are used to attract visitors, for various purposes including education and fund-raising.

ii) Zoo animals are on exhibit, this is related to point (i), but has distinct implications.

iii) Zoo animals are often surrounded by large crowds of humans, who constitute a substantial element in their environment.

iv) Zoo animals have not usually been domesticated, in any sense, rather attempts are made to promote 'wildness'.

These are just a few of the differences. The matter will be treated more extensively later. The term 'enrichment' has been widely used in connection with the lives of both domesticated and zoo animals (eg Markowitz 1982; Dow 1986; Chamove 1989). The word is usually qualified adjectivally, for example as: environmental-, habitat-, or behavioural-enrichment. Making richer in these contexts usually means adding components that lead to increased complexity. This provides a key question of this paper: Does the putative enrichment actually enhance/improve the life of the animal(s) for which it is intended? This question can be rephrased as a procedural question: how do we determine how an animal reacts to, and benefits (or otherwise) from enrichment measures?

The procedural question applies to the entire spectrum of welfare concerns that relate to animals in human care. Dawkins (1990) has given an extensive review of the complexities involved in deciding issues about abating animal suffering and promoting welfare. Her article was accompanied by a 'precommentary' (Singer 1990) and some 40 peer comments. This is a large subject with a wide range of viewpoints. Fraser (1995) even suggested that eliminating value-based criteria and objectifying determinations of welfare may be impossible. The situation for non-domesticates may be even more difficult. We have little

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knowledge of the environmental requirements of most wild animals, beyond such basic matters as their physiological needs (responses to the physical environment, nutritional needs etc). We urgently need to advance both the conditions in zoo exhibits, and the techniques for determining our success. To achieve these two ends research is fundamental and, I will argue, it must extend beyond pragmatism or tinkering to involve basic studies of fundamental biology. It is likely that the effects of habitat changes that are intended to promote enrichment will prove easier to measure in relation to visitors' perceptions, and the animals' behaviour, than their effect on the animals' welfare.

Using our intuitions, a method of approaching welfare issues suggested by some scientists and philosophers, may be occasionally rewarding but it is fraught with risk. There is danger in assuming that animals react to all the stimuli that they are capable of perceiving, or that insights based on our *Umwelt* (perceptual world) are a reliable guide to theirs. Thus, although we would guess that a richly complex simulated forest is, other things being equal, likely to be more positively stimulating for the appropriate zoo animals than a tiled, barred, cell, we might be wrong. For an animal born in a relatively simple environment, such an exhibit could be stressful in its complexity. Studies of neophobia in migratory birds (Greenberg 1983, 1984) are very relevant here; some species seem very conservative in their reactions to environmental novelty. Rather than anticipate the arguments on welfare issues I leave these (largely) to the concluding pages.

The two points below provide a provocative preface to what follows:

i) Are there some enrichments that would enhance welfare but cannot be made because of visitor sensibilities? Achieving a balance may be difficult. For example, studies of the ethology of felids (Leyhausen 1979) suggest that we could greatly enrich the lives of these predators if they could stalk, pursue, kill, dismember and eat live prey animals. This would also be powerful education against the 'peaceable kingdom' myth. However, in this case it also raises issues of great philosophical and ethical complexity. Enhancing the welfare of a predatory species would involve decreasing the welfare of a prey species. For zoos, the public's sensibilities extend beyond objections to predators in zoos killing and eating animal prey; at the National Zoological Park we even get letters saying, 'you can't say the lions are fed horse-meat because my daughter loves horses.'

ii) Because of naive visitor preconceptions/misconceptions, we may be limited in attempts to enhance welfare by providing animals with functional substitutes for natural objects. To do so could trigger widespread protests. For example, animals that need a soft, resilient substrate, that is not a source of food or medicinal herbs, could be provided with a better-than-natural substitute, easy on their feet and good to sleep on. Plastic Astroturf would be excellent, but protesters would suggest that it deprived animals of their natural footings. It seems likely that animals with relatively small numbers of cones in their retinas, assumed to be lacking human-quality colour vision, probably would not benefit from the functional substitute being green (ie natural-looking). Green would probably appear to them as white. But seeing tigers, wolves, or prairie dogs, on grey plastic carpeting, despite the educational value of using this to teach about variations in the extent of colour vision, would almost certainly not be acceptable to many visitors.

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Before tackling the question of a methodology of planning habitat enrichment for the multiple purposes of enhancing welfare, education, and good husbandry, a review of the history of enrichment in zoos is appropriate.

The history of enrichment

The great pioneer in the field of enriching the lives of zoo animals, long before the terms 'behavioural enrichment' and 'environmental enrichment' were in use, was Hediger (1955, 1964, 1969). He was keenly aware of the need to consider the ecological and behavioural needs of animals in zoos, and of the urgent need to study them. His analyses were pioneering. However, many subsequent enrichment approaches have been pragmatic, concerned with problem-solving, and without any specific theoretical underpinning. Hutchins *et al* (1978, 1979) considered the use of behavioural engineering (then a buzzword) in solving the problems of behavioural enrichment. Yet, in a later paper by Hutchins *et al* (1984 p 28) this solution is opposed and the case for using nature, 'as a model to formulate an alternative approach to zoo management which we feel is more appropriate, less expensive, and has a greater potential for solving the behavioural problems of captive animals', is argued. Chamove (1989) reviews, rather broadly, the subject of behavioural enrichment but concentrates on particulars rather than precepts. Eisenberg and Kleiman (1977 p 81) argue that, 'there are too many species that have been maintained unsuccessfully in zoos, the failures in part resulting from a lack of knowledge of the species natural history.' Although advocating the use of natural history data in enhancing zoo exhibits, many of the examples of enhancement that they cite have their origins in captive studies, including the observation of behavioural abnormalities.

Tudge (1991 p 29) reviews examples of relatively simple pragmatic changes in zoo exhibits and comments, '...Nothing smaller than a national park could truly simulate the wild....' In his book on the role of zoos in conservation, Tudge (1992) examines the interpretation and analysis of animal behaviour before moving to the subject of behavioural enrichment, and recognizes a fundamental dichotomy in past approaches to this subject. One, attributed to Hagenbeck, is the creation of naturalistic-looking habitats (in zoos); the other, attributed to Yerkes, is the approach solely concerned with the welfare of the animals (actually in research establishments), and not the appearance of their environment. (As will be repeatedly emphasized, appearance may be a major limiting/restrictive factor in establishments, such as zoos, where public perceptions and expectations now strongly favor 'naturalism'. On the other hand, in research establishments the audience of scientists can accept functional substitutions that are not 'naturalistic'.) The one tradition produced what might be called a human-viewpoint-based 'naturalism', the other produced solutions based on apparatus – very much in the style continued by Markowitz (1975, 1982). The use of quotation marks for naturalism and naturalistic is to make a distinction between what we humans may perceive as natural and what another species may so perceive.

Another view of this dichotomy is that it is based on the theoretical constructs of experimental psychology (apparatus), rather than of ethology or natural (without quotes) behaviour. This is often not stated in such terms but it may be heuristic, though slightly imprecise to categorize it this way. Chamove (1989 p 155) goes so far as to state that, 'the study of enrichment may be viewed as a conceptual extension of past research investigating

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the effects of early experience on the development of behaviour'. This statement can be interpreted as emphasizing a psychological approach to enrichment.

More general reviews of zoo enrichment methods often fail to systematize the range and complexity of the issues involved. The largest single-author publication on this subject (Markowitz 1982), devotes only 15 out of 210 pages to introducing the topic and raises only one major theoretical construct (that I can discern), that of whether naturalness is a desirable quality in solutions to behavioural deficit problems. European ethologists from the classical period, with the exception of Hediger (see earlier) and Oskar Heinroth (Director of the Berlin Aquarium in the early part of this century), seem to have rarely commented on zoos and their problems. I have reviewed (Robinson 1989, 1992a) the views about zoos, and the condition of animals in them, of some of the leading figures of classical ethology. For instance, Morris (1968 p 78) categorizes mammals as either specialists, or non-specialists. Of course this is an oversimplification, since there is clearly a broad spectrum between these extremes. Despite the simplification involved this is a very useful concept. He also comments, '...The specialists are those animals that have put all their evolutionary effort into one survival trick. The non-specialists, on the other hand, are forced to live the lives of opportunists, forever investigating, forever on the move. The opportunists are precisely the animals that find the sterile, restricted life of the zoo so frustrating and damaging. The nervous system of the opportunist seems to abhor inactivity. And inactivity is just what the zoo cage has to offer.'

According to Morris, the consequence of being a specialist is that the animal has relatively simple needs and if we satisfy them, then it is happy. Lorenz (1952) in his book *King Solomon's Ring*, saw essentially the same problems with zoos. He remarks (on p 49) that in 'larger zoos one will frequently find that people are in the habit of wasting sentimental pity on animals that are absolutely contented with their lot, while genuine suffering...may pass unnoticed'. On p 53 he asks, 'which are the animals that are really to be pitied in captivity?' He then lists animals that clearly belong to the category Morris calls generalists/opportunists and which include dogs and wolves; raccoons, martens and mongooses; the monkeys and the apes; and humans. These, and similar animals, can be a challenge to us all, but one that we in the zoo profession have already gone some way towards meeting. For most species, there is probably nothing insoluble about the challenge of the opportunists given time, money and good research. Tinbergen would have appreciated the essence of this behavioural enrichment challenge, but I never heard him discuss it during my years with him.

It is still the essence of ethology to discover, and then define, the world in which species live; it is the role of those of us responsible for the care of animals in zoos to provide the animals with their world, or as much of it as possible, given the tensions between public perception and reality. For this we need to strengthen ethological studies so that we can identify the components of habitat that animals attend to. An analysis of articles in journals dealing with zoo biology, animal behaviour and ethology (as opposed to applied ethology) shows that studies of the reactions between species and their physical environment are in a minority compared to studies of intraspecific or social behaviour.

Behavioural ecology has developed rapidly, but my review of its leading journals shows that, despite its name, the great majority of papers deal with reproduction, predator/prey interactions, parasitism, and other forms of interaction with other animals. Furthermore, the *Instructions for Authors* from *Behavioural Ecology* (1996) read: 'The journal accepts papers

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in areas such as *habitat selection*; foraging, antipredator, mating and parental care strategies; dispersal and migration; sexual selection; cooperation and conflict; communication; spacing and group behaviour; and social organization.' (My italics.) We do not even know what other components of the *milieu exterior* are essential for a full and 'happy' existence for most species. We guess at these things or adjust them by trial and error; we seldom study them logically or systematically. In fact we probably know more about housing farm animals, based on scientific study, than we know about the environmental needs of wild animals.

A comparison between the zoo situation and that of domesticated animals (farm and companion animals) is important. Particularly in intensive agricultural and urban surroundings, domesticates are not usually kept in circumstances that simulate naturalistic conditions. Even when ungulates, for instance, have 'free-range' pastures, these may bear little resemblance to their original habitat(s). Contemporary intensive husbandry methods have tended to accentuate the unnaturalness of the 'habitats' for domesticated animals. At their extremes, these range from the wire cages of battery hens to the city apartments of humans containing housebound domestic cats. Improving the lives of domesticates has tended, in the main, to involve apparatus in the broad sense, rather than 'naturalness'. Unlike zoo animals, farm animals are not seen by hundreds of millions of visitors whose perceptions about natural environments affect their judgments about welfare. Exposures of the conditions in these off-public situations by electronic and film media can, and do, serve to affect public attitudes to animal farming, but 'naturalism' is not usually the first concern they raise. An expanding volume of research is involved in enriching the lives and the welfare of domesticated animals and raises many of the issues involved in environmental enrichment for zoo animals. The discipline of applied ethology is now seeking, in part, to solve welfare problems. My review of its literature suggests a current concentration on the welfare of farm and laboratory animals. The following give some flavour of the subject matter and types of research involved: Dawkins (1980, 1983, 1988, 1990); A F Fraser (1988, 1989); Hughes and Duncan (1988); Houpt (1991); D Fraser (1995); and the contributions in Monaghan and Wood-Gush (1990).

A 1993 symposium on environmental enrichment for bioexhibit animals (Shepherdson *et al* 1998) covers, among its wide range of topics, the history of the subject, but was not available until after completion of this manuscript. I think that the field awaits review and that some formal schematization of the issues at stake would greatly help to clarify both the basic problems, and additionally, some of the problems arising from some existing attempts to provide enrichment.

Towards a theoretical basis for studying enrichment

One way to deal with complex questions of this type is to start by defining the issues involved. Here is an attempt to do so by classifying them:

1. What ecological and/or behavioural needs do given species of animals have when maintained in zoos?

   Subsumed under this question are several subsidiary questions:

   (a) What are our sources of knowledge to make these determinations; how reliable are they; what can we do if the necessary data are absent; are there species whose needs are predictably easier to assess than others?

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(b) How fixed are these needs; do they vary within species, and/or between populations of a given species; if so, why (eg genetic and acquired differences); do they apply only to wild-caught individuals; do they diminish or disappear in zoo-bred animals; can they only be satisfied by naturalistic approaches?

(c) How are these needs of one species related to those of others that may be kept in the same exhibit?

(d) What effect do people (keepers, other staff, and visitors) have on the ecology/ behaviour of zoo animals?

(e) Do people's perceptions of these ecological and behavioural needs differ from reality; can these needs and false perceptions be used as bases for educational programmes, so that negative impressions can be mitigated?

2. Are there some species which it is impossible to exhibit adequately because their ecological and behavioural needs are difficult (technologically, logistically, financially) or impossible to satisfy under zoo conditions?

   Subsumed under this question are several subsidiary questions:

   (a) What kinds of data are available to make such determinations; are they based on field observations or on analyses of zoo-based behaviour?

   (b) Can we predict which categories of animals are most likely to present insoluble problems?

3. What is the importance and role of naturalism in satisfying the environmental and behavioural needs of animals in zoo conditions?

   Subsumed under this question are several subsidiary questions:

   (a) How far is it desirable to use non-natural functional substitutions for components of environments?

   (b) How far is it desirable to modify the behaviour of zoo animals by conditioning (or other behaviour-modification paradigms) so that natural motivational systems are given non-natural outlets?

Ecological needs

Data

The ecological needs of an animal are part of a continuum of subject matter that ranges from habitat analyses through behaviour to physiology. Despite this, it is worth formally separating habitat enrichment from behavioural enrichment for purposes of discussion. Dittrich (1990) has used the extremely useful term 'functional substitution' to describe the replacement of an element of the natural environment with something that may serve the same function for the zoo animal. As mentioned, a striking example of functional substitution in human habitat requirements would be the replacement of grass surfaces with Astroturf in arenas designed to support the range of behaviours involved in American football. Astroturf was designed to provide the characteristics needed by humans as a substrate for running, skidding, flailing, kicking, fighting, falling, scrabbling in heaps of bodies and so on. Football players have no biological requirement for the grass substitute to be photosynthetic, edible, natural in colour, or diverse in species composition. This comparison is not an extravagant attempt at humour – there is a real point to be made here. We can precisely define the habitat requirements of the ecology of football playing. The fact that the grass, comprising the surface of the primordial playing fields, is a plant capable of being utilized as food by a wide range of animals, and that grass grows on soil, which is a complex

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ecosystem in its own right, is ecologically irrelevant to the activity that occurs on it during the game of football (or baseball, or cricket for that matter). Interestingly enough, although the material need not be aesthetically pleasing to support the game being played, an appropriate colour may be an audience-pleasing requirement. The parallel here with tensions between zoo exhibit-needs versus zoo animal-needs is close. The needs of animals are certainly more complex than those of football players since the latter's activities are but a small part of the human behavioural repertoire. However, it is unfortunate that we cannot define as precisely the ecological requirements of most of the animals that we maintain in zoos. (For details of the use of artificial turf as a substrate for monkeys see Bayne *et al* 1992.)

In fact, ecological research has not tended to study those aspects of environmental ambiance to which animals may have a specific response. To define ambiance we can cite the animal welfare concerns of many zoo visitors. These often seem to reflect the most pressing deficits in our knowledge and research. For example, they criticize exhibits when the animals in them cannot see/experience blue skies, sunshine, leaves on trees, or even 'smell the flowers'. However, we have absolutely no idea whether any species reacts to any of these phenomena in the manner we infer from our own subjective experiences. Here, the tension between visitor preconception and functional substitution is likely to be intense. To illustrate this point, consider the fact that in natural habitats, male klipspringers (*Oreotragus oreotragus*) choose to stand on high ground, usually on rocky outcrops (Tilson 1980; Figure 1a). Although this vigilance behaviour undoubtedly has adaptive significance, and the preference for high ground may be hard-wired: i) does this sentinel-post need to be real rock; ii) does it need to be of a certain elevation; or iii) will these animals be 'satisfied' if we provide them with wooden platforms 2m tall?

Ecologists cannot normally determine the answers to the first and last of these questions in the wild. Of necessity they are most easily susceptible to experimentation in zoos. They can only answer the question about elevations if they can find situations where this is the only variable - and then only if they are very astute and sensitive observers. This is, in many ways, an example of a generic question. Klipspringers and a wide variety of zoo animals readily accept functional solutions to providing vantage points (Figure 1b). This is a simple case when compared to the relevance of blue skies, sunlight, real trees with bark and leaves and so on to the life of animals.

In the absence of fundamental research, studies of ambiance needs can be based on pragmatic experimentation, involving controlled changes in enclosure conditions. These can be carefully thought out, or inspired trial and error (for want of a better description). One can then measure the animal's response to the modifications. When one can monitor increases in desirable activity and/or decreases in undesirable activity this can lead to judgments about welfare enhancement. We can even measure physiological indicators of stress; these can include neurological symptoms (Chapman 1990) and non-invasive assays of stress hormones (Carlstead 1996; Carlstead *et al* 1993). It is also possible – as suggested by Adams & Babladelis (1977) - to carry out studies of zoo ecology, applying normal ecological research methods to existing zoo habitats (ie exhibits).

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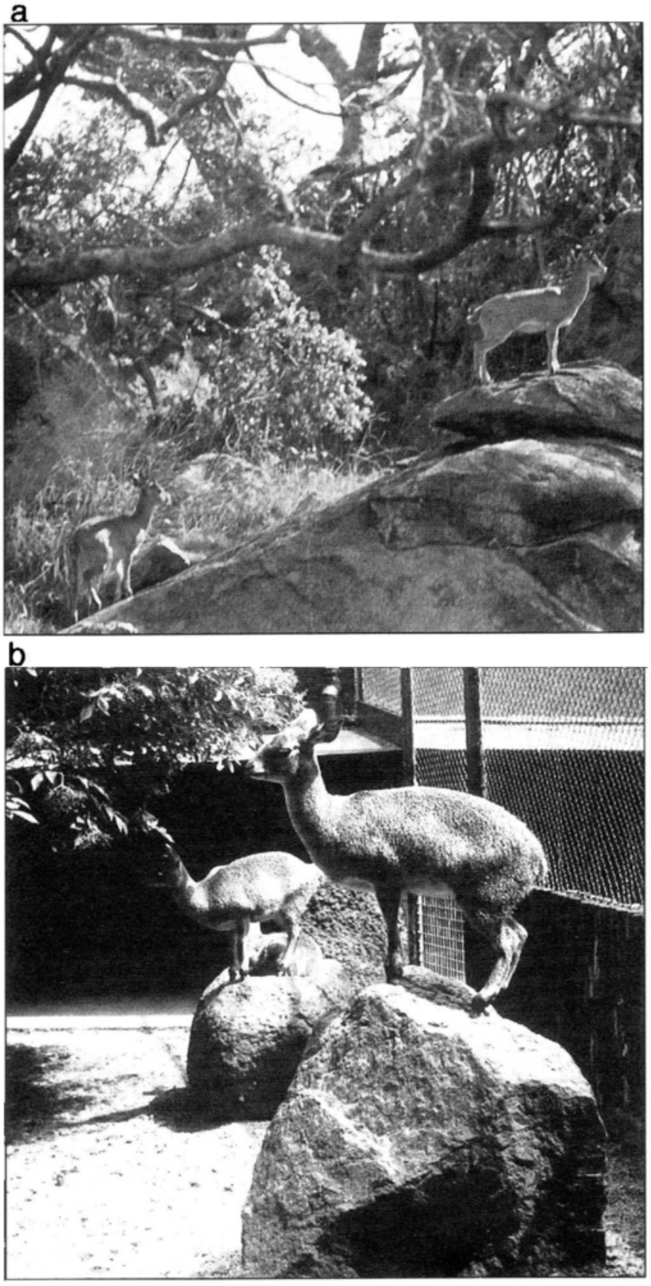

Figure 1 (a) Wild klipspingers standing on rocky outcrops in East Africa. (b) In a non-naturalistic environment at Frankfurt Zoo, rocks simulate natural outcrops for captive klipspingers. (Photo: B Beck).

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Zoo habitats may themselves be architecturally, or aesthetically inspired, with little or no input from biologists or animal care staff. Or they may be the product of biologists' insights or guesswork, or of simple tinkering. Whatever their origins, zoo habitats do constitute a basis for ecological study. They are 'homes' for the animals they contain. Furthermore, inter-zoo comparisons between the different zoo habitats of animals of the same species – as suggested by Adams & Babladelis (1977) – are a potentially fruitful and presently expanding field of research. Objections that such comparisons test only for the 'lesser evils', and that they are merely a 'Hobson's Choice' would be largely invalidated if a full range of natural behaviours, manifested at normal levels of occurrence and intensity, were present in the 'best' zoo habitats. Veasey *et al* (1996a,b) discuss this approach and comment on its problems and prospects.

Sources of insights for experimental changes in zoo habitats

It is likely that the ecological needs of some species are easier to predict and satisfy than others. The earlier discussion about specialists and generalists is germane to this point. For instance, grazing and browsing herbivores that spend the majority of their waking hours cropping grass or leaves, and then masticating them, chewing cud, refecting faeces, or sleeping, would seem to be predictably simple animals to provide for. Here, visitors' perceptions seem to accord with our prediction: the number of complaints by zoo visitors that involve ungulates, for instance, is very low indeed (Robinson unpublished data 1993-1994). Observations on the daily life of sloths and koalas suggest that their highly specialized folivory does not usually involve high levels of complexity in habitat requirements. (Although sloths need to be able to descend trees periodically to bury their faeces [Meritt 1985].)

Data on the perceptual worlds of animals can also enrich our assessment of relevant factors. Colour is clearly irrelevant to animals with monochromatic vision, and probably of low importance for the estimated large number of dichromatic mammals; odour is not of high relevance to animals with a poor sense of smell, and so on. In this respect we also need to consider one of the important lessons of ethology; that animals do not necessarily attend to all the stimuli that they are capable of perceiving. One area that we neglect because of our own sensory biases is the olfactory environment. In zoos, because of considerations of hygiene and housekeeping we may remove (daily or regularly) all the odour marks that macrosmatic animals (ie those with a well-developed sense of smell) make – and in the process destroy the sense of security that individual (personal), and home range markers provide. Because of anti-infection sterilization requirements, the excessively aromatically sterile cages of laboratory animals may be less 'hospitable' to their occupants than smelly cages permeated with friendly scents. By alternating the presence of individuals of zoo animals in the same enclosures we may provide threatening situations through the persistent odour markers of rivals. This may not be a negative factor, since threat and fear may be necessary for complete lives (Berlyne 1960) but we must consider all odour effects carefully. Inglis and Sheppard (1990) provide a wide-ranging survey of the sensory modalities involved in animal communication, and insights into how various signals can be used in managing the behaviour of animals. The relevance of these sensory factors needs to be part of our efforts to educate against anthropomorphisms and other naive conceptions of animal behaviour, by designing appropriate exhibits, and educating visitors about perceptual worlds that differ from their own.

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A further source of insights can be derived from experiments that are drawn from the methodology of experimental psychology. Two major procedures, choice tests and operant conditioning have been widely used in work on the welfare of farm animals, and are applicable, in principle, to zoo animals. These have been reviewed by Dawkins (1988, 1990) and advocated and/or used by her (eg Dawkins 1977, 1980, 1983). Choice tests have been criticized on the grounds that they may present the animal with a choice between suboptimal conditions with the lesser, or least, of the evils being chosen. A different criticism comes from Novak and Meyer (1990) who argue that forced-choice tests may reflect only short-term needs. Tannenbaum's (1991) extensive discussion of these tests, and the underlying assumptions of their critics, is forceful and worth careful attention. His argument that many choices by humans and other animals may increase 'pleasure' while decreasing health is an important one. Choices are influenced by the strength of appetite. Appetites that are adaptive in the circumstances in which they first evolved, can be maladaptive when we, or other animals, are given unlimited access to unnatural quantities or qualities of their target. Zoo animals frequently overeat. Tiger (1992) illustrates this general point with a wealth of examples.

In designing enrichments for zoo animals, one can present the animal with a choice between the old conditions and a new environment modified according to insights into needs. The methodology is well established. The testing of mock-ups of exhibit designs, using living animals, prior to finalizing and building them, is clearly feasible, although it may be expensive. This approach was extensively used for the development of designs for London Zoo's Clore Small Mammal Facility (Morris 1961a,b; 1965). Significantly, these methods seem not to have been used very extensively in zoo design since then. The novelty of a new enclosure environment may affect animals positively or negatively on their first encounter.

Using conditioning techniques, derived from experimental psychology, involves making the animal 'work' to obtain access to some stimulus or resource. Operant conditioning techniques have been used by ethologists to investigate natural behaviours, for example by Rasa (1971) in assessing appetence for aggression in damsel fishes. The extent to which the animal is prepared to invest activity, for example bar-pressing in laboratory rats (*Rattus norwegicus*), in obtaining a resource is held to be proportional to the deprivation, but there are real problems with this (Dawkins 1988, 1990). Apart from technical difficulties in interpretation, such techniques may fail because, 'short-term choices made in response to an immediate need may not reflect the animal's long-term preference.' (Dawkins 1990 p 6). The techniques of aversion learning can also be utilized in this regard, but may themselves be thought to infringe the animal's welfare (Dawkins 1988). Thus, in aversion learning experiments, shocking an animal, or subjecting it to a sonic aversion stimulus, clearly results in pain and stress. In addition, such techniques are often unreliable (Dawkins 1990 pp 6-7).

Variability

Some assumptions about the fixity of ecological requirements are potentially dangerous. One of the spin-offs of the golden-lion tamarin (*Leontopitheus rosalia*) breeding and reintroduction programme has been the realization that zoo-bred tamarins have significant behavioural 'deficits' compared to forest-dwelling wild tamarins. Zoo-raised tamarins often show limited exploratory behaviour, and deficits in coping with a variety of environmental factors including unstable substrates (for instance, bouncing tree branches), venomous or

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other dangerous animals (snakes, spiders, poisonous frogs), and predators. These undeveloped or underdeveloped behaviours were evident in zoo-raised animals when introduced into the wild (Beck *et al* 1991; Kleiman 1996).

One interpretation is that these behaviours are learned in specific conditions that are not usually present in zoos. This view is consistent with the fact that the behaviours can be established by permitting the zoo-bred animals access to benign learning conditions – real trees *sans* danger (Bronikowski *et al* 1989). Under zoo conditions, environmental complexity is always less than that in Brazilian rainforest. Missing factors include: predators, small dangerous animals, varying climatic conditions, the very wide range of natural foods, and the complex and non static/impermanent three-dimensional structures of the forest within the animals' fluctuating home ranges. Rather than implying pathologies or teratologies of behaviour, which is possible, such 'deficits' may imply considerable propensities for variability in behavioural ontogeny. Only a rigorous analysis of each type of 'deficit' could elucidate whether it could be described as a frustrated normal behaviour or an adaptive response to circumstances. This opens up a philosophical issue of considerable moment. The popular phrase, 'you can't miss what you've never had' epitomizes one possibility. It is clearly wrong to assume that being deprived of high complexity causes suffering even though it prevents some behaviours from developing. On the other hand, the occurrence of vacuum and/or redirected activities in animals deprived of complex environments would be suggestive. This entire question needs further evaluation in discussions of welfare needs.

Mixed species situations

Providing appropriate ecological ambiance for mixed species assemblages may not simply be an additive process. On logical grounds, there is clearly a possibility that species from the same macrohabitat can have microhabitat needs ranging from overlapping to conflicting. This may not be a problem in the wild where conflicts can be resolved naturally. In the zoo, however, these needs may constitute a problem because natural resolutions are unacceptable on welfare grounds. To add to the philosophical complexities of considering mixed species welfare concerns it is worth noting that the trophic separations that occur in many environments, for instance between tropical stream fishes, or African grassland mammals, break down at times of drought and migration. This may increase or reduce conflict. In the tropics migratory birds form mixed-species flocks with residents (Moynihan 1979). Such species may be pre-adapted, to some extent, for benign mixed species exhibits.

The role of humans and conditions external to the exhibits in the zoo ecosystem

The presence of humans can affect both the quality of the zoo ecosystem and the behaviour of the animals. Such effects can be positive or negative. Leyhausen (1961) analyses such impacts on small cats. Since small cats are themselves subject to predation they have to be fearful, and visitors adversely affect their behaviour. On the other hand, he concludes that, '...the keeper is, of course, the most important item in the captive cat's life'. He shows how good keepers minimize stress and enrich the lives of the animals under their care with positive interactions, particularly play. Zoo exhibits are unusual as animal habitats in that they abut, on the outside, areas often densely packed with human visitors of all ages, shapes and sizes. These humans frequently produce a considerable volume of noise, and may actively try to engage the attention of zoo animals in a variety of ways. The noise level in zoos from extra-habitat sources may be exacerbated by mechanical noises, music from boom-

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boxes - licit and illicit, vehicular transport, and public address systems. The inside perimeter of zoo exhibits is often bounded by keeper areas or maintenance space where other forms of disturbance may occur. Vacuum cleaners are often-disregarded noise sources there. All these factors have their effect on animal habitats (see for example, Carlstead *et al* 1993).

When welfare-enhancing enrichment is being planned, the diminishment of stress-producing disturbances is frequently ignored. We do not know, for instance, the levels of noise that are disruptive of normal life and behaviour in most species. But there are bases for inferring this for some species. For example, we know of a number of species that have successfully invaded urban areas where many of the potential disturbances found in zoos are present. In addition, there are data on habituation to the use of various devices involving, flashing lights, noise, vibrations and fearful objects to repel so-called pests (Inglis and Sheppard 1990). One solution to dealing with situations, or particular locations, where human-caused intrusions cannot be reduced to levels tolerated by some species, could be to use them for exhibits containing species that can tolerate such intrusions – for reasons outlined above. Wild Polar bears (*Ursus maritimus*) in the vicinity of Anchorage, Alaska have habituated to what must once have been the terrors of the town dump. Did the bears' habituation entail stress that would be ethically indefensible, or was it parallel to my experience of living next door to the bass amplification of the teenage rock enthusiast, to which I have – improbably – habituated?

Behavioural needs

Since there is a continuum from ecology to behaviour, many of the above remarks apply to both subjects. In the field of behaviour there is a history of a dearth of studies, relatively speaking, of interspecific behaviour, foraging, food-finding, reactions to environmental components, and so on. This is particularly true of field studies of many of the major vertebrates that commonly comprise zoo collections (see Robinson 1990, and references therein). However, recent developments in behavioural ecology have started to amplify knowledge in these areas. The new data emerging from such studies should, eventually, greatly help zoo enrichment processes. In addition, there are a number of present sources available to us.

Insights and experiments

Some insights into the behavioural requirements of animals, derived from classical ethology, have already been cited in the introductory section on the history of this subject. Insights can also be derived from studies of zoo animals, in public and non-public areas, which have revealed fixed patterns of behaviour (eg Leyhausen 1961, 1979; Morris 1962; Lyall-Watson 1967; Kleiman 1974; Robinson 1990). Analyses of many of the early behavioural studies carried out on zoo animals raise the question of how far the animals were fully expressing natural behaviours. (The possibility that this could be the case is suggested by the 'deficits' discovered in zoo-born tamarins.) This question is discussed by Kummer (1957, 1968); Kummer and Kurt (1965); Robinson (1990); and Carlstead (1996). In general, there are good reasons to assume that such basic studies of wild-caught animals can provide insights for behavioural enrichment. I have suggested (Robinson 1990, 1991) that, despite some recent emphases on the variability of intraspecific behaviour, there are many areas of behaviour where we should expect that selection has operated to reduce variability. These should be

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the areas where enrichment needs are easiest to assess. For instance, hunting animals should have little variability in their response to the movement of prey-sized objects. Functional substitutions for living prey have been developed (Markowitz 1975, 1982; Snyder 1977; Gewalt 1990). A wide range of animals including tigers, piranhas, pike, squid, boas and frogs, will clearly need to be stimulated by such movements. The occurrence of behavioural deficits in zoo-raised animals is also a source of insights into the ontogenetic needs of animals. For example, normal arboreal locomotion in tamarins may be partly dependent on the richness of their early experience (Bronikowski *et al* 1989; Beck *et al* 1991).

The effects of zoo conditions on the behaviour of wild mammals have been extensively reviewed by Carlstead (1996). The study of behavioral abnormalities (as opposed to deficits) in zoo animals can be an important source of data and insights, as emphasized in the following passage from a review (Robinson 1990 p 128) of the potential of zoo-based research. 'A further set of research opportunities result from bad animal husbandry practices. This situation parallels that of studying anatomical or health deficiencies, in human or other animals, due to improper nutrition. Animals may develop behavioral defects in zoos, due to the absence of appropriate outlets, confinement and so on. Abnormalities can be important clues to the function and origins of normal behavior as in human psychology. This is also true of trauma-related and pathological behavior abnormalities that can be detected in closely observed populations such as are present in zoos. Major treatments of this aspect of the behavior of primates in zoos can be found in Erwin, Maple and Michell (1979).'

Zuckerman's (1932) study of hamadryas baboons (*Papio hamadryas*) at London Zoo is a classic case of the abnormal behaviour resulting from markedly unnatural (high) population densities. Aggression was raised to lethal levels (see for instance, Robinson 1990 pp 136-138). Abnormalities in the form of behaviour have been called stereotypies if repetitive, relatively rigid in character, and apparently functionless. They have been extensively described, and analysed as to causation or probable causation (well-reviewed by Carlstead, 1996 pp 325-26). They reveal much about inadequacy of conditions, and are often corrected by tinkering. However, they may result in some form of self-generated stimulus-enrichment and/or stress reduction. It is noteworthy that aspects of 'normal' animal behaviour, particularly displays involved in courtship, aggression and territoriality have often evolved from conflict situations involving fear, and 'stress'. These include behaviours that putatively reduce stress in natural situations, such as visual 'cut-off' (Chance 1962), and facing-away (eg Smith 1977 p 354). The further study of stereotypies could involve the possibility that some of them function to reduce stress (eg Dantzer and Mittleman 1993; Lawrence and Rushen 1993).

There is also a possibility that we may be ignoring an important area of behaviour that would increase the welfare of our collection animals. We know little about whether or not outlets for the expression of aggression, territoriality, and competition are an essential part of a healthy life. Because of this, it is possible that even the most apparently 'satisfied' of our animals may be deprived of important behavioural components. Neither do we know what is the role and extent of unpredictability and stress in the lives of animals in nature. Exploration and curiosity often appear to be associated with fear (Berlyne 1960). In our animal management procedures we try to minimize aggression, fighting and unpredictability and may unwittingly be doing our animals a disservice.

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Exploration and curiosity contrast with what is often described as boredom. Carlstead (1996 p 336) states: '...the term 'boredom' is often used to describe the way confined mammals experience their undiversified world. Boredom is the psychological response to an environment that fails to meet the animal's needs for stimulation due to low stimulus diversity. An animal's needs for stimulus diversity are difficult both to define and to quantify.' There is a great deal of difficulty in operationally deciding whether an animal is bored, in the sense suggested by Carlstead, or not. Certainly zoo animals that seek to manipulate the behaviour of the visiting public would seem to be under-stimulated. Carlstead cites examples of this, including begging, throwing objects, and spraying urine. In the Colombo Zoo, Sri Lanka, I saw chimpanzees (*Pan troglodytes*) scream repeatedly until a crowd had gathered, and then throw faeces into it, eliciting screaming in response.

Exploration, in its various manifestations, is a form of information-gathering behaviour. It is often associated with learning home ranges – or even their cognitive mapping. Inspection, the close examination of a novel stimulus, can be regarded as a form of exploration often used to 'determine' possible threats, predators, or rivals. All can be comprehended under the heading of exploration and curiosity. Lorenz's (1982) masterly treatment of this subject should, in my opinion, be a starting point on this subject for students of enrichment.

The extent to which animals apparently seek out novel stimuli varies considerably with their ecologies, and this leads back conceptually to Morris's (1968 p 78) classification of animals into specialists and generalists. If one were to guess which animals would need to be given stimulative enrichment to promote curiosity and exploration, the generalists – or what Lorenz (1982) calls 'specialists in versatility' – would be high on the list. Neophobes (Greenberg 1983, 1984) would be low on the list, but migratory animals in general, are an *a priori* high. The rat, somewhat disparaged by classical ethologists, belongs to the mammalian Explorer's Club, and the corvids to the avian one, along with some highly generalist feeders including starlings (see Inglis and Ferguson 1986).

Omnivory is itself a predisposing factor promoting food-exploration. The enrichment of zoo life should include dietary variety for the generalists, and stimulation for food-finding. A large number of examples of the enriching effects of food scattering and hiding now exist, and Carlstead (1996) provides a good review. The beneficial effect of stimulus-complexity on activity patterns in ape exhibits clearly emerges from Wilson's (1982) survey of exhibits in 41 zoos. We should also take propensities for playfulness into account when we plan enrichment. Lorenz (1982 p 330) states that, 'exploratory behaviour is impossible to distinguish from play by sharp definitions', (see also Wood-Gush and Vestergaard 1991). Playful animals are excellent attractors of visitor attention and enhance educational opportunities. They almost certainly reflect good habitat ambience.

Variability

Variability of behaviour in the wild, at the individual level, is likely to be largely a product of learning. Behavioural differences between populations of the same species, may reflect cultural transmission. This has been reported from mammals and birds (eg Curio *et al* 1978; Lefebvre 1986; Delius 1989, 1991). Most examples relate to feeding behaviours, with the food-processing behaviours in Japanese macaques (*Macaca fuscata*) being a case in point (eg Itani 1958). The extent to which the other various kinds of learning affect the *natural*

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behavioural repertoires of animals, in such a way as to impinge on welfare, is an area of relatively scant information.

Mixed species situations
Providing behavioural enrichment for zoo animals may be subject to constraints resulting from conflicting behavioural needs of other species housed in the same area. At the very simplest level there could be conflicting activity cycles, needs for the coincident use of substrates and so on. Given our limited knowledge of the range of requirements of many animals this is an important factor to be borne in mind as we progress from single-species to multi-species exhibits.

The role of the human/animal relationship in behavioural enrichment
This is an area of considerable controversy. Kiley-Worthington (1990, 1993) is a good source of background material.

Perceptions and education
The behaviour of animals in zoo exhibits is often the primary negative factor affecting visitors to zoos. Misconceptions abound. This is an area for major educational efforts.

Possibly impossible species

There is certainly a logical possibility that some species have ecological or behavioural requirements that make them unsuitable as zoo animals. The criteria that we might use to arrive at a determination of unsuitability are not easily defined, but can be based on welfare, on exhibit requirements, on visitor perceptions, or on some or all of these. Welfare-based criteria for species rejection could include an inability to satisfy real rather than perceived habitat requirements, and real rather than perceived behavioural needs. In the latter category, my own view is that behavioural imperatives need not be satisfied by natural means – as long as we can provide other outlets that exhaust the motivations of the species concerned. For example, artificial lures can provide outlets for hunting, chasing and killing drives (Markowitz 1975, 1982; Snyder 1977; Gewalt 1990).

A priori, one can make a number of predictions about which types of animals should be carefully and critically analysed for the potential exclusion list. To quote a few examples, some verging on the absurd: the large whalebone whales, which cruise over enormous distances, and filter-feed hundreds of tonnes of plankton each year, may be intrinsically unsuitable for zoo exhibits; so might those whales that sing in the ocean depths; birds which soar on thermals could be behaviourally deprived in normal zoo conditions. Should it be determined that soaring is a strongly motivated behaviour (and it should not be assumed, automatically, that it is), then it is possible that a good designer could build a thermal-producing device into a condor aviary. At first sight this seems improbable but the possibility should not be dismissed.

Birds such as the albatross, which seldom stop being airborne, and some swallows which fly for extended periods, may also be impossible to keep happy and active in zoos. For animals that exist in large social groups in the wild, the majority of zoos are incapable of providing an adequate social milieu for the full expression of group behaviour. Behavioural appetites for aggression, competition and rivalry may be unsatisfiable in zoo conditions. All

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this needs examination from a welfare standpoint. There may be animals that arouse strong and ineradicable feelings of the suffering which they are wrongly assumed to undergo in zoos, creating strong negative feelings, so they should not be exhibited. For a substantial minority, no amount of rational explanation and education can remove these feelings towards some species. It's time to admit it.

What is the role of naturalism?

There are very strong views within the zoo/aquarium profession on the question of naturalism (Dittrich 1990). At present I would guess that the overwhelming majority of zoo directors, programme planners, and professional zoo exhibit designers stand strongly in favour of habitat exhibits. These seek to replicate natural-*looking* habitats, ecosystems and even biomes. They are frequently triumphs of art and technology. They are often triumphs of art and technology over reality – elaborately sophisticated stage settings, often like the towns in Western movies: all 'store-fronts' and nothing of substance behind the façade. In fact, Spinelli and Markowitz (1985) found that there is little evidence that natural-looking exhibits lead to more normal behaviour than non-natural ones. On the other hand, there is no doubt whatsoever that it is very important to educate our visitors about the disappearing ecosystems of the world. For instance, replicated rainforests are a powerful tool in highlighting the wonder and glory of that biome.

Good habitat exhibits are convincing to us because we design them literally from our point of view, even though *Homo sapiens* has a rather distinct perceptual world and, as a species, we have what is almost certainly a minority viewpoint. We have stereoscopic colour vision that is acute only at distances related to our social interactions, upright posture, and evolutionary history. Compared with most other mammals we have a relatively inefficient sense of smell, and a limited range of hearing. Most of us realize that our world is very different from that of the cats and dogs with which we share our houses. Despite this we seldom apply a similar understanding to the rest of nature. That leads us into many misconceptions. In addition, we ourselves have largely abandoned naturalism in our civilized lives. We live in insulated, climate-controlled houses for a substantial part of each day; in these we are separated from most of our conspecifics. We eat a wide range of substances that are either extremely rare in, or totally absent from, the natural world. We amuse ourselves in vicarious ways and transport ourselves by mechanical devices at speeds unimaginable to humans in the wild state.

One could greatly extend this list of unnaturalisms. The real point is that modern life is highly attractive, in its non-naturalness, to a substantial number of humans. We should be able to use this situation to combat misconceptions about naturalism for animals. For all these reasons I would argue that we need to be careful about the siren song of naturalism when it comes to the life of animals. I would insist that we need to show visitors the differences between the world of other animals and ours; this is an urgent educational task. It also leads straight back to the concept of functional substitution, and to the need for basic research into animal needs.

A further plea for functional substitution

For zoo habitat (ie ecological) enrichment, the functional substitution of some elements can proceed fairly simply in the absence of field data, by using a number of pragmatic

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approaches. One is to present choice tests on such matters as substrate, bedding, sleeping areas, and daily feeding regime. However, our naive perceptions of the characteristics of the natural components of these elements may be misleading. Animals are often programmed by evolution to respond to stimuli that we cannot ourselves readily distinguish, and may not discover in our studies. Thus cats may habitually use grass-straw to line their sleeping holes in the wild, but actually select something as unnatural as wool strands if offered them in a multiple choice test. In the wild situation the stimulus characteristics of straw are unique - but there may be dozens of substitutes available in the zoo that trigger the same response. Eibl-Eibesfeldt's (1963) experiments on nestbuilding by rats are full of insights into functional substitution and the stimuli involved. A nice (unpublished) example from the work of Baker and Robertson (quoted by Dawkins 1990) concerns nestbuilding by pregnant sows, which will build nests similar to those of wild pigs and work to obtain straw to do so. However, when provided with large waterbeds they do not work to obtain straw and show little nestbuilding behaviour. The waterbed, perhaps not surprisingly, seems to be a good functional substitute for a straw nest. Bower birds (in our increasingly rubbish-covered world) choose pieces of blue plastic to garnish their courts in response to the same innate programme that led them to choose blue fruits and flowers in the unpolluted past.

In experiments with zoo animals, Morris (1962) found that green acouchis (*Myoprocta acouchy*) carried out their elaborate scatter hoarding behaviour with large dog food pellets. This was clearly an acceptable functional substitution for the fruits and seeds that they store in nature. The pellets triggered a full-scale response. It is possible that acouchis would even select pellets in preference to the palm nuts that they hoard in the wild, but he did not test that. Since choice tests may require conditions such as plentiful space, and a standardized layout, they may be difficult to carry out in public exhibits. (Although if they were, they could be exploited in educational programmes and be doubly worthwhile.) This approach verges on tinkering, but despite my strictures on this approach, and the urgent need for fundamental research, it may be an economical and time-saving short-cut. Insights into a species' behaviour, particularly if they are derived from close familiarity with the species in question, can be useful in deciding which aspects of zoo conditions may be susceptible to functional substitution. It is preferable to do tests on the responses of animals to exhibit components in mock-ups before the designs are finalized, rather than fix-its afterwards. This would be the equivalent of what museum exhibit designers call formative evaluation. Inter-zoo comparisons of exhibit ecologies, and information exchange through professional organizations and electronic publication, could greatly assist in preventing design errors. As with all such exchanges, standardization of data collecting is important to facilitate comparisons and information exchange.

Behaviour can sometimes be modified to fit exhibition requirements without affecting welfare. Reversing day/night rhythms is a case in point. Those changes that involve various kinds of conditioning may be less simple. This approach has been critically appraised by Hutchins *et al* (1978, 1979, 1984) among others. The question of whether we can, and should, exploit behavioural engineering by training animals to do things, or by a direct human/animal relationship, is an interesting one. There is clearly a continuum from the extreme of training animals to do things outside their natural behavioural repertory at one extreme, to providing 'natural' circumstances and stimulation in which they are able to find outlets for all their drives, at the other. At one end is the chimpanzees' tea party or the

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harmonica-playing elephant and at the other is the food-burying acouchi. In between, are all those behaviours that are a fascinating part of the animal's survival apparatus but redirected at a functionally substituted stimulus. For example: an orb-weaving spider responding to a tuning fork is exhibiting natural behaviour directed at a stimulus that adequately substitutes for a prey item in stimulating attack; a cheetah chasing a moving object, albeit a tattered plastic bag pulled by a cord powered by an electric motor, is qualitatively in the same category; a tiger swimming in a moat and playing with a floating beer-barrel is still exhibiting elements of natural behaviour. Snyder (1977) describes some excellent mechanical innovations used to stimulate hunting behaviour in pumas (*Felis concolor*) and sand cats (*Felis margarita*). Powell (1995) has reported on environmental enrichment techniques used with lions (*Panthero leo*) at the Atlanta Zoo which essentially involved presenting objects that had no visual characteristics of natural prey. They significantly increased licking and gnawing activity as well as pawing but not, as far as I can determine, any of the behaviours associated with hunting and prey capture.

All these cases seem legitimate to me. The problem is that some behaviourally engineered responses can convey totally wrong messages about animals. The potential for this increases both as the objects involved become less likely to be identified with natural situations, and also as the behaviours become more trivial and less obviously connected with survival and 'real life'. This problem is also an opportunity. With good interpretation, important lessons can be learned by zoo visitors from most of the behaviours that involve stimulus substitution rather than training for unnatural acts. That a tuning fork can substitute for a fly, or a moving plastic bag for a gazelle, can in fact highlight very important points about animal behaviour.

In the case of vertebrate predatory behaviour, substitutes for live prey clearly exist which would provide the visitor with interesting and non-distressing spectacles. However, it remains to be determined if they could satisfy the complex of motivations involved in predatory behaviour (Leyhausen 1979). When I see our bobcats (*Felis rufus*) seizing whole dead rats, and flinging them across their enclosure to then pounce on them, I realize that in this case we have denied them something important. We have missed the attraction of movement, and denied them pursuit and killing. The first two we could provide by functional substitution. With ingenuity we should even be able to provide for a neck-bite kill on a dummy. But do they really need the reinforcement of a struggle, squeal, and flowing blood? The issue of normally unfulfilled predatory behaviour, is critically examined by Hutchins *et al* (1984). The tension between welfare considerations and biological education is nowhere more explicit than in relation to predation and aggression. Ensuring the welfare of prey animals may mean perpetuating the public's prevalent, and largely sanitized, view of the wild world.

Tinkering; and experiments on fundamentals

Many of the experiments that have been used to develop methods and systems of ecological/behavioural enrichment have frequently involved what I think must be called tinkering. Of course, most of us also regard this as pragmatism. Tinkering is defined as 'repairing in a makeshift way' and is frequently applied to existing problem exhibits. Clearly we should try to remove problems, mitigate welfare concerns, and eliminate behaviours that rightly or wrongly diminish the educational impact of our exhibits, but tinkering is a

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fundamentally backwards methodology. However, it is widespread, and there is a growing literature on this approach. For instance, my analysis of the abstracts of papers presented at a recent conference (Shepherdson *et al* 1998) suggests that the great majority of those that dealt with concrete examples fall into the tinkering category. Many, perhaps most, of the problems encountered in exhibits could be dealt with at the design stage, if the needs of the animals could be adequately defined and then catered for in the final construction. However, few zoos escape from the confines of an exoskeleton of past structures, and budgets that fund the possible rather than the optimal. Tinkering will probably remain with us, although ideally we should do the experiments before building the exhibits, not after.

Fundamental research by systematic investigation into the importance of environmental factors in the biology of animals is crucial to the future of enrichment. This will involve studies that are, in a sense, incidental to enrichment, but should contribute to it. Their primary purpose would be to advance understanding of which environmental factors animals actually attend to, and how they react to them. Instead of concentrating on intraspecific stimuli – the majority of such studies have been on social behaviour – they would concentrate on the non-social environment. As I have repeatedly emphasized, there are many unanswered questions about habitat requirements. When asked if great apes have an irreplaceable need for blue skies, sunlight and flowers we cannot presently answer. In zoos we could manipulate things so that we could find the answers.

The best laid plans...an important caveat

Despite the actual and potential input of research into exhibit development, the final result may be unsatisfactory because of the often unpredictable decision-making by the person, or persons, with authority over construction budgets and general finances. A further complication occurs when aesthetic and architectural decisions have priority over husbandry and welfare considerations.

Clearly if we are to achieve the best results, the considerations of animal welfare must be given priority in financial and design decisions. We may have to work very hard to impart a message about the nature of nature, about the amorality of the wild, and the inevitable restriction of humane conditions to situations under human control. Yet, this is one way in which we can establish a moral basis for our concerns for the future of life on earth.

Animal welfare implications

This attempt to systematize an approach to enrichment raises crucial questions about the connection between existing knowledge about the ecology and behaviour of species in zoos, the educational need to maximize the range of behaviour and overall activity of these animals, and their welfare.

Enrichment is clearly an important task for us all. It means, quite simply, that we should ensure that the animals in our care have the greatest possible opportunity to satisfy their behavioural imperatives, and to express their full range of natural behaviours. If we succeed in this task we will all have more interesting zoos, with more humane conditions. The answer to the question about whether we have adequate data is, in my view, overwhelmingly negative. The absence of data is regrettable, but it does not mean that we cannot proceed to enrich our exhibits and enlarge the lives of our animals. Despite my belief that tinkering is

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a backwards approach to enrichment, we are under pressure to act quickly for the benefit of the animals, to remove problems of perception, and to enhance our message.

As outlined, we can use a variety of insights into animal needs, derived from several sources, to change our exhibits and try out a wide variety of functional substitutions. If we work systematically and document our procedures, we will be accumulating data as we do this. These data, and our insights, should suggest topics for pursuing fundamental research into the animal/environment relationship, and into fundamental aspects of the motivation and mechanisms of behaviour. Zoos may be very good places to conduct such research. They are places where environments can be controlled and manipulated. This research may have great utility both in conservation and in animal welfare.

There is also the vexed issue of naturalism. If this means replicating natural environments without relevance to those elements that are significant to the animal species that they contain, then we may be failing to educate about the difference between perceptions of relevance and reality. We may increase the expense of our animal areas without even increasing the welfare of their inhabitants. In the pursuit of verisimilitude we may even promote an anthropocentric view of species' needs that is positively harmful. On the other hand, we need to create a feeling for habitat preservation and the protection of biodiversity and to do so requires us to inspire and move people to concern for the environment by building replicas of unfamiliar habitats. To balance these two factors will require all our skills.

The tension between visitors' perceptions of animals' welfare needs, their biological needs, our lack of full understanding of the real nature of ecological and behavioural needs, and the need to educate through exhibits is real. The wide range of opinions about animal welfare and animal suffering that were published alongside Dawkins' (1990) article, together with their many antecedents and sequelae, are indicative of the complexity and passion that the subject entails. My inclination is to return to Fraser (1995 p 103) who states: '...science is limited in its ability to determine the "overall" welfare of an animal and compare welfare in different environments...the role of science should be seen as *identifying, rectifying* and *preventing* welfare problems'. We should find this central to our mission, and the framework detailed above should facilitate this.

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