THE SYMBIOTIC NATURE OF ANIMAL RESEARCH

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In recent years the ethical basis for the use of animals by humans has been questioned and political pressure has been brought to reduce, if not eliminate, our interaction with other animals [1]. While this situation has directly affected all who use animals commercially, few have been more affected than scientists who use animals in their research. As a result, researchers have found it necessary to defend their use of animals.

The usual justification given for animal research is that the benefits of the research to humans outweighs the costs to the animals [2, 3]. However, this argument raises the question of how many animals we are justified in sacrificing in order to benefit ourselves. This question arises because the relationship between humans and animals is viewed as one-sided, with humans benefitting at the expense of animals. Indeed so pervasive is this view, that current United States government policy directs that the number of animals used in research be minimized and that alternatives to animal research be sought—with the implied goal of eventually ending animal research [4, 5].

But is the use of animals in research (or, for that matter, for food and clothing) an exploitative relationship in which all of the benefits accrue to humans? In answering this question, it is important to realize that all living organisms have close relationships with others and that these relationships have been the subject of scientific study. Ironically, the knowledge gained from such studies has not been applied to the debate concerning the use of animals in science.

The purpose of this paper is to examine our use of animals in terms of what is known about the relationships between living organisms, particularly symbiotic relationships. In doing so, it is necessary to consider the general issue of domestication, of which animal research is a part, and to examine the use of the reproductive strategy known as kin selection. As will be seen, such an analysis leads to conclusions that have relevance to our use of animals.

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Symbiosis

The term symbiosis was first used in 1879 by Anton de Bary, a German mycologist at the University of Strasbourg, to refer to the living together or close association of two different species [6]. Although it has sometimes been used to refer to interactions in which both species (the symbionts) benefit, it is more commonly used in a broad sense to refer to all types of interactions (as originally used by de Bary). One form of symbiosis is parasitism, in which one symbiont obtains food and/or shelter at the expense of another, but without causing immediate death; indeed, it is the most common lifestyle found in nature [7]. Examples include the various bacterial, viral, and other diseases that infect all organisms including humans. A second form is commensalism, in which one species obtains food and/or shelter from another at little cost (or benefit) to the host. The house mice and rats that consume small amounts of our food and the mites that live in our beds are not considered to be noticeably detrimental to our survival, although they may occasionally be so [8, 9]. However, it is mutualism, in which both parties benefit, that is of most relevance here. A prime example is our own bodies, for humans, like other mammals, are properly considered as complex organisms consisting of animal cells and bacteria: the bacteria that inhabit our gut not only outnumber the cells of our body, but constitute a complex ecosystem whose metabolic activity is on par with that of the liver and without which we could not survive [10].

The measure of benefit derived from a mutualistic relationship is the amount that the relationship has contributed to the reproductive success of both species and, conversely, has reduced the probability that either might become extinct. Species that are considered relatively resistant to extinction have the following characteristics: they are quite numerous with the result that a sudden reduction in their numbers will not reduce the population below the minimum necessary for survival (i.e., the minimum viable population), they are geographically widespread and thus can survive local environmental changes that may eliminate them from particular locales, and they are phenotypically diverse making them adaptable to new and changing environments [11]. Thus, the success of a species can be estimated in terms of these three characteristics, which reflect the long-term probability that they will continue to pass on their DNA.

Domestication is a Mutualistic Relationship

The initial interaction of *Homo sapiens* with animals was a predator-prey relationship—we were usually the predator. Over 10,000 years ago, this relationship started to change as humans began to domesticate animals [12, 46]. The consequences were profound: not only did we gain reliable

sources of food and clothing, but of power as well (e.g., horsepower). Along with the domestication of plants, the domestication of animals has made humans one of the more successful of extant mammals—not only have our numbers increased, but we have successfully invaded a wider variety of habitats as a result of domestication.

If humans have succeeded as a result of domestication, so have the animals we domesticated. Like humans, domestic animals have increased their numbers far beyond their wild ancestors and they have spread to every continent on the globe. In addition, the diversification of domestic animals into numerous breeds has led to greater phenotypic variation than existed in the wild populations. In short, domestication is a mutualistic relationship that has made domestic animals far more successful and much more resistant to extinction than their wild ancestors while simultaneously strengthening mankind's ability to survive.

An example of this benefit can be seen in the spread of domestic animals to North America as a result of European colonization. It has been remarked that during the early colonial period, domestic animals far outnumbered humans in the New World [13]. They still do [14]. The spread of domestic cattle provides a revealing illustration of this process.

Domestic cattle are bovids and belong to the subfamily Bovini, which includes the American bison [15]. Interestingly, bison are so closely related to domestic cattle that they can interbreed and produce fertile offspring [16]. Prior to the advent of European colonists (both human and animal), there were estimated to be 30 million bison in North America and, of course, no domestic cattle [17]. Now the situation is reversed. Currently, there is only a remnant population of around 65,000 bison, but there are 140 million domestic cattle in North America and over 250 million more in South America [14, 17]. In other words, there are now far more Bovini in the New World than there were before the advent of domestic cattle. Moreover, the diversity of bovids has increased markedly—whereas there were previously only two or three varieties of bison [16, 17], there are over fifty breeds of cattle [18]. Thus, it is clear that engaging in a mutualistic relationship with humans is an extraordinarily successful survival strategy for animals [19]—at least as long as there are humans.

The Role of Kin Selection in Domestication

Domestic cattle not only demonstrate the success of forming mutualistic relationships with humans, they also provide a clear example of a common strategy for perpetuating one's genes, namely, kin selection. Kin selection is a strategy in which the ability of individuals to reproduce directly is reduced either because their own lives are put at risk protecting their close relatives or because their individual reproductive efforts have been curtailed and their efforts directed instead to aiding the reproductive success

of their close relatives [20]. A common example of the former is a sentinel animal that gives warning calls of predators to protect others in its group, but at the risk of drawing the attention of the predator to itself [21]. Examples of individuals that forego reproduction are found among social animals, the classic examples being eusocial insects, such as ants, bees, and termites, whose workers devote their efforts to caring for the offspring of the queen to whom they are closely related [20]. A similar arrangement is found among mammals in colonies of naked mole rats (*Heterocephalus glaber*) where a single reproducing female (the "queen") suppresses the sexual development of the other females in the colony by excreting a hormone in her urine [22].

Two points should be noted. First, kin selection does not usually involve choice on the part of the individuals involved. Instead, it is a strategy imposed on them by natural selection—it persists because it is successful. Second, for kin selection to work, the genetic success of the "donor" must be greater than that which would result if it attempted to reproduce directly and this can only occur if relinquishing direct reproductive efforts benefits an animal's close relatives more than others. Thus, the benefit to others must be in proportion to the degree of kinship with the donor and, among mammals, the closest relatives are parents and full siblings as well as offspring.

Returning to the example of cattle, it can be seen that most individual animals do not have the opportunity to reproduce before they are slaughtered and thus do not contribute directly to their gene pool. However, they do have an indirect, but powerful influence on the success of their genes because, as noted by Charles Darwin, we continue to breed closely related animals in order to perpetuate the desirable features of those that we use [23]. Indeed, it has been stated that "the only sure test of an animal's breeding worth is the quality of its offspring" [24]. Thus, the selection of breeding stock is based not simply on the characteristics of the breeding animal itself, but on the characteristics of its offspring with the result that offspring that exhibit desirable characteristics (e.g., rapid weight gain) increase the reproductive success of their parents and, most importantly, the success of their own genes. As a result, whereas kin selection plays a small role in wild cattle, as when members of a herd defend each other from predators, it has become a major mechanism for perpetuating the genes of domestic animals.

It should be noted that the increased use of kin selection by domestic animals has not necessarily changed their overall mortality rates (although their survivorship curves have changed as a result of human protection of newborn animals; for a description of survivorship curves, see [20]). In the wild, first-year mortality rates for animals are typically 80% or higher, especially when the environment has reached its carrying capacity [25, 26]. Furthermore, among those animals that survive, the competition for a mate and resources to reproduce is so intense that many fail to breed successfully [26]. Humans, however, protect domestic animals from the ravages

of nature and it is those animals that otherwise would not have survived that we use. Although the reproductive rates of domestic animals could be reduced to compensate for their reduced mortality due to human protection, this, of course, would eliminate their usefulness to us and we would no longer have sufficient reason to continue our relationship with them.

Whether in the wild or in association with humans, the death rate in a stable population will be the same—it will equal the birth rate (assuming equal immigration and emigration rates) . However, the death of an animal in the wild from starvation, predation, or disease is wasted effort on the part of the parents in that it contributes nothing to the perpetuation of their genes. The death of an animal for human use, on the other hand, contributes to its genetic success by encouraging us to protect its genetic line. Thus it should be clear that the only losers in this relationship are the predators and parasites that attack animals in the wild.

The Mutualistic Nature of Animal Research

The use of animals in research is another example of mutualism in which the same points regarding domestication and kin selection apply. Most species commonly used in research had already established relationships with us before they expanded into the laboratory. Laboratory mice and rats are recent descendants of wild house mice (*Mus musculus*) and Norway rats *(Rattus norvegicus*) that evolved as commensals to live in our houses and feed off our stores of grain [12]. Similarly, dogs are scavengers and are believed to have begun their relationship with us by feeding off our garbage and wastes—as they still do in parts of Africa and the Middle East [27]. Indeed, the coprophagic habits of dogs were well known to polar explorers who depended on sled dogs [28] and are still familiar to dog owners with children in diapers (personal observation). The domestic cat entered into a mutualistic relationship with us by eating the wild rodents that feed on our grain. Thus, even before becoming domesticated, mice, rats, cats, and dogs were already dependent on humans for their survival.

During the latter half of the 19th century, it became apparent that the use of animals in research would greatly expand our knowledge of medicine and physiology. This was made apparent by research on animal diseases, such as anthrax and rabies, that helped establish the fact that microorganisms (germs) can cause disease. Indeed, up until that time, the medical community had overwhelmingly rejected the germ theory of disease and it was the application of the animal research of Pasteur and others that led surgeons to begin washing their hands before, instead of after surgery [29]. At about the same time, animals were used in increasing numbers as physiological research began to expand.

The movement of animals into the laboratory represents their expansion into a new ecological niche [48]. In the case of mice and rats, their relation-

ship with us has been elevated from commensalism to mutualism. Because we now breed them, both their numbers and genetic diversity have increased to the point that there are now well over two hundred stocks and strains of laboratory rodents [30, 47]. Indeed, the fact that the various types of laboratory mice and rats are reproductively isolated from each other and have diverged genetically may justify considering them as new species (for discussion of the debate on what constitutes a species, see ref. 31). The fact that humans are responsible for their reproductive isolation is yet another illustration of the well-established principle that one species can affect the evolution of another (compare, for example, the coevolution of flowering plants and the insects that pollinate them).

Some animals, such as cats and dogs, had already established mutualistic relationships with us and their movement into the laboratory represents an expansion of this relationship. Other animals, such as macaques and chimpanzees, have no close relationship with us outside the laboratory. However, chimpanzees are currently in danger of becoming extinct and the best chance for their survival may be to establish a mutualistic relationship with us, i.e., to become domesticated. Thus, one obvious survival strategy for chimpanzees would be to expand their use of kin selection and, capitalizing on their genetic similarity with humans, become essential to medical research thus increasing their own ability to survive—as well as ours.

Regardless of whether the use of previously domesticated animals in research results in a significant increase in their numbers, they benefit from our research in an indirect, but important way. Domestic animals have developed a dependence on humans no less extreme than the dependence of flowering plants on insects. Because they are now inextricably tied to us, anything that benefits us automatically benefits them and, conversely, anything that threatens our survival is a threat to theirs. For the moment, humans have what appears to be a relatively secure position on this planet. We have achieved this through the use of our intellect which has allowed us to stabilize our food supply, develop new sources of energy, and hold many diseases at bay (few diseases have actually been eliminated). However, history teaches us that all species eventually become extinct [11] and the best we can hope for is to delay this inevitability as long as possible. Thus, to restrict our acquisition of knowledge by reducing the use of animals in research is not in the best interests of the animals involved—not only because it decreases a laboratory species' usefulness to us and shuts it out of an ecological niche, but because it reduces the survivability of their major symbiotic partner, us.

Ethical Issues

If research animals benefit from their mutualistic interactions with humans, why would anyone think that these interactions are exploitative

and should be discontinued? Although the answers are usually based on personal philosophical principles [e.g., 32], there are two points that can be addressed objectively. These are: that life in a laboratory is inferior to that in the wild, and that humans would never accept a similar type of relationship. Both of these points merit scrutiny.

The first point is based on the observation that most research animals are not given the opportunity to reproduce, that they are euthanized before they reach senescence, and that they live in environments (laboratories) that differ from their wild habitats. But is the laboratory environment inferior to that found in the wild? As previously noted, animals in the wild suffer high mortality rates, are subject to starvation, predation, and disease, and many, if not most, fail to breed successfully [26]. It would appear that, at worst, the laboratory environment may sometimes be as harsh as life in the wild—for example, when animals are infected in order to study a disease, although even these animals do not have to worry about finding food and shelter or avoiding predators while they are ill. But the fact that animals in captivity live healthier and, in many cases, longer lives than their wild counterparts demonstrates that it is, in fact, a better environment.

Along this line, it should be noted that the natural habitat of animals bred for research is the laboratory—laboratory mice and rats are incapable of surviving in the wild. That they require us to survive does not make them "degenerate" any more than flowering plants that require insects for pollination are degenerate. Thus, animals bred for research are properly viewed as animals that have successfully invaded the laboratory niche, relying heavily on kin selection to perpetuate their genes. Similarly, wild animals brought into the laboratory (or other human environments, such as a zoo) can be viewed as animals exploring a new ecological niche. Interestingly, a mutualistic relationship may develop between humans and wild animals without us directly breeding them. This is because a demand for a wild species may lead to a commercial interest in perpetuating it by maintaining it's wild habitat—a classic example being the maintenance of habitats by sportsmen [33, 34]. Thus, we seem to have an inherent tendency to elevate our interactions with other animals to one of mutualism and our desire to save endangered animals from extinction may be due in part to a desire to hold open the possibility of future mutualistic interactions with them.

The second argument against our use of animals is that we would not accept a similar relationship in which some humans would have to suffer in order for others to benefit and that it is therefore unethical to impose such a relationship on animals. However, we do accept such relationships. While we would like all members of our species to live long and productive lives, we constantly compromise by sacrificing some for the benefit of others—a common example being the altruistic actions of soldiers in time of war.

However, a much more common (and largely overlooked) example of sacrifice is our use of the automobile.

In the United States, about 30,000 people are killed each year in accidents involving passenger vehicles [35]. Moreover, automobiles, like animal predators, tend to be inefficient, and over 1.5 million disabling injuries can be attributed to such accidents. Yet no one has had the temerity to seriously propose abolishing the automobile and forcing people to use much safer public transportation (or restricting travel altogether, which would save even more lives). If we accept for ourselves the principle that some must inevitably suffer so that others can enjoy the advantages of private transportation, then should we deny animals the opportunity to make a similar arrangement in order to ensure their very survival?

There is, however, one ethical principle that can be used in evaluating our relationships with animals. It is simply to ask whether we are providing them with a better situation than they would encounter in the wild, i.e., whether we are giving them a "better deal." There are examples of human-animal interactions in which the answer to this question is obviously no—for example, a predator-prey interaction in which animals are hunted to extinction. Domestication, on the other hand, is clearly an interaction in which animals are more successful than they are in the wild. In short, the use of animals by humans, whether it be for the accumulation of knowledge through research or any other reason, typically causes us to work to ensure the continuation of their genetic lines. And that, after all, is the purpose of life [23, 36].

Mutualism and the Debate on Animal Welfare

Although the mutualistic nature of our interactions with animals has received recent notice [27, 34], it appears to have gone unrecognized by animal researchers and thus has not been applied to the debate on animal research. However, it has occasionally been mentioned by those who argue we should change the way we interact with animals and it is of interest to see how they address the issue of mutualism.

One of the more extensive discussions of the fact that domestic animals owe their existence to humans has been made by the philosopher, Peter Singer [37, 38, 39]). Singer brings up the issue by citing the nineteenth-century British philosopher Leslie Stephen who wrote in his *Social Rights and Duties* (1896) that "The pig has a stronger interest than anyone in the demand for bacon. If all the world were Jewish, there would be no pigs at all." [40]. Singer, in the 1975 edition of his book, *Animal Liberation*, says that the flaw in this argument "...lies in the implication that we confer a favor on a being by bringing it into existence..." He then goes on to claim that there is no one to confer such a favor on as there is no such thing

as "..nonexistent animal(s), unborn and unconceived...waiting around in limbo for someone to bring them into existence." [37].

What Singer totally overlooks, of course, is the existence of genes and that the only reason an animal exists is because its ancestors strove to perpetuate their genes—any group of animals for which reproductive success takes on secondary importance will rapidly go extinct. Interestingly, Singer modified his position on this point in the second edition of his book [38] which, as he notes, is the only philosophical point on which he has changed his mind. In that edition, he suggests that it might be acceptable to raise animals in environments in which they are happy and then kill them painlessly. However, he still makes no reference to genes and bases his views on abstract reasoning as opposed to how the biological world works. Thus, while he is aware that humans are responsible for the existence of domestic animals, the biological bases of this relationship, that is, genetic fitness, plays no role in his philosophy.

The issue of reproductive success has been brought up by the biologist Marion Stamp Dawkins, who advocates preference testing as a way of assessing what is best for an animal's welfare [41, 42]. In a recent discussion of how to determine the state of an animal's welfare, Dawkins argues that longevity is by itself an inadequate measure as "...animals have been selected to reproduce, not just to live a long time as individuals." [42]. As she points out, it is not unusual for animals to put their health and lives at risk during breeding as exemplified by male animals that sustain injuries by fighting and female junglefowl which eat little while incubating eggs. However, having dispatched longevity as an adequate measure of an animal's welfare because it fails to take into account the need to propagate one's genes, Dawkins then abandons reproductive success as a measure because it would lead to the conclusion that modern factory farming, with high egg production and large litters of piglets, is a successful reproductive strategy for animals.

In the views of Singer and Marion Dawkins, then, the issue that domestic animals owe their existence to humans is not a major factor in evaluating our interactions with them. This raises the question as to why reproductive success, the cornerstone of modern biology, should be left out when addressing human-animal interactions poses a question? The answer may lie in a common view of the relationship between humans and animals, namely, that domestic animals are the products of "artificial" selection and that the environments we provide for them are "unnatural."

The term "artificial selection" was used by Charles Darwin to distinguish selection specifically by humans from selection involving nature in general, i.e., natural selection. Indeed, the development of Darwin's ideas on natural selection was based heavily on his study of the breeding of domestic animals. It should be noted, however, that Darwin was very sparing in the use of the term and it appears only once in *The*

Origin of Species [23]. Instead, Darwin preferred the phrase "selection by man," which he divided into methodical and unconscious selection [43]. Since Darwin's time, the term "artificial selection" has been widely used to refer to domestication with the connotation that it is inferior and unnatural (e.g., [44]).

While it may occasionally be useful to distinguish between human and natural selection, there is no basis in biology for such a dichotomy. This is because we and our interactions with other species are the products of natural selection, no different from the interactions between other species, with perhaps one exception—we have evolved language, which forms the basis of our consciousness and permits us to reflect upon our place in nature. Indeed, it is just this ability that has led to the reexamination of how we interact with other animals. However, in proposing to change these interactions, we are taking the view that we can improve upon nature by using our intellect. This may be true—if we fully understand the human-animal interactions we are attempting to change. But as the mutualistic nature of our interactions with animals appears to have been overlooked, we may be committing what has been referred to as the "fatal conceit" [45]. That is, we may be rejecting a naturally evolved system, which does not appear rational to us, not because it is irrational but because we do not fully understand it. Our current interactions with other animals are a naturally evolved system that has increased the reproductive success of all species involved. To replace it with an untried system simply because it appeals to our intellect is to risk the survival of all species involved.

The Antisymbiotic Movement

Domestic animals, including those used in research, have developed a mutualistic relationship with humans in which they depend on us for their survival. It is clear, then, that for us to sever this relationship would lead to their extinction. Because the animal rights movement aims to abolish all interactions between humans and animals, it is most appropriately characterized as an "antisymbiotic" movement. It is inaccurate to refer to it as a "rights" movement for it seeks to deny domestic animals the one right they need in order to survive, that is, the right to associate with humans. Even to argue that we should continue to care for domestic animals without making use of them is a threat to their survival; to do so would reduce their relationship with us to, at best, one of commensalism which, in times of hardship, would degenerate into parasitism—with humans as the host. Such a state of affairs would not be conducive to their long-term survival.

Moreover, it is also inaccurate to state that this movement is attempting to extend the ethical standards of the treatment of humans to the treatment of animals. What is being applied is not an ethical standard, but a reproductive strategy, one that foregoes mutualistic interactions and kin selection. However, there is no question but that the termination of our

mutualistic relationships with animals would be the end of their genetic lines. The ethics of promoting policies that will lead to the extinction of entire species would seem questionable, no matter how well-intentioned.

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NOTES ADDED AFTER PUBLICATION

46. Recent DNA evidence indicates that dogs originated from wolves more than 100,000 years ago. See Vila, C., et al. Multiple and ancient origins of the domestic dog. *Science* 276:1687-1689, 1997; Morell, V. The origin of dogs: Running with the wolves. *Science* 276:1647-1648, 1997.
47. The web site of the Jackson Laboratory in Bar Harbor Main lists over 1,700 stocks and strains of mice. Accessed February 25, 2000, <htt://www.jax.org/resources/documents/>.
48. The validity of an ecological niche can be determined by asking whether abolishing that niche would reduce the population size. Clearly, abolishing domestication would lead to a massive reduction,if not outright extinction, of domestic animals. Slavery, on the other hand, is not a valid ecological niche as its abolition does not result in a decline in the numbers of former slaves and their offspring. Thus, the arguments justifying domestication cannot be used to justify slavery.