

Towards Welfare Biology: Evolutionary Economics of Animal Consciousness and Suffering*

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ABSTRACT: Welfare biology is the study of living things and their environment with respect to their welfare (defined as net happiness, or enjoyment minus suffering). Despite difficulties of ascertaining and measuring welfare and relevancy to normative issues, welfare biology is a positive science. Evolutionary economics and population dynamics are used to help answer basic questions in welfare biology: Which species are affective sentients capable of welfare? Do they enjoy positive or negative welfare? Can their welfare be dramatically increased? Under plausible axioms, all conscious species are plastic and all plastic species are conscious (and, with a stronger axiom, capable of welfare). More complex niches favour the evolution of more rational species. Evolutionary economics also supports the common-sense view that individual sentients failing to survive to mate suffer negative welfare. A kind of God-made (or evolution-created) fairness between species is also unexpectedly found. The contrast between growth maximization (as may be favoured by natural selection), average welfare, and total welfare maximization is discussed. It is shown that welfare could be increased without even sacrificing numbers (at equilibrium). Since the long-term reduction in animal suffering depends on scientific advances, strict restrictions on animal experimentation may be counter-productive to animal welfare.

KEY WORDS: Animal, Biology, Consciousness, Economics, Evolution, Natural Selection, Suffering, Welfare.

1. INTRODUCTION

Biology in general and population biology and ethology in particular have been studied predominantly if not exclusively in an objective sense, being concerned with such questions as how natural selection leads to the maximization of population size, growth rate or fitness and what animals do. While these problems are no doubt important, an equally, if not more important issue is the welfare of the individual sentient in a or all species. Here, (net) welfare or well-being of an (not necessarily human) individual is its (net) happiness, or total enjoyment minus total suffering.

Scientists in general are usually very reluctant to speak about subjective happiness and suffering, preferring to deal with more objectively measurable magnitudes. In fact, even when they use the apparently subjective terms of well-being such as "welfare" (e.g. Wilson 1980, Ch. 6), they actually mean fitness for survival or abundance in the number of the species concerned, as if the subjective sense of "welfare" has absolutely no place in science. This tendency is partly due to the difficulties in measuring welfare (which are, however, not

insurmountable; see Section 2) and partly due to the influence of positivism in general and Watson-Skinnerian behaviourism in particular. However, in my view, the importance of objective studies does not preclude the usefulness and even the necessity, at some stage or other, of dealing with the subjective variables of happiness and suffering. It is better to be roughly right on something important than to be accurate but wrong or irrelevant.

Until fairly recently, the very discussion of such subjective concepts as consciousness was almost tabooed. In the past two decades or so, partly due to the increasing concern with animal welfare and partly due to the realization of the unreasonableness of extreme behaviourism,¹ biologists, psychologists, and other scientists have started to examine the area of animal consciousness. (See e.g. Dawkins 1980, 1990; Duncan 1974, 1987; Gallup 1985; Gould 1985; Griffin 1976, 1982, 1992; Lorenz 1971, 1977; Ristau 1991; Thorpe 1974; Wiepkema and Adrichem 1987; the entire issue of *Applied Animal Behaviour Science*, February 1989).

The attack on extreme behaviourism dates back to Chomsky's (1959) review of Skinner's (1957) book, *Verbal Behaviour*, when behaviourism was at its peak. Not long after, Burt (1962) argued strongly for restoring the study of consciousness. He began by describing the situation then: "Nearly half a century has passed since Watson (1913) ... proclaimed his manifesto. Today, ... the vast majority of psychologists ... still follow his lead. The result, as a cynical onlooker might be tempted to say, is that psychology, having first bargained away its soul and then gone out of its mind, seems now, as it faces an untimely end, to have lost all consciousness" (p. 229).

However, more than three decades later, the converted still does not seem to outnumber the un-converted. Attempts to suppress the subjective concepts of welfare, suffering, intention, etc. still abound (e.g. McFarland 1989, p. 36, p. 125; Colgan 1989; Yoerg 1991). Nevertheless, an increasing number of scientists are changing their mind, as typified by this quote: "I used to tell students that no one ever heard, saw, tasted, or touched a mind. So while minds may exist, they fall outside the realm of science. But I have changed my mind." (Gallup 1985, p. 633). (See Rollin 1989 for a critical history of the changing views).

The time is ripe for the recognition of welfare biology as a valid field of scientific study. This recognition could be facilitated by the arguments that welfare biology is a positive study which could be made independent of value judgements (Section 2), that evolutionary logic can be used to help answer fundamental questions in welfare biology, such as which species are conscious (Section 3), that the "economics of evolution" can be used to suggest that individual sentients failing to survive to mate successfully probably suffer negative welfare (Section 4), that simple models of population dynamics could be used to show how animal welfare could be dramatically increased (Section 5 and Ng 1992b).

The present writer is a welfare economist in training. Despite a fair amount of effort, he is bound to be deficient in expert knowledge in many areas relevant to the topic tackled. However, it is hoped that some perspectives from someone in

a different discipline may bring fresh insights and may stimulate more rigorous contributions from experts in the relevant fields. Just as Dawkins' (1990) interesting proposal of animals' demand curves is just *one* of the methods of estimating welfare, our more conceptual analysis is not meant to preclude other conceptual and empirical studies.

2. WELFARE BIOLOGY AND ITS SCIENTIFIC STATUS

Welfare biology is the study of living things and their environments with respect to their well being or welfare. What is meant by "welfare"? An unpretentious and common sense definition is adopted here. Welfare of an individual sentient is just its net happiness. The (net) happiness of an individual sentient over a period of time is the integral of its affective feelings over that period of time. This is illustrated in Figure 1.

The vertical axis measures the intensity of positive (happy) and negative (unhappy) affective feelings. The curve in Figure 1 represents the intensities of this feeling through time. The happiness of an individual sentient for any period of time is just the integral of the curve representing its affective feelings over that period of time, counting its positive affective feelings as positive and its negative affective feelings as negative. In other words, its happiness is the total area above the line of neutrality minus the total area below that line.

What do we mean by positive and negative affective feelings? Positive feelings are those that feel good in themselves, including sensuous pleasures and spiritual delights. Negative feelings are those that feel bad in themselves, including sensuous pain and mental sufferings.

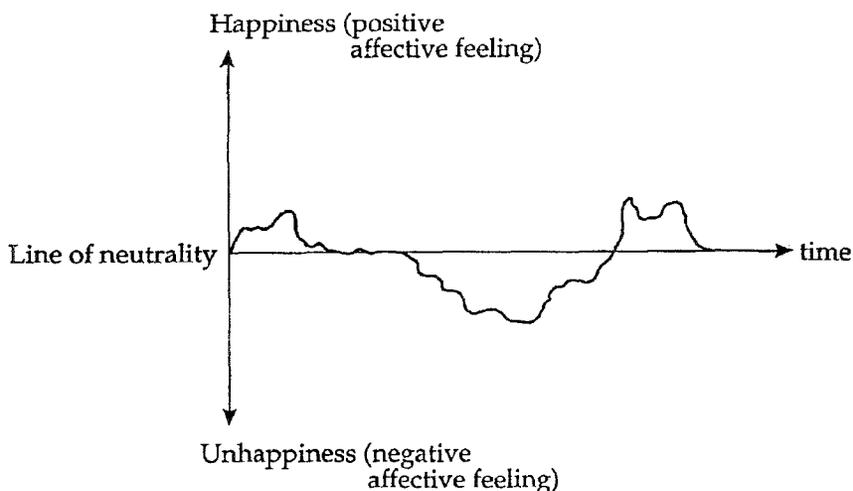


Fig. 1.

Since there are qualitatively different types of both positive and negative affective feelings, a question arises as to whether they can be captured by a measure of a single dimension. This issue has been debated for ages by philosophers, for example, on poetry versus push-pins. My view is that differences in quality that matter can be reduced to some sort of quantities, for example, greater intensity, duration, favourable side-effects, external effects on other individuals, etc. Sexual frustration may be much more important than simply boredom but only because the former is stronger in intensity, side-effects, etc. My feelings of seeing a beautiful scenery and those of enjoying a nice cup of tea also differ qualitatively since they are two different types of feelings. But if they don't differ in intensity, duration, side-effects, ..., I don't mind at all which feelings I have. However, it is certainly beyond the scope of this paper to discuss this age-old issue in detail.

Of course, the measurement of welfare in practice is fraught with difficulties. However, with the complementary use of revealing preferences, measuring relevant physiological correlates like analgesic peptides, adrenal cortical activities, and event-related potentials (Donchin *et al.* 1983), studying brain stimulation and overt behavioural patterns like stereotypies, and examining the effects on fitness, etc. will give us a good if not perfect assessment of animal welfare (Cf. Broom 1988). For humans, the use of questionnaire surveys may be useful (Ng 1975, 1992a; Veenhoven 1984). Psychophysical measures based on stimulus-response may also be derived for both human and animal subjects (e.g. Cabanac 1979; Krueger 1989). Moreover, some purely deductive reasoning based on plausible assumptions may also give us much insights, as argued in Sections 3–5 below.

“Sentients” is usually defined as beings that are capable of subjectively perceiving or feeling by means of the senses. This includes not only beings capable of the feeling of being happy and/or unhappy, but also includes beings just capable of perceiving things without having any affective feeling. In principle, it is possible for some sentients to be capable of perceiving the external world but without feeling happy or unhappy. One could have sensations of perceiving different colours without enjoying or disliking seeing them; one could have the sensation of being touched or even being squeezed without feeling pain or pleasure. Such non-affective sentients really do not have any positive or negative welfare. Their welfare is necessarily zero, just like non-sentients. Hence, for the purpose here, the important dividing line is not between sentients and non-sentients, but between affective sentients and non-affective beings (sentient or non-sentient).

Since welfare biology purports to study the welfare of affective sentients, many scientists may have reservations about its scientific status on the grounds that (i) welfare is difficult to measure, (ii) welfare is normative, making welfare biology not a positive study. Such beliefs can be easily refuted.

The difficulty of measurement may make many (but not all) statements in welfare biology difficult to be put in precise forms but does not make it unscientific. Many accepted sciences (e.g. archaeology, cosmology, meteorology)

also deal with variables difficult to measure precisely. While scientists strive to be as precise as possible, this does not mean that they should stay clear of important issues simply because of the difficulties in achieving perfect precision. "Furthermore, the difficulty, or even the impossibility of conveying to others the exact nature of something does not rule it out of existence or deprive it of significance. Many things have been profitably analysed by scientists long before their nature could be defined in complete detail. It can be questioned whether any important scientific entity can be described with 100 percent completeness. ... Darwin and Wallace could not directly observe and measure the evolution of animals or plants in the remote past. Had they been inhibited from speculative inferences by the sort of paralytic perfectionism that prevents ... behaviorists from investigating animal consciousness, one of the most far-reaching of scientific developments would have been severely hampered if not prevented altogether" (Griffin 1992, p. 6 and p. 23). After noting the successful indirect studies of mental imagery in humans and animals by cognitive psychologists, Griffin (1992, p. 9) concludes that "the reluctance to become concerned with cognition or consciousness in animals seems to result at least in part from a philosophical aversion rather than insurmountable barriers to scientific investigation".

If true, the argument that welfare biology is not a positive study is a methodologically more damaging objection. However, it is not true. A positive study answers questions like "What is?", while a normative study answers questions like "What ought to be done?". Welfare biology answers questions like: "Is this animal suffering?", "Is its welfare positive?". Moreover, we define suffering and welfare as the negative and positive affective feelings of the sentient concerned. Though these feelings are subjective to the sentient concerned, they exist objectively. That my toothache is subjective to me does not make it non-existent.

The existence of mental states, consciousness, and affective feelings in at least some other species is beyond doubt (Dawkins 1980, 1990; Griffin 1992; Rollin 1989). Some researchers deny such existence by adopting very restrictive definitions of these concepts. For example, Maxwell (1984, p. 100) denies the existence of mind to all animals and human neonates but recognizes that they have "some sensation ... some feelings ... but not much more." But sensation and feelings are of course mental. Gallup (1985) seems to believe in the existence of mind in the higher primates but doubts its existence for lower species. This is not surprising since he defines mind as "the ability to monitor your own mental states, and the corresponding capacity to use your experience to infer the experience of others" (p. 633). This is more a definition of self-awareness plus awareness of the mental states of others rather than "mind" or "consciousness" which, doing the least violence to common usage, I take to include all states that an individual subjectively perceives or feels.²

Welfare biology, as a science, does not answer the question as to what ought to be done. For example, the establishment of the result that if we do X, we can increase the welfare of dogs, does not in itself imply that we ought to do X.

From Hume's law, no normative conclusion can be drawn from positive propositions alone. To reach a prescriptive statement, we need some normative premises such as: "It is desirable (or we ought) to increase the welfare of some sentient if the welfare of no other sentient is decreased" (i.e., the Pareto criterion extended to include all sentient). Such a normative premise may be very reasonable and acceptable to most people. For people who do accept it, then certain propositions in welfare biology, in combination with that premise, may imply that certain actions are desirable. But this does not make welfare biology *itself* normative. Someone may (based partly on some normative premises and partly on some other judgements) make the prescription that a bridge should be built if it is constructionally sound and costs less than \$Y. The engineering and economic analysis of the relevant situation may reveal that such a bridge is in fact constructionally sound and will cost less than \$Y. Together with the given prescription, this analysis implies that the bridge should be built. However, this does not make the engineering and economic analysis normative. The normative part is contained in the given prescription.

It is true that the very *choice* of what to study (e.g. welfare instead of life) may be influenced by values. However, the study itself can be value free. For example, if the use of euphorics increases net affective feelings even taking the long-term side-effects and any external effects (on other individuals) and indirect effects into account, then one must agree that the use of euphorics increases welfare as defined above. However, when it comes to whether it is desirable to use euphorics, one may ask the question whether welfare so defined is the only thing we want to maximize. A non-utilitarian ethical theorist may then argue against the use of euphorics on some non-utilitarian grounds. However, this ethical objection to the use of euphorics does not affect the positive result that the use of euphorics increases or decreases (as the case may be) net affective feelings, if that can be established.

Economists regard economics as a social science, hence a positive study dealing with what is. However, the study of economics would not be of much interest if it could not be used, in combination with some value premises or prescriptions, to say something about the desirability or otherwise of certain economic policies. As A. C. Pigou put it, bearing fruits is more important than shedding lights. Thus, in economics, there is a well-developed branch called welfare economics which explicitly studies such questions as how resources could be allocated such that some individuals could be made better off without making others worse off. In itself, welfare economics is a positive study (Ng 1983, pp. 6-7). However, since it is directly concerned with the welfare of individuals, its propositions are very closely related to policy prescription. Nevertheless, one can logically distinguish the positive welfare economic analysis from the value premises necessary for policy prescription.

Similarly, biology is an extremely interesting study in itself. Its light-shedding aspects are profoundly illuminating. It has also borne enormous fruits, for example, in serving as a foundation for medical sciences. Within its own confines, however, its achievement in light-shedding far outweighs that in fruit-

bearing. This is at least partly due to the non-existence of welfare biology as a major branch of study. Most biologists are trained with scarcely any exposure to issues of welfare. In contrast, most students in economics are required to master the basic elements of welfare economics.

An explanation of the above contrast is perhaps that the economy calls for many policy actions while the biosphere calls for the maintenance of its natural equilibrium. This explanation is not very convincing. Most economists also believe that, under certain conditions, the market economy is most efficient in its natural equilibrium. This does not make the study of welfare economics useless. Secondly, without welfare biological studies, how do we know that the natural equilibrium in the biosphere is desirable, even if we agree on some objective function (e.g. one that is increasing in the welfare of the various species with that of our own featuring prominently)? For example, if all species suffer enormously at the natural equilibrium, then it is clearly an undesirable state according to the agreed objective function. Thirdly, strictly speaking, the preservation of the natural equilibrium is simply impossible in the inevitable presence of our population growth, economic development, and technological advance.

I am in favour of extreme caution before we do anything that may disturb the biosphere. However, this does not prevent us from studying welfare biology. Also, biologists who wish to be completely value-free may study welfare biology as a positive study without advocating *doing* anything. This again does not preclude others, as citizens, from advocating doing something they believe would increase animal welfare enormously at small costs to ourselves.

3. THE FIRST BASIC QUESTION: WHICH SPECIES ARE AFFECTIVE SENTIENTS?

This is obviously a basic question in welfare biology. If members of a species are not affective sentients, this species is not directly within the scope of welfare biology though its effects on other affectively sentient species are legitimate concerns by welfare biologists.

While the belief that all animals are sentients is quite widespread among the lay public, most biologists believe that many apparently sentient species are mindless, "hard-wired" automata. For example, remarking on the construction of orb webs by spiders without learning, Gould and Gould (1982, p. 275) assert categorically: "Doubtless all this is accomplished through one master program and several subroutines and requires no conscious grasp of the problem." This may well be true, but it can hardly be described as "doubtless".

It is understandable that most biologists hold a contrasting view to the lay public. Many behavioural patterns appear to be purposeful, intelligent and even optimizing choices appropriate to the situations on hand. However, closer analyses reveal that they are genetically determined responses triggered by appropriate stimuli. For example, the brain of a frog is genetically programmed to respond mechanically to a few stimuli. Among others, it responds to small moving objects (usually insects) by swallowing them. However, when presented

with a variety of stationary insects, a frog makes no response and may starve to death in the presence of plenty.³ Might the responses of a frog not be purely mechanical like a calculator without subjective feelings?

It is true that a frog can learn from its experience. But so can a computer be programmed to learn from its experience (e.g. in playing chess). Also, it has been found that the spinal cord of a frog is capable of some learning even after it is disconnected from its brain (Rensch and Nolte 1949). The ability to learn does not ensure the capability for consciousness.

For another example, a goose, upon spotting an egg that has escaped from her nest, will proceed to retrieve it by rolling it gently back into the nest with her bill. This looks to be a conscious action intelligently made for a rare contingency. However, Lorenz and Tinbergen (1938) show that geese will also retrieve ping-pong balls, batteries, and beer bottles. Moreover, removing the egg after the goose begins to reach for it does not prevent her from gingerly rolling the non-existent egg back into the nest. This led Gould and Gould (1982, p. 271) to believe that “the egg-rolling response is a mindless bit of programming based on an innate recognition circuit which triggers a prewired, centrally co-ordinated motor response”.

However, while we should free ourselves from the naïve lay public view by enriching our knowledge from biological studies, we should also be careful not to go to the other extreme of prematurely denying consciousness to most animals displaying “hard-wired” behaviours. We know (with almost 100% confidence) that members of our own species are sentient, but many of our own behaviours are also hard-wired and/or could be interpreted by an outside observer to suggest the lack of consciousness. For example, while the “mechanical” response of the goose remarked above suggests that we should not be rash in attributing consciousness upon seeing the apparently intentional behaviour of egg-retrieval, we should not conclude that geese are not sentient. For, when using the same criterion, I observed myself many times over to be not sentient. (The following is factual. For other examples of obsessive behaviour, see Toates 1990.)

When I first learned how to drive a car, I kept forgetting to push the choke back after the car had warmed up. Once I left the choke on for so long that the engine made very loud noises. That scared me quite a bit and after that I made a habit of ensuring that the choke was pushed back either by looking at it or by pushing it or both even after driving for a long time. What is remarkable is that, sometimes, even just *after* I had looked at the choke and known that it was already pushed right back, my left hand still reached for it and pushed at it again! This is similar to a goose retrieving a non-existent egg! If the conscious I can reach to push a choke having known that it is already right back, a goose, even if conscious that the egg no longer exists, may continue to perform the retrieval ritual. The genetically programmed urge to retrieve the egg may be too powerful to be overcome by the knowledge that the egg is no longer there.

As we have to avoid attributing mind to each and every apparently responsive creature (one is reminded of plants that move and capture insects) on the one hand, and to avoid denying mind to creatures exhibiting hard-wired behavioural

patterns (one is also reminded that many of our own actions such as the knee jerk are hard-wired), the classification of sentient species is a very difficult endeavour. Are there some principles or methods that can help in this task? Since we attribute mind to other human beings by their similarities with ourselves, their flexible behaviour, and their communications, perhaps we could apply similar principles with respect to other species.

If we discount pansychism and believe that a necessary condition for mind is a functioning brain, then the similarity of the structure and functions of the brain of a species to those of our own may be important in influencing our belief as to its mental capabilities. Thus, species with well-developed cortical brains are ranked higher than those with more primitive brains. However, one has also to be cautious here. While cortices may be important for intelligence, lower parts of the brain may be more relevant or at least sufficient for the feelings of pain and pleasure. Since, for our purposes here, we are more interested in feelings than in intelligence, there may not be much ground in discriminating against species without cortices. Neurology may be of substantial assistance here.⁴

Another aspect in which a species can be similar to us is in accordance with its position in the phylogenetic scale. According to this principle, primates rank higher than other mammals which rank higher than reptiles which in turn rank higher than invertebrates.

We regard plasticity in behaviour as relevant in assessing the presence of mind partly because of the similarity with ourselves and partly because organisms that lack plasticity could just be mindless genetically programmed machines. Moreover, one can argue from the principles of evolutionary economy that organisms without plasticity cannot be conscious as outlined in the next subsection.

3.1 Evolutionary Logic of Consciousness⁵

Certain principles helpful in answering the first basic question can be derived from the following axioms which are either well-established in evolutionary biology or argued below to be very reasonable.

Axiom 1: Major mechanisms that do not contribute to fitness do not survive in evolutionary equilibrium.

Here, a “mechanism” is any biological organ or function in any species. The ability to move, eyes, etc. are examples of “mechanisms”. Any mechanism is costly in terms of requiring maintenance and energy consumption. If a mechanism does not contribute to the ability of the individual to survive and reproduce, it cannot compete with mutants that dispense with that mechanism. (For example, the prolonged copulation in certain species of spiders is regarded as a “problem” to be explained by some counteracting benefits; see Suter and Parkhill, 1990.) Due to the coexistence of sexual selection with natural selection, certain sexual attributes can be exaggerated to the extent that is clearly fitness-

reducing from the viewpoint of the whole species but fitness-consistent from an individual viewpoint. "Evolutionary equilibrium" does not rule out species in evolutionary transition, since "equilibrium" need not be static equilibrium. Evolutionary equilibrium rules out temporary mutants that are quickly competed out of existence.

Due to the fact that evolution has to develop step by step based on whatever is already there, existing physiology of an organism needs not be optimal (e.g. the clumsy thumb of the panda; see Gould 1980). Some minor remnants may persist for relatively long periods. Also some mechanisms may develop as a by-product of evolution being neutral to fitness (on such issues, see Gould and Lewontin 1979 and references therein). Excluding these "minor" mechanisms, the "major" mechanisms must contribute to fitness to survive. Moreover, even if a mechanism is neutral to fitness gross of the costs of its maintenance, it must still contribute to fitness net of these costs. Then, Axiom 1 is true even for mechanisms (including "minor" ones) that are grossly neutral to fitness.

Axiom 2: Consciousness as such does not contribute to fitness; it may contribute to fitness only by affecting the activities of the individual.

This axiom is self-evident. If an individual sentient takes no action of evading a predator even if it is conscious of its imminent attack, such consciousness does not help the individual to survive.

Axiom 3: Consciousness affects the activities of the individual by influencing its choice through its reward/punishment system.⁶

Here, "choice" is taken to be in contrast to automatic activity such as reflex actions, for example, an animal withdraws its arm as its fingers are burnt. Such reflex actions need no consciousness. In fact, it has been established that the consciousness of pain occurs *after* the action of withdrawing the arm. The former occurs in the brain while the latter is mechanically effected by the spinal cord *before* the signal initiated by tissue damage travels to the brain. Nevertheless, the pain felt afterward is useful in motivating the individual to avoid burning itself in the future.

Axiom 4: Consciousness is a major evolved function of the nervous system.

This axiom may be debatable. Panpsychists (who believe that all matter, including inorganic things like sand, neutrinos, possess mental states) certainly disagree. Creationists may also dispute the axiom. Nevertheless, most biologists will accept consciousness as an evolved function of the nervous system. Given this acceptance, it is clear that consciousness is a major mechanism rather than just a minor remnant or by-product of evolution. The evolution of conscious species from non-conscious species must be one of the greatest milestones in the history of evolution. On the other hand, if the panpsychists are right that all

matter possess consciousness, consciousness is not even an evolved function, minor or major.

From the preceding axioms, it is not difficult to see that we have

Proposition 1: Ignoring transient mutants, species that lack plasticity in their behaviour do not possess consciousness.

Here, plasticity in behaviour is in contrast with fixed patterns of responses predetermined by genetic programming which are triggered by certain environmental stimuli. Plasticity requires the organism to have flexibility or be able to choose different responses for a given situation. All hard-wired responses are non-plastic. "Soft-wired" responses (those that involve learning) may or may not be plastic depending on whether the learning is completely fixed genetically. If so, while the response itself is only soft-wired, the learning pattern is hard-wired (Cf. Bunge 1980, p. 45 on the definition of plasticity). Thus habituation and imprinting are examples of non-plastic behavior, while potato-washing by macaques and herding by sheepdogs demonstrate plasticity.⁷

If consciousness is an evolved function (Axiom 4), it must contribute to fitness to survive natural selection (Axiom 1). However, consciousness as such does not contribute to fitness (Axiom 2). Hence, if consciousness survives evolutionary competition, it must affect the activities of the organism by influencing its choice (Axiom 3). Such organisms are by definition plastic. So all conscious species (ignoring transient mutants) are plastic.⁸ Hence, Proposition 1 must be true.

Proposition 1 helps us answer the first basic question since sentients must be conscious. Thus, we may exclude all non-plastic species. If our knowledge regarding the behaviour of a species allows us to regard it as non-plastic, we can rule out the possibility of its being sentient. Extending the scope of Proposition 1 to a part of an organism, we may also rule out the possibility that the spinal cord itself is conscious, while philosophical theorizing alone cannot rule this out. However, Proposition 1 neither allows us to say that all plastic species are conscious nor to say that all conscious species are affectively sentient. We would get a proposition (Proposition 1' below) that allows us to affirm the latter if we could strengthen Axiom 3 to:

Axiom 3': Consciousness affects the activities of the organism by influencing its choice *only* through its reward/punishment system.

The only difference between Axiom 3' and Axiom 3 is the addition of the word "only". But this makes a big difference. The acceptance of Axiom 3' (together with other axioms above) allows us to have, on top of Proposition 1.

Proposition 1': Ignoring transient mutants, all conscious species are affectively sentient.

This is so because from Axioms 1 and 4, consciousness must contribute to

fitness and from Axioms 2 and 3', it can only contribute to fitness through the reward/punishment system. But an organism having a reward/punishment (pleasure/pain) system is by definition affectively sentient.

The acceptability of Axiom 3' is much more debatable than Axiom 3. It might be thought that Axiom 3' is certainly false since we know that we do consciously engage in such activities as death avoidance, e.g. moving the head away from a falling log without being motivated by pleasure or pain avoidance. However, aren't such activities instinctively programmed such that, even though we may be consciously aware of our engaging in it, our consciousness does not affect it? (That this may well be the case is supported by experimental results reported by Deecke, Grozinger and Kornhuber 1976 and Libet *et al.* 1979.) On the other hand, for those activities that we consciously direct ourselves to engage in, are they not designed to ensure our survival so that we can enjoy life later? It may also be argued that an additional problem exists for Axiom 3'. To some extent, people and other animals seem to engage in activities that do not enhance their survival chances, for example, when people risk death for political causes, or when monkeys work to obtain painful electric shocks (McKearney 1970). It might be replied that these are by-products, perhaps transient ones, of survival-favouring processes. More convincingly, humans may derive the psychic reward of contributing to a worthwhile cause and monkeys may derive the reward of excitement. Nevertheless, it must be admitted that Axiom 3' and perhaps some other axioms above and below need further studies before we can be more confident on their validity.

Even if we opt to accept Axiom 3' and hence Proposition 1', they do not allow us to say that all plastic species are affectively sentient. This is so because Proposition 1 implies that all conscious species are plastic, not necessarily that all plastic species are conscious. However, it may not be unreasonable to accept.

Axiom 5: Plastic species are conscious.

The behaviour of a plastic species is not *completely* programmed, in the sense that given stimuli would trigger fixed responses (not precluding fixed patterns of learning). Rather, it can *choose* what responses to take in particular cases. It is difficult to imagine an unconscious organism able to have such flexible choices not completely genetically programmed. With Axioms 1-5 (excluding 3'), we have

Proposition 2: All conscious species are plastic and all plastic species are conscious.

If we strengthen Axiom 3 to Axiom 3', we have

Proposition 2': All conscious species are plastic and all plastic species are affectively sentient.

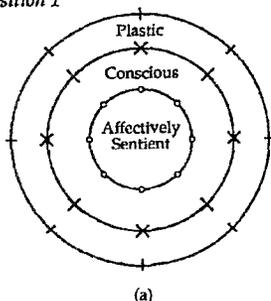
The acceptance of Proposition 2' allows us to transform the first basic question

from a subjective form regarding affective feelings into a relatively more objective form regarding the behavioural patterns. To decide whether a species is affectively sentient, we only have to know whether it is plastic or not. Though the answer to this latter question is still very difficult, it is much more tractable than the first basic question itself.

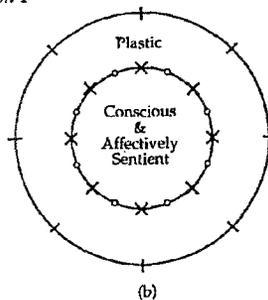
It is debatable whether lower vertebrates and invertebrates are plastic. (See e.g. Griffin 1984). It is more acceptable to many biologists that higher vertebrates (birds and mammals) are plastic. For example, many species of birds not dependent on summer flying insects “appear to make individual or group decisions about whether to make winter migration, or stay put” (Walker 1983, p. 198). For another example, see Griffin’s (1984, pp. 140–3) review on experiments on pigeons’ choice. However, a lot more studies have to be done for us to know with greater confidence as to which species are plastic.

The meanings of the four propositions above on the relationships between plastic, conscious and affectively sentient species may be illustrated in Figure 2. In each case, an inner circle is a subset, but need not necessarily be a proper subset of an outer circle. For example, Proposition 1 rules out the possibility that the set of plastic species is a proper subset of the set of conscious species but does not rule out the possibility that the two sets are identical.

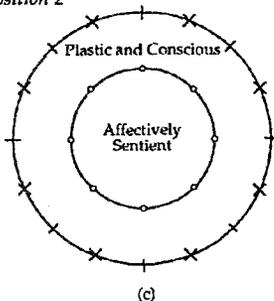
Proposition 1



Proposition 1'



Proposition 2



Proposition 2'

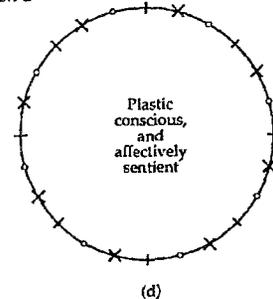


Fig. 2.

3.2 *The Evolution of Affective Feelings*

It is well-known that the brain consumes a disproportionately large amount of energy. In our own species, for example, while the brain accounts for about 2–3% of body weight, it consumes about 20% of energy. While it is true that not the whole of the brain function is mental (a lot is at the sub-conscious level), it is of little doubt that those brain functions that make an organism conscious must also be energy-consuming. Thus, consciousness can survive natural selection if it not only contributes to fitness but also contributes to fitness by a sufficiently big margin to offset its energy requirements on the organism.

Consciousness can only contribute to the fitness of the organism if it affects its activities. But why spend resources to create consciousness which in turn affects activities? Why not effect whatever the required activities directly without the mediation of consciousness? The answer is that, for complex enough situations, evolution does not know in advance what should be the right activities. Where many variables are involved, it would be too costly to program all optimal responses genetically. The possible combinations must be astronomical.⁹ Hence, for sufficiently advanced species that deal with sufficiently complex situations, it is more economical to spend some resources to endow the organism with a mind that can be aware of its environments and decide what is the best thing to do at any specific situation *ex post*. For example, the shell-opening skill of the European oystercatcher (which feeds mainly on mussels) is learned rather than inborn. The mortality rate among slow learners is high (Norton-Griffiths 1969). While endowing the skill innately would eliminate such mortality, this would probably preclude its flexible use, as the learned skill is actually also used by the oystercatcher to feed on other shelled molluscs (Walker 1983, p. 204).

As conscious plastic species evolved, how does evolution ensure that these organisms use their newly evolved capabilities for consciousness and choice in a fitness-consistent way? If they are rigidly genetically programmed to ensure that all their responses are fitness-consistent, they are no longer plastic. And this, as we have seen in the last subsection, makes consciousness redundant. Evolution (or God) solved this ingeniously by endowing the conscious and plastic species with a reward and penalty system. As a rule, activities that are consistent with fitness (e.g. eat when hungry, have sex with healthy members of the opposite sex) are rewarded with pleasures, and activities that result in fitness-reducing consequences (e.g. injuries) are penalized with pain. The maximization of net happiness or pleasure provides the quantitative tradeoffs between various motivation, making pleasure as the common currency (Cabanac 1992).

In fact, it can be argued (in the rest of this subsection, and more rigorously in Ng 1992b) that, as species evolved to occupy more and more complex niches, natural selection favours more and more rational species. Here, a more rational species is defined as one whose behaviour is controlled (relatively) more by the reward-penalty system than by the automatic, inflexible, programmed responses.

It is true that “the historical record of life on this planet, whether animal or

plant, whether vertebrate or invertebrate, indicates that those organisms that exist today are here not because of an advance along a single road with ever increasing complexity, but because of divergence along a multiplicity of roads and by adaptation to whatever environment through which those diverging roads led. In some cases, that adaptation calls for increasing complexity. In other cases, that adaptation calls for increasing simplicity” (Hodos 1982, p. 40). Nevertheless, some trend towards more complexity cannot be denied. For one thing, about 1.5 billion years ago, the most complex organism was probably not much more complex than amoeba. The most complex species existing at any time almost monotonically increases in complexity right through the blue-greens (about three billion years ago) to the modern *homo sapiens* (which emerged only around forty thousand years ago).

Since brain is the most complex matter known and is also the control centre of the organism, the proportion of brain size to body size is one measure of the complexity of the organism.¹⁰ As a general statement, it is not wrong to say that there is a progressive increase in relative brain size in the sequence of fish, reptiles, birds, mammals and especially primates, despite some overlappings. Hodos (1982, p. 45) cites Jerison (1973) to refute this general statement. However, the oft-cited Jerison’s data and regressions clearly support the general statement, with few, if any, overlappings.

Before the evolution of living things, the environment prevailing then was fairly simple. The emergence of simple organisms increases the complexity of the environment which favours the evolution of more complex species. Moreover, the more complex species had to base on the relatively simpler species. A very complex species cannot evolve in a single mutation from a very simple one.¹¹ Thus, the evolution of more complex species both makes the evolution of even more complex ones possible and more selectable as the more complex niches created favour more complex species. This is so since a simple environment requires only a few fixed responses for the species to survive. The more complex the environment, the less successful are the fixed responses. More rational species are thus favoured. The demonstration of this result as a rigorous proposition based on some reasonable axioms is contained in Ng (1992b).

4. SECOND BASIC QUESTION: POSITIVE OR NEGATIVE WELFARE?

For species that are affectively sentient, is their welfare positive or negative? This is obviously an important question. At least from the viewpoint of welfare maximization (which could be argued to be the rational objective; see Ng 1989b, 1990b), a life is only worth living if welfare is positive. The first subsection below provides a general argument that most sentient animals that do not survive to mate successfully probably have negative welfare. The next subsection argues the same, using what might be called the “economics of evolution”.

4.1 Animal Suffering

First, do animals and possibly other sentients suffer at all? No one can expect anyone to prove in a mathematically or logically conclusive way that they do. In this sense of “proof”, we cannot even prove that any human being or sentient other than each of us as our own self exists. However, we all accept that a dog is suffering when it howls after an injury, and that most sentient animals are suffering when starving. We accept those mainly because of our own experiences and those of other people (whom we can question) under similar situations. However, there is an additional support for our acceptance on the ground of evolution. When a reward and punishment centre in the nervous system had evolved, it helped the survival of individuals in the species concerned if activities (e.g. eating, having sex) conducive to the survival of the gene are rewarded and conditions (injuries, starvation) bad for survival are punished. Thus, if dogs did not suffer when injured, they wouldn’t still be around now. (On ways of estimating animal suffering, see Dawkins 1980, Morton and Griffiths 1985; on testing pain mechanisms in animals, see Vyklický 1984; on the validity of physiological and behavioural measures, see Barnett and Hemsworth 1990.)

While animals do suffer, how do we know that their net welfare is negative since they also enjoy when they eat, play, and have sex? For an individual animal that manages to avoid starvation and to have the opportunity of mating, it probably enjoys positive welfare. However, for most species, for any such a fortunate individual, there are dozens or thousands of other less fortunate individuals that are either starved to death or physically hunted down and eaten, most of them well before they are mature enough to mate. Table 1 gives data on the average number of offspring per reproductive season for selected species. In a more-or-less equilibrium situation where the total population of a species is

Table 1. Number of offspring per reproductive season for various animal species.

<i>Homo sapiens</i>	man	1/litter
<i>Canis familiaris</i>	dog	7(1–22)/litter
<i>Sturnus vulgaris</i>	starling	4–6 eggs/clutch
<i>Terrapene carolina</i>	box turtle	2–7 eggs/clutch
<i>Rana catesbeiana</i>	bullfrog	6,000–20,000 eggs/brood
<i>Salmo trutta</i>	trout	200–6,000 eggs/spawning
<i>S. aguabonita</i>	trout	1,380–2,280 eggs/spawning
<i>Homarus americanus</i>	American lobster	8,500 eggs/spawning
<i>Argopecten irradians</i> (<i>Pecten irradians</i>)	common scallop	2,000,000 eggs/spawning
<i>Crassostrea virginica</i>	eastern oyster	500,000–1,000,000 eggs/spawning
<i>Drosophila melanogaster</i>	fruit fly	100 eggs/female
<i>Vespula maculata</i>	bald-faced hornet	25,000–35,000 eggs/queen
<i>Musca domestica</i>	housefly	75–200 eggs/female

Note: Reproduced from Solbrig and Solbrig (1979, p. 37).

roughly stable, among the many offspring mothered by an adult female over all her life, on average not more than *one* female can survive to maturity to produce the next generation of offspring. Thus, from the clutch size of a species, we can have an idea as to how many times is the number of those destined to starvation or to be captured.

The clutch size of a species is not determined by any consideration on the welfare of the species but by the chance for the survival of the gene. Since capture by predators is difficult to avoid, many species ensure survival by producing a large number of offspring. It is true that, a doubling in clutch size does not double the number of surviving offspring. Beyond a certain point, it may actually reduce the number. That is why evolution does not result in an infinitely large clutch size. The clutch size of a species probably maximizes the number of surviving offspring, i.e. those that can produce the next generation of offspring. (See Lack 1954, Cody 1966, Parker and Begon 1986.)¹² If the non-survivals are suffering from negative welfare, this result of natural selection is far from welfare maximization of the species but is not too far from the maximization of miseries.

For most species, a major source of enjoyment derives from mating. (This has a clear evolutionary explanation.) However, to increase the chance of successful survival, many species adopt the strategy of allowing only a tiny fraction of the strongest males to have a chance of mating with any female. Thus, a typical individual is destined to starvation, capture, or struggling unsuccessfully for mating. It is difficult to imagine a positive welfare for such a life. Thus, while a mathematical proof is impossible, reason requires us to accept that, in all probabilities, the welfare level of an individual (affective) sentient that fails to survive to have successful mating is negative. It follows that, if we can reduce the number of such miserable individuals, other things being equal, we can increase the level of over-all welfare.

4.2 Non-surviving Individuals Do Suffer; God-made Fairness?

Our common sense recognition of the suffering of a typical non-surviving individual in most species may be supported by a simple argument based on evolution. We start by asking, why do we enjoy eating but suffer in starvation? The answer is that this genetic program provides us with the right incentives to do things favourable to survival. But why suffering? Why not just less enjoyment when starving and more enjoyment when eating? If the difference in the degrees of enjoyment between the two is big enough, we will still do the "right things". However, the existence of suffering may be explained below.

First, both enjoyment and suffering are costly in terms of energy requirement, tissue maintenance, etc. This is why we feel neutral most of the time when we are not starving, eating, having sex, etc. (It would be nice if we could be programmed to feel ecstatic most of the time.) Secondly, it is likely that the extra (or marginal) costs involved in having an extra unit of enjoyment (or suffering) increases with the amount of enjoyment (suffering). Viewed differently, we have diminishing marginal returns in both enjoyment and

suffering per unit of cost.¹³ Thirdly, it is likely that the costs (generalized resource costs, not subjective welfare costs) of suffering are unlikely to be significantly less, and maybe actually more, than those of enjoyment.

With the above three general conditions, Appendix A shows that the following proposition may be established.

Proposition 3 (Buddhist Premise): Under the assumptions of concave and symmetrical functions relating costs to enjoyment and suffering, evolutionary economizing results in the excess of total suffering over total enjoyment.

In proving the above proposition, Appendix A also shows that those species facing higher probabilities of success enjoy less (if successful) relative to the suffering of failure. Thus, there is a kind of God-made (or evolution-created) fairness between species, a totally unexpected result.

I understand that Proposition 3 is controversial and that the various conditions used for its derivation need further scrutiny. The main point here is that the issue whether animals enjoy positive or negative welfare is of paramount importance and demands further study. Both conceptual analysis and empirical studies are needed to strengthen our knowledge.

5. THIRD BASIC QUESTION: WAYS TO INCREASE WELFARE

It is argued that most sentient animals, at least for those failing to survive to mate successfully, probably suffer negative welfare. What are the effective ways to increase their welfare or reduce their suffering is our third basic question. The answers to this question are of course very wide-ranging. Here, only a crucial aspect that follows from the conclusion of the previous section is addressed. The basic idea is that, given that non-surviving individuals suffer negative welfare, natural selection that results in growth maximization may lead to great suffering which contradicts the requirement of welfare maximization.

Consider the simple case of a single population not limited by any resource constraint and growing exponentially. That growth maximization as might be favoured by natural selection need not be welfare maximizing can be shown most simply by distinguishing only between those that die before leaving offspring and those that do leave offspring. Other aspects such as differential fertility, generation length, age structure, sex, etc. are ignored.

Suppose natural selection has resulted in each mature adult bearing ten offspring of which three survive to adulthood to give the next generation of offspring. The (asexual) population is then trebled every generation, a phenomenal rate of growth. However, this spectacular growth in number may also be a growth in misery. For example, suppose that each individual who survives to bear offspring derives a lifetime welfare level of two units and each individual who does not survive until adulthood derive a lifetime welfare level of -1 unit. Then, for the ten offspring of an adult, their aggregate welfare is $2 \times 3 - 1 \times 7 = -1$.

Starting from any given initial population size (e.g. 10), this negative aggregate welfare explodes exponentially as the population trebles after each generation (e.g. $-10, -30, -90, -270, -810, \dots$ to $-34, 867, 844, 910$ after only 20 generations).

On the other hand, suppose that, by lowering birthrate per adult from ten to five, the number of individuals surviving to adulthood drops from three to two. Then, the population only doubles (instead of trebles) each generation. For the five offspring of an adult, their aggregate welfare is $2 \times 2 - 1 \times 3 = +1$, even assuming that the welfare levels of an adult and a minor have not been increased. Instead of a negative aggregate welfare for the offspring of any given adult, we now have a positive aggregate welfare. This positive welfare also grows exponentially, doubling every generation (e.g. 10, 20, 30, \dots to 10, 485, 760 after only 20 generations). This exponential growth in positive welfare accords more with welfare maximization than the exponential growth in misery in the case of possibly growth maximization as might be the result of natural selection described in the preceding paragraph.

The above example illustrating exponential growth in misery versus positive welfare does not really describe growth and welfare *maximization*. This involves not only some technical details but also raises the intriguing questions as to whether average or total welfare (i.e. average welfare per individual times the number of individuals) should be maximized and if the former, average over what time period. These interesting questions are addressed in Ng (1992c) where it is shown that growth maximization results in growth in total suffering and differs from either average welfare or total welfare maximization for both exponential and non-exponential growth. More remarkably, for the case of two competing species, the Lotka-Volterra model gives equilibrium population sizes dependent only on resources and initial sizes, not on the intrinsic rates of growth. This implies that welfare could be dramatically increased by reducing birthrates (hence reducing proportions of non-surviving to surviving individuals) without even sacrificing numbers at equilibrium. Moreover, this remarkable result is generalized to any number of species, to non-competition relationships such as symbiosis, and more complicated interactions.

The results of this section and Ng (1992c) may be summarized as

Proposition 4: The number of offspring of a species that maximizes fitness may lead to big suffering and is different from the number that maximizes welfare (average or total). In the Lotka-Volterra model of competing species and its generalizations, the choice of different birthrates does not affect the population sizes at equilibrium. Welfare could be much higher at lower birthrates without even reducing number (at equilibrium).

6. CONCLUDING REMARKS

We have seen above that logical analysis of evolutionary economics and population dynamics can help answer basic positive questions in welfare biology. In this concluding section, let us diverge from the purely scientific

viewpoint and remark briefly on the normative aspects.

The several propositions derived above have significant implications on the appropriate treatment of animals. For example, even if we want to avoid inflicting pain on animals, Proposition 1 implies that we need not do so with respect to non-plastic species since they are not even conscious, not to mention affectively sentient, and hence do not suffer any pain. An important area for further research is to establish the plasticity of various species. Another important area of research is to examine further whether the various axioms or assumptions adopted in deriving our propositions are valid.

Segal (1990) asks, why is the clear existence of objective reinforcing and aversive stimuli not “enough to justify concern for animal well-being ... Why muddy the waters with talks of subjective feelings, mental suffering ... ?” The answer is simple, objective responses as such have no moral significance in my and most people’s moral systems. Automatic nociceptive reflex may protect an organism from tissue damage from burning with no pain involved (as in a human paraplegic with an injury to the upper spine but intact lower spinal reflexes). If insects only have such reflexes but no affective feelings (Eisemann *et al.* 1984; Fiorito 1986; Rowan 1990; Wigglesworth 1980), they cannot have any well-being or ill-being to speak of. Most biologists take fitness as the ultimate criterion for determining what is good or detrimental to an individual or a species. However, it is absolutely obvious that most people (and presumably most animals) would not like to be born and to live long and have many offspring if they and their offspring have all to suffer miserably. It is long overdue that biologists look more at welfare than at fitness.

While I agree with Singer (1990) that the welfare of all sentient individuals should rank equally as a matter of ideal ethics,¹⁴ I make a distinction between ideal ethics and practical policies affected by self-interests (Ng 1989a; see also Gray 1990). For the latter, we need some more widely acceptable criteria. First, it is compelling that, if the welfare of some species increases while no species suffer a decrease in welfare, this is a *sufficient* (but not a necessary) condition for a good change.¹⁵ To move a little forward, many people may be prepared to accept that it is desirable to increase animal welfare enormously at a small cost to human welfare. Admittedly, this involves interspecies comparisons of welfare, but such comparisons, though very difficult to be precise, are not meaningless (Ng 1990a). We may reach different conclusions on the exact interspecies comparisons for a particular situation and may also differ as to how big an increase in animal welfare is required for any given cost on us. However, most people would probably agree that, provided the increase is big enough relative to the cost, it is a desirable change. I submit that a practical change that satisfies this criterion is some minimum legal provisions in factory farming to increase the welfare of the animals involved to zero or even a positive level. A 50% increase in living space for overcrowded chicken, pigs, etc. may reduce their suffering enormously at a very small cost to humans – a small increase in the price of meat. (Toates believes that “this would *increase* human welfare through a variety of ecological benefits”.) The self-interested objections by

factory farmers are largely based on ignorance. Since these industries are fairly competitive, there would be no permanent losses after a transitional period of adjustment, provided that the regulation is economy-wide. If the welfare of farm and factory animals can be increased to a positive level, meat-eating by humans actually contributes to the welfare of those animals. There would then be no moral reason to be a vegetarian on the extended utilitarian ground. (There may however be non-utilitarian or non-moral reasons, e.g. health.)

On the other hand, while cruelty and the unnecessary infliction of pain on experimental animals should be eliminated, strict control of animal experiments may hamper scientific progress to the severe detriment of animals themselves in the long run. The large scale reduction in animal suffering relies on continued scientific advances. For example, our analysis in Sections 4 and 5 above suggests that animal suffering could be dramatically reduced by lowering their birthrates. However, such drastic measures that could have important repercussions throughout the whole biosphere can hardly be undertaken in the near future. Its feasibility crucially depends on huge advances in science. Thus, the salvation of animals depends on scientific advances. Strict control of animal experimentation may be very counter-productive for animal welfare in the long run. Champions of animal welfare may be wiser to direct their effort to raise the standards of factory farming than to impose strict control on animal experimentation.

Another area where animal welfare and science have a common interest is increased funding for scientific research, especially in the area of welfare biology and related disciplines such as ecology, ethology, genetics, neurology, psychology, physiology. Advances in science in general and in these disciplines in particular not only increase our knowledge and contribute to human welfare but can also eventually lead to quantum leaps in animal welfare. Moreover, the economic costs of funding are likely to be over-estimated by economists and the public. Most economists emphasize the excess burden of taxation to fund public expenditures and most taxpayers do not like paying higher taxes. "But with the predominance of detrimental externalities of production and consumption due to environmental disruption and relative income effects, most goods and services have to be taxed to achieve the first-best efficient optimum to start with, the actual excess burden of taxation may thus be much smaller than that indicated by traditional [economic] analysis or even be negative ... a pure increase in GNP (even without any deterioration in income distribution) may be welfare-reducing unless environmental protection and other welfare-improving measures are facilitated ... Thus, despite the excess costs (excess burden, administrative, compliance, and policing costs) of raising public revenue, more public expenditure in the right areas (e.g. research) may yet be most welfare-improving" (Ng and Wang, 1993, pp. 19–20).

A likely objection to my proposed long-term attempt to alleviate animal suffering is that it is very risky; the ecological system is too dangerous to tamper with. At our current levels of scientific and technological capabilities, I fully agree with this objection and do not advocate actions in the near future.

However, this should not prevent us from aspiring to understanding more and hope to be able to help alleviate animal suffering in the future. Some people may believe that we should *never* think about tampering with the ecosystem. This may well suit the purpose of our lucky species which appears to enjoy positive welfare. But what if I am right that most other sentient species are suffering enormously? If and when we can confidently reduce their suffering enormously at a small cost and very small risk to ourselves, should we cautiously proceed to help them or should we postpone indefinitely? Analogously, if people in poor countries are suffering enormously from their poverty, and if people in the rich countries can help them develop out of their poverty at a very small risk of aggravating the global environment, should the help be extended? What if you were one of the suffering poor? What if we were one of the suffering species? Let us at least agree that more resources be put into the study of welfare biology.

APPENDIX A

The Proof of the Buddhist Premise on the Predominance of Suffering

With the three general conditions stated in Section 4.2, the situation is as depicted in Figure 3. Here, the cost of enjoyment and that of suffering is taken

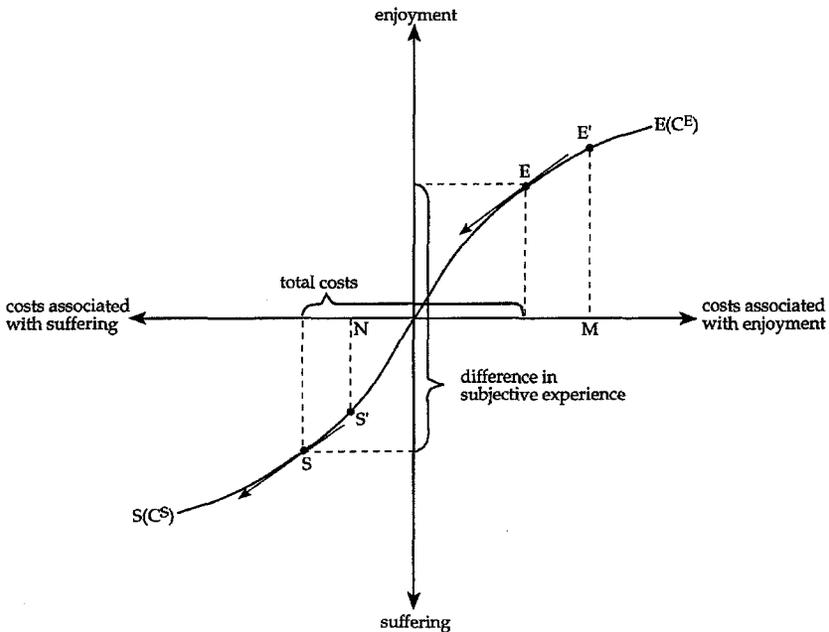


Fig. 3. The game God plays with sentients.

as the same so that the curve is symmetrical around the origin. It can easily be seen that, either to maximize the difference in subjective experience with given resource costs or to minimize resource costs for a given difference in subjective experience, the solution involves two symmetrical points such as E and S , where one (E) involves positive enjoyment and the other (S) positive suffering of the same amount. (For simplicity, we only consider cases where the outcome is either a complete success or a complete failure). The relaxation of the symmetry assumption means that these two points may not be of the same amount (of enjoyment and suffering respectively), but is unlikely to change the result that S involves positive suffering, unless enjoyment is very much less costly than suffering. Usually, it is less costly to reward right actions and penalize wrong conditions than to doubly reward right actions.

Even if the reward-penalty curve in Figure 3 is symmetrical about the origin, enjoyment (E) and suffering (S) need not be symmetrical if there is a difference in the numbers of successful and failing individuals. (In Figure 3, E and S are located under the implicit assumption of one success versus one failure.) This can be seen in the following analysis.

Let the amount of enjoyment E and suffering S both be functions of the associated costs C^E and C^S . If for each success, we have n failures, the maximization of $E(C^E) + S(C^S)$ subject to $C^E + nC^S = \text{constant}$, gives the following first-order condition,

$$nE_C = S_C \tag{A1}$$

where $E_C = \partial E / \partial C^E$, $S_C = \partial S / \partial C^S$. For the case $n = 1$, and where $E(C^E)$ and $S(C^S)$ are similar functions, we have the symmetrical solution points E and S illustrated in Figure 3. If $n = 2$, we have the non-symmetrical solution points E' and S' instead. (With $n \neq 1$, it may seem that, if sophisticated individuals take account of the relevant probabilities of avoiding S and attaining E , the result may be different from Equation A1. However, as shown in the last five paragraphs of this appendix, despite accounting for this sophistication and the related constraint on resources, the result of Equation A1 does not change.)

Taking $E(C^E)$ and $S(C^S)$ as more or less similar or symmetrical as illustrated in Figure 3, the result in (A1) is interesting since it means that there is a kind of God-made (or evolution-created) fairness between species. Those facing higher probabilities of success will enjoy less relative to the suffering of failure (E versus S in Figure 3) than those facing lower probabilities (E' versus S'). However, the purpose of this appendix is to support the belief that failing individuals in most species derive negative levels of welfare. In fact, a stronger result has been unexpectedly reached. At least for the symmetrical case and for $n > 1$, we have, from (A1), the result that total suffering (nS) exceeds total enjoyment (E), under our reasonable assumption on the concavity of the relevant functions illustrated in Figure 3. For example, if $n = 2$, for each successful individual with a positive welfare of $E'M$, there are two failing

individuals each with $S'N$ of negative welfare. It is easy to see that $2S'N > E'M$ since the points S' and E' satisfy (A1). Thus, our analysis here suggests not only that failing individuals suffer, but also that the sum total of suffering by failing individuals exceeds the sum total of enjoyment by successful individuals, since n is typically much larger than one. This is summarised as Proposition 3 on the validity of the Buddhist premise on suffering (in Section 4.2).

Even if the enjoyment and suffering functions are not concave as shown in Figure 3, it may still be fitness-maximizing to impose suffering on failures due to the existence of intermediate states between success and failure. To illustrate the point, suppose the enjoyment and suffering functions are as depicted in Figure 4, with $n = 1$. If we have only either success or failure, the symmetrical solution indicated by the points E and S does not maximize the difference in subjective experience. The solution indicated by E' and S' achieves a higher difference in subjective experience at the same cost.

However, between failure and success, there are intermediate states. In fact, there are different degrees of failure and success, and most of the time, an individual may just be in a neutral state. For simplicity, just consider a single intermediate state between failure and success. Then the solution of E and S

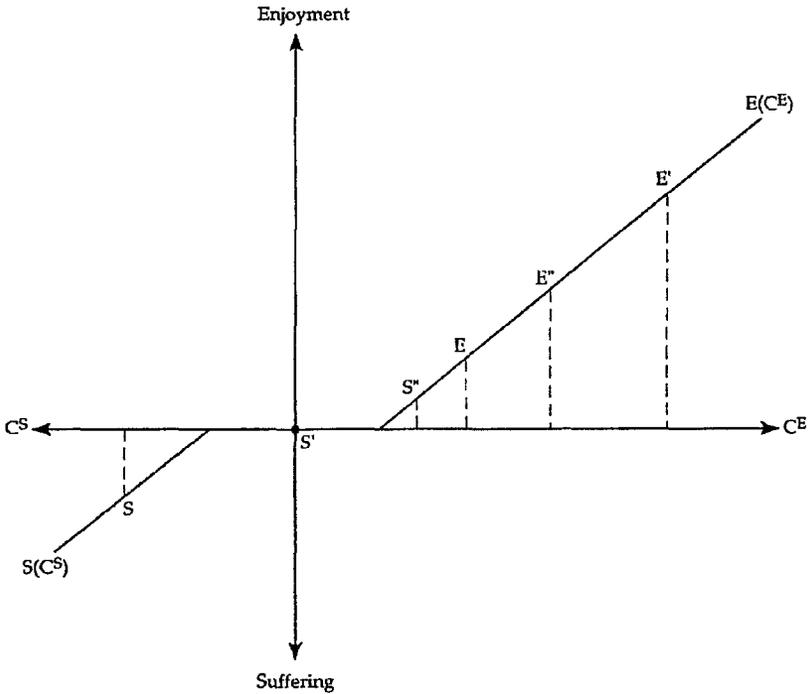


Fig. 4. The significance of an intermediate state of neutrality.

with S' as the intermediate state still involves the same total cost. On the other hand, the solution at E' and S' with an intermediate state at E involves higher total cost. To keep the total cost unchanged, we may end up with E'' and S' with S'' as the intermediate state. This may involve less difference in subjective experience in comparison to the symmetrical solution E , S and S' . Since an individual is in the neutral state most of the time, this is an important consideration ensuring that failures are associated with suffering.

It may seem that the maximization of $E + S$ (by God) despite $n \neq 1$ is based on the implicit assumption that individuals in the species concerned are naïve in the sense that each is motivated by $E + S$, not taking into account the probabilities of avoiding S and attaining E . In fact this was my original intuition which suggests that, for a perfectly rational species where individuals take full account of the probabilities involved, God cannot “fool” them by choosing E' , S' and He has to revert to E , S instead despite $n \neq 1$. However, the following analysis shows that this seemingly plausible intuition is not true.

A perfectly rational individual may be expected to maximize its expected net welfare

$$P(Y)E - \{1 - P(Y)\}S - D(Y) \quad (\text{A2})$$

where P is the probability of attaining enjoyment E associated with success and Y is the effort (measured in terms of “resource” consumption) expended by the individual in striving for success, and D is the (subjective) disutility of such effort to the individual. Maximizing (A2) with respect to Y , we have the first-order condition.

$$E + S = D_Y/P_Y \quad (\text{A3})$$

where a subscript denotes partial differentiation. Thus, given the functions $D(Y)$ and $P(Y)$, assuming the satisfaction of the second-order condition, then the larger $E + S$ is, the more the individual will be motivated to strive for a higher Y . As illustrated in Figure 5, a higher Y (e.g. Y^2 instead of Y^1) is associated with a higher $E + S$, since D_Y/P_Y increases with Y .

Since Y is itself resource-consuming, it can be questioned that the constraint of $C^E + nC^S = \text{constant}$ in God's maximization problem is not adequate. However, accounting for Y as well does not change our preceding conclusion, as shown below.

For simplicity, we ignore complications such as individual differences, multiple and interrelated events over time, etc. Let God (or evolution) maximize the probability P that a representative individual in a species will successfully survive, subject to a form of resource constraint. Given other factors regarded as exogenous here, this probability is an increasing function of effort Y which is in turn an increasing function of the incentive I involved. As shown above, this incentive is simply the sum of enjoyment E and suffering S , even for rational

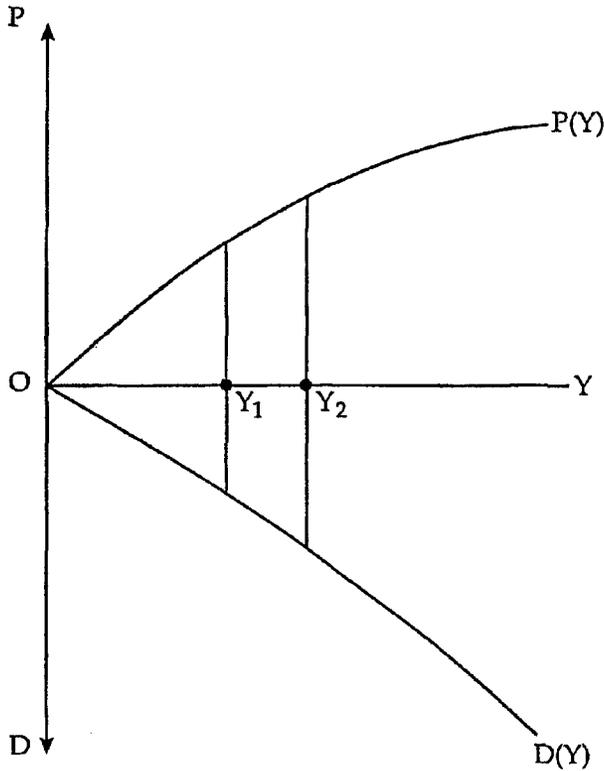


Fig. 5. The choice by rational sentiments.

species. (For simplicity, we consider only an all success or all failure outcome.)

Both E and S are taken as functions of the cost (C^E) associated with E and that (C^S) associated with S . The “resource” constraint is that the total costs involved do not exceed a given amount \bar{R} . If a representative individual has a probability P of success, the population has a proportion P of successful individuals and $1 - P$ of failing individuals, at least on average. We may thus write the resource constraint (in per individual terms) as

$$PC^E + (1 - P)C^S + Y = \bar{R} \tag{A4}$$

Maximizing P with respect to C^E and C^S , subject to (A4), yields the following first-order condition, assuming differentiability and the satisfaction of the second-order condition,

$$(1 - P)E_C = PS_C \tag{A5}$$

which is the same as (A1) since $n = (1 - P)/P$.

The fact that the inclusion of effort Y in the resource constraint does not affect the outcome may be briefly explained. It is *not* due to the fact that Y applies to all individuals since Y is not a constant. Rather, it is because P , the objective, can be increased only via Y . God can only (in our model) choose between C^E and C^S to maximize P via Y . Hence the first-order condition (A5) remains similar to (A1). In a more complete analysis, we may want to model the resources invested in raising the functions $E(C^E)$ and $S(C^S)$ themselves. If we again have diminishing marginal returns in this, our basic result remains unaltered.

NOTES

* I wish to thank S. E. G. Lea, F. M. Toates, and anonymous referees for very helpful comments. I have also benefited from the peer discussion of a preliminary version appearing electronically in *Psychology*.

¹ Behaviourism itself is fine and has led to spectacular advances in psychology. But extreme behaviourism denies the acceptability of dealing with subjective concepts such as consciousness and hence hampers the scientific study of welfare. In the words of Maynard Smith (1984, as reprinted in Catania and Harnad 1988, p. 53), 'it may sometimes be fruitful for psychologists to treat the brain as a black box, but that is no excuse for claiming that the box is empty'. For an example of the objectionable claims on the non-relevance of purpose and mind and the attempt to reduce almost everything (even the definition of goodness) to operant conditioning, see Skinner (1981, p. 502–503). For peer commentaries and Skinner's replies, see Catania and Harnad (1988).

² The most preposterous view about consciousness I know of is that of Jaynes (1976) who equates the existence of consciousness with the *objective* evidence (verbal or written) of an analogy "I" narratizing in a mind-space and hence dates the beginning of consciousness at only about 3,000 years ago, well *after* the evolution of language (about 40,000 years ago). Had World War I destroyed all our historical records that allow us to infer the existence of an analogy "I" narratizing in a mind-space, Jaynes would have concluded that consciousness emerged only less than a hundred years ago.

³ For an illustration, see Jastrow (1981, p. 69).

⁴ Neurology of consciousness supports the idea that species closer to us in the phylogenetic scale are also similar to us in brain structure and functioning. (See Walker 1983 for a review.) For example, as pointed out by Ojemann (1986, p. 164), "in the thalamocortical portion of the reticular activating system, we have an old system that is present in animals, not unique to man, but is changed and adapted in the human brain ... It is not likely, then, that this system which seems to be essential to conscious experience is something that was only evolved 4,000 years ago." Some researchers (e.g. Chapman 1990) believe that only mammals are capable of suffering as lower classes do not have the limbic brain capable of emotion. This may be due to their acceptance of Cassell's (1982, p. 640) narrow definition of suffering as "the state of severe distress associated with events that threaten the intactness of the person". Also, one must not commit the mistake of asserting "that a jet plane cannot fly because it has no propellers" (Dawkins 1990, p. 50).

⁵ Consciousness is defined in the sense similar to "awareness" as defined by Bunge (1980, p. 175) who defines consciousness differently. "Consciousness" is used here because it is awkward to speak of an "aware organism". The usage here also coincides with the commonsense usage.

⁶ Consciousness may just be an "afterthought" in some cases (Deecke, Grözinger and Kornhuber 1976; Harnad 1982). If consciousness is always just an afterthought, Axiom 3 is unlikely to be true. But even so, this does not make the scientific study of consciousness impossible or uninteresting.

⁷ The plasticity of intermediate patterns of behaviour requires further research. It may also be noted that, while plasticity is necessary for consciousness, the consciousness of a plastic individual may also be involved in some of its non-plastic patterns of behaviour. Similarly, the adaptiveness of tool-using may be essential for the evolution of our sophisticated hands which are however also used for

less sophisticated manoeuvres. Also, the relationship between behavioral plasticity and brain plasticity (including the flexibility of neuronal functions, the synaptic gaps, and quantum uncertainty) remains to be explored.

⁸ The truth of Proposition 1 is widely believed. For example, Bunge (1980, p. 74) hypothesizes that the plastic neural systems are the “seats” of the mental. The difference of our approach here is to deduce Proposition 1 from some more basic axioms. Also, much of Griffin’s (1984, 1992) discussion and the arguments of many authors he cites therein are largely based on the close relationship of consciousness and plasticity, though Griffin (1984, p. 7) himself “believe[s] that plasticity or learning may not be necessary for conscious thinking”. See also Penrose’s (1989, Ch. 10) view that consciousness is necessary for forming judgments and Dawkins’ (1987) argument that suffering is most likely to arise in organisms that have the capacity to take actions to avoid danger and to obtain something important for fitness.

⁹ One solution adopted by evolution is to have pre-programmed learning and conditioning without consciousness. These are defined as non-plastic here since no real *choice* is involved. Also, while this solution increases the ability of an organism to tackle more complicated environment, it cannot be compared with what is achievable by conscious choice. As concluded by Lieberman (1990, p. 285 and p. 288) after reviewing the literature on conditioning and reinforcement without consciousness, “when awareness is rigorously assessed, subjects do not learn unless they are aware of the reinforcement contingency ... If learning does sometimes occur without awareness, such learning is almost certainly the exception rather than the rule”.

¹⁰ A better measure might be the positive proportionate divergence from Jerison’s (1973, pp. 57–62) equation: brain weight = a constant fraction of the $2/3$ power of body weight; this divergence is the encephalization quotient. The reason for the power being $2/3$ is because the surface area of the body increases with the square while the body weight increases with the cube of the proportionate increase in length, width, and thickness. The $2/3$ power increase is thus required simply to coordinate the body senses and direction for body movement. The excess over this may then be taken as a measure of intelligence. As expected, modern man ranks first in accordance to this measure.

¹¹ While there are more recent theories (e.g. the theory of punctuated equilibrium) than Darwin’s belief in gradual evolution, no one envisages a dramatic mutation into a monkey from, say, a crocodile. Similarly, no one can credibly hold that full-grown consciousness and intelligence at the levels of *homo sapiens* evolved overnight. Thus, if we accept that consciousness is an evolved function, the existence of some degrees of consciousness in other primates and mammals, if not birds and lower vertebrates, is inevitable.

¹² As the parent may survive until future breeding attempts, the clutch size in any one breeding season actually represents a tradeoff between the parent’s fitness gain from the current breeding attempt and its survival to future breeding attempts (Williams 1966; Murray 1979). If we replace clutch size by the number of births in all clutches during the life time, which is really more relevant for our purpose here, the maximization of the number of surviving offspring is closer to the mark.

¹³ The all-or-nothing principle involved at very low range of stimulus-sensation levels and the gate-control theory of pain (Melzack and Wall 1965) mean that we do not have a strictly continuous response. This discreteness is ignored for simplicity and increasing marginal costs in the large is taken to be the rule. Psychological studies of stimulus-sensation response function yield results (e.g. the Fechner-Weber law of sensation = $k \log$ stimulus, Stevens’ power law; see, e.g. Luce and Galanter 1963; Krueger 1989) consistent with diminishing marginal sensation. While these refer to objective stimulus, the replacement by the cost on the individual does not change the result if this cost is a proportional or convex function of stimulus. Even if this is a concave function, its degree of concavity has to be strong enough to offset the concavity in sensation as a function of stimulus, an unlikely possibility.

¹⁴ The ethical argument for altruism is categorically different from apparent altruism arising from group selection in the maximization of inclusive fitness. Some critics of Singer completely miss the relevant ethical argument. When Singer says that “I must imagine myself as living the lives of all those affected by my decision ...”, these lives are the result not only of the objective circumstances but also of whatever subjective (biological and psychological) constituents of the individual sentient concerned. Hence, it is impossible to have the result: “... suppose I am extraordinarily tough ... I

might then prefer some actions or policies that others would consider too severe" (DeGrazia 1990). Also, if giving more care to one's own children, one's neighbours, one's fellow human beings, etc., would increase the sum total of welfare more due to biological, psychological, and social factors such as commitments and kinship, such special considerations are not against the ethical principle that, as far as *ultimate* effects on welfare is concerned, the welfare of all sentient beings should be treated equally. (Compare the confusion of non-ultimate considerations with basic values discussed in Ng 1990b).

¹⁵ If the welfare of all individuals in a species increases or at least does not decrease, then it is less controversial to say that the welfare of that species has increased. With intra-species, inter-individual changes (both positive and negative) in welfare, it is more controversial when the welfare of a species can be said to have increased. (There is a big literature on the appropriate social welfare function for such cases; see Mueller 1989 and Ng 1983, Ch. 5 for reviews.) Nevertheless, there are certainly cases where the welfare of a whole species can be said to have increased. Thus, it seems reasonable to extend the Pareto criterion regarding individual welfares to the welfares of individual species. Alternatively, some readers may wish to replace the word "species" in the text by "individuals" (of any species).

REFERENCES

- Barnett, J. L., and Hemsforth, P. H.: 1990, 'The validity of physiological and behavioural measures of animal welfare', *Applied Animal Behaviour Science* **25**, 177–187.
- Broom, D. M.: 1988, 'The scientific assessment animal welfare', *Applied Animal Behaviour Science* **20**, 5–19.
- Burt, C.: 1962, 'The concept of consciousness', *British Journal of Psychology* **53**, 229–242.
- Bunge, Mario: 1980, *The Mind-Body Problem: A Psychological Approach*, Pergamon, Oxford.
- Cabanac, M.: 1979, 'Sensory pleasures', *Quarterly Review of Biology* **54**, 1–29.
- Cabanac, M.: 1992, 'Pleasure: the common currency', *Journal of Theoretical Biology* **155**, 173–200.
- Cassell, Eric J.: 1982, 'The nature of suffering and the goals of medicine', *New England Journal of Medicine* **306**, 639–645.
- Catania, A. C., and Harnad, S. (eds.): 1988, *The Selection of Behavior*, Cambridge University Press.
- Chapman, C. Richard: 1990, 'On the neurobiological basis of suffering', *Behavioral and Brain Sciences* **13**, 16–17.
- Chomsky, N.: 1959, 'Review of *Verbal Behaviour* by B. F. Skinner', *Language* **35**, 26–58.
- Cody, M.: 1966, 'A general theory of clutch size', *Evolution* **20**, 174–184.
- Colgan, P.: 1989, *Animal Motivation*, Chapman and Hall, London.
- Dawkins, Marian S.: 1980, *Animal Suffering: The Science of Animal Welfare*, Chapman & Hall, London.
- Dawkins, Marian S.: 1987, 'Minding and mattering', in: *Mindwaves*, ed. C. Blakemore & S. Greenfield, Blackwells.
- Dawkins, Marian S.: 1990, 'From an animal's point of view: motivation, fitness, and animal welfare', *Behavioral and Brain Sciences* **13**, 1–9, 49–54.
- Deecke, L., Grözinger, B., and Kornhuber, H. H.: 1976, 'Voluntary finger movement in men: cerebral potentials and theory', *Biological Cybernetics* **23**, 99–119.
- DeGrazia, David: 1990, 'On Singer: more argument, less prescriptivism', *Behavioral and Brain Sciences* **13**, 18.
- Donchin, E., McCarthy, G., Kutas, M., and Ritter, W.: 1983, 'Event-related brain potential in the study of consciousness', in: R. J. Davidson, G. E. Schwartz, and D. Shapiro, eds. *Consciousness and Self-Regulation*, Vol. 3, Plenum, New York, 81–121.
- Duncan, I. J. H.: 1974, 'A scientific assessment of welfare', *Proceedings of the British Society for Animal Production* **3**, 9–19.
- Duncan, I. J. H.: 1987, 'The welfare of farm animals: an ethological approach', *Science Progress (Oxford)* **71**, 317–326.
- Eisemann, C. H., Jorgensen, W. K., Merritt, D. J., Rice, M. J., Cribb, B. W., Webb, P. D., and Azlucky, M. P.: 1984, 'Do insects feel pain? A biological view', *Experientia* **40**, 164–167.

- Fiorito, G.: 1986, 'Is there pain in invertebrates?' *Behavioral Processes* **12**, 383–386.
- Gallup, Gordon G. Jr.: 1985, 'Do minds exist in species other than our own?' *Neuroscience and Biobehavioral Reviews* **9**, 631–641.
- Gould, J. L.: 1985, 'How bees remember flower shapes', *Science* **227**, 1492–1494.
- Gould, J. L., and Gould, C. G.: 1982, 'The insect mind: physics or metaphysics?' in: Griffin (1982).
- Gould, S. J.: 1980, *The Panda's Thumb*, Norton, New York.
- Gould, S. J., and Lewontin, R. C.: 1979, 'The spandrels of San Marco and the Panglossian paradigm: a critique of the adaptationist programme'. *Proc. Royal Soc. London B* **205**, 581–598.
- Gray, J. A.: 1990, 'In defence of speciesism.' *Behavioral and Brain Sciences* **13**, 22–23.
- Griffin, Donald R.: 1976, *The Question of Animal Awareness*, New York: Rockefeller University Press.
- Griffin, Donald R., ed.: 1982, *Animal Mind – Human Mind*, Berlin: Springer-Verlag.
- Griffin, Donald R.: 1984, *Animal Thinking*, Harvard University Press.
- Griffin, Donald R.: 1992, *Animal Minds*, University of Chicago Press.
- Harnad, S.: 1982, 'Consciousness: an afterthought', *Cognitive Brain Theory* **5**, 29–47.
- Hodos, W.: 1982, 'Some perspectives on the evolution of intelligence and the brain,' in: Griffin (1982), 33–55.
- Jastrow, Robert: 1981, *The Enchanted Loom: Mind in the Universe*, Simon & Schuster, New York.
- Jaynes, J.: 1976, *The Origin of Consciousness in the Breakdown of the Bicameral Mind*, Houghton Mifflin, Boston.
- Jerison, Harry J.: 1973, *Evolution of the Brain and Intelligence*, Academic Press, New York.
- Josephson, B. D. and Ramachandran, V. S.: 1980, *Consciousness and the Physical World*, Pergamon, Oxford.
- Krueger, Lester E.: 1989, 'Reconciling Fechner and Stevens: Toward a unified psychological law', *Behavioral and Brain Sciences* **12**, 251–320.
- Lack, D.: 1954, *The Natural Regulation of Animal Numbers*, Clarendon, Oxford.
- Libet, B., et al.: 1979, 'Subjective referral of the timing for a conscious sensory experience', *Brain* **102**, 193–224.
- Lieberman, D. A.: 1990, *Learning: Behavior and Cognition*, Wadsworth, Belmont, California.
- Lorenz, K.: 1971, *Studies in Animal and Human Behavior*, Vol. 2. Methuen, London.
- Lorenz, K.: 1977, *Behind the Mirror*, Methuen, London.
- Lorenz, K. Z., and Tinbergen, N.: 1938, 'Taxis and Instinkthandlung in der Eirollbewegung der Graugans', *Z. Tierpsychol* **2**, 238–342.
- Luce, R. D., and Galanter, E.: 1963, 'Psychophysical scaling'. in: R. D. Luce', R. R. Bush and E. Galanter, eds. *Handbook of Mathematical Psychology*, Vol. 1. Wiley, New York.
- Maxwell, Mary: 1984, *Human Evolution: A Philosophical Anthropology*, Columbia University Press, New York.
- Maynard Smith, J.: 1984, 'A one-sided view of evolution', *Behavioral and Brain Sciences*. Reprinted in Catania and Harnad (1988).
- McFarland, D.: 1989, *Problems of Animal Behaviour*, Longman.
- McKearney, J. W.: 1970, 'Responding under fixed-ratio and multiple fixed-interval fixed-ratio schedules of electric shock presentation', *Journal of Experimental Analysis of Behavior* **14**, 1–6.
- Melzack, R., and Wall, P. D.: 1965, 'Pain mechanisms: a new theory', *Science* **150**, 971–979.
- Morton, D. B. , and Griffiths, P. H. M.: 1985, 'Guidelines on the recognition of pain, distress and discomfort in experimental animals and an hypothesis of assessment', *Veterinary Record* **116**, 431–436.
- Mueller, D. C.: 1989, *Public Choice II*, Cambridge University Press.
- Murray, B. G. Jr.: 1979, *Population Dynamics: Alternative Models*, Academic Press, New York.
- Ng, Y-K.: 1975, 'Bentham or Bergson? Finite sensibility, utility functions, and social welfare functions', *Review of Economic Studies* **43**, 545–570.
- Ng, Y-K.: 1983, *Welfare Economics*, 2nd edition, Macmillan, London.
- Ng, Y-K.: 1989a, 'What should we do about future generations? Impossibility of Parfit's Theory X', *Economics and Philosophy* **5**, 235–253.
- Ng, Y-K.: 1989b, 'Individual irrationality and social welfare', *Social Choice and Welfare* **6**, 87–101.

- Ng, Y-K.: 1990a, 'The case for and difficulties in using "demand areas" to measure changes in well being', *Behavioral and Brain Sciences* **13**, 30–31.
- Ng, Y-K.: 1990b, 'Welfarism and utilitarianism: a rehabilitation', *Utilitas* **2**, 171–193.
- Ng, Y-K.: 1992a, 'Happiness surveys: ways to improve accuracy and comparability', Monash Economics Seminar Paper No. 14/92.
- Ng, Y-K.: 1992b, 'Complex niches favours the evolution of more rational species', Monash Economics Paper No. 16/92.
- Ng, Y-K.: 1992c, 'Population dynamics and animal welfare', Monash Economics Seminar Paper No. 15/92.
- Ng, Y-K. and Wang, Jianguo: 1993, 'Relative income, aspiration, environmental quality, individual and political myopia: why may the rat-race for material growth be welfare-reducing?' *Mathematical Social Sciences* **26**, 3–23.
- Norton-Griffiths, M.: 1969, 'The organization, control and development of parental feeding in the oyster catcher', *Behaviour* **34**, 55–114.
- Ojemann, G.: 1986, 'Brain mechanism for consciousness and conscious experience', *Canadian Psychology* **27**, 158–168.
- Parker, G. A., and Begon, M.: 1986, 'Optimal egg size and clutch size: effects of environment and maternal phenotype', *The American Naturalist* **128**, 573–592.
- Penrose, R.: 1989, *The Emperor's New Mind*, Oxford University Press, Oxford.
- Rensch, B. and Nolte, A.: 1949, 'Über die Funktion auf den Rücken transplantierte Augen'. *Zeitschrift für vergleichende Physiologie* **31**, 696–710.
- Ristau, C. A.: 1991, *Cognitive Ethology: The Minds of Other Animals*, Essays in Honor of D. R. Griffin. Hillsdale, Lawrence Erlbaum, N.J.
- Rollin, Bernard E.: 1989, *The Unheeded Cry : Animal Consciousness, Animal Pain and Science*, Oxford University Press.
- Rowan, Andrew N.: 1990, 'To suffer, or not to suffer? That is the question', *Behavioral and Brain Sciences* **13**, 33–34.
- Segal, Evalyn F.: 1990, 'Animal well-being: There are many paths to enlightenment', *Behavioral and Brain Sciences* **13**, 36–37.
- Singer, Peter: 1990, 'The significance of animal suffering', *Behavioral and Brain Sciences* **13**, 9–12.
- Skinner, B. F.: 1957, *Verbal Behavior*, Appleton-Century-Crofts.
- Skinner, B. F.: 1981, 'Selection by consequences', *Science* **213**, 501–504.
- Solbrig, O. T., and Solbrig, D. J.: 1979, *Introduction to Population Biology and Evolution*, Addison-Wesley, London.
- Suter, R.B., and Parkhill, V.S.: 1990, 'Fitness consequences of prolonged copulation in the bowl and doily spider', *Behavioral Ecology and Sociobiology* **26**, 369–373.
- Thorpe, W. H.: 1974, *Animal Nature and Human Nature*, Methuen, London.
- Toates, F.: 1990, *Obsessional Thoughts and Behavior*, Thorsons, Wellingborough.
- Veenhoven, R.: 1984, *Conditions of Happiness*, Dordrecht, Holland.
- Vyklický, L.: 1984, 'Methods of testing pain mechanisms in animals', in: P. D. Wall and R. Melzack, eds. *Textbook of Pain*, Churchill Livingstone, Edinburgh.
- Walker, Stephen: 1983, *Animal Thought*, Routledge & Kegan Paul, London.
- Watson, J. B.: 1913, 'Psychology as the behaviorist views it', *Psychological Review* **20**, 158–177.
- Weizsäcker, Carl C. von: 1965, 'Existence of optimal programs of accumulation for an infinite time horizon', *Review of Economic Studies* **32**, 85–104.
- Wiepkema, P. R., and P. W. M. van Adrichem, eds.: 1987, *Biology of Stress in Farm Animals*, Martinus Nijhoff, Dordrecht.
- Wigglesworth, V. B.: 1980, 'Do insects feel pain?' *Antenna* **4**, 8–9.
- Williams, G. C.: 1966, 'Natural selection, the costs of reproduction, and a refinement of Lack's principle', *American Naturalist* **100**, 687–690.
- Wilson, D. S.: 1980, *The Natural Selection of Populations and Communities*, Benjamin/Cummings, London.
- Yoerg, S. L.: 1991, 'Ecological frames of mind: the role of cognition in behavioral ecology', *Quarterly Review of Biology* **66**, 287–301.