The Early Evolution of the Domestic Dog

Animal domestication, commonly considered a human innovation, can also be described as an evolutionary process

Darcy F. Morey

Sometime within the past 12,000 or so years, most of humankind began to experience a profound shift in lifestyle. Stone Age hunters and gatherers of wild foodstuffs started to cultivate plants and raise animals for their own use. A landscape full of wild grasses, woolly mammoths and sabertooth cats gave way to giant-eared corn, fat cattle, toy poodles and many other new species. For reasons that remain obscure, the shift happened rapidly, by evolutionary standards, and in the mere space of a few thousand years, different domestic animals and plants appeared independently in several parts of the world.

The archaeological record indicates that humankind's best friend—the domestic dog, *Canis familiaris*—was likely also its first. Consequently, I think of dogs as the pioneers of an evolutionary radiation that had radical effects on the composition of the earth's biota and on the way people live. As such, dogs are an appropriate focal point for an ongoing debate about the origins and nature of animal domestication. Central to this discussion is the issue of intentionality—whether domestication must be understood as a human decision, as is commonly thought, or, rather, is best modeled strictly as an evolutionary process.

Those who explain domestication as a rational decision suggest that people recognized the potential benefits of bringing animals and plants under control. The assumption is that people intentionally sought to raise, cultivate and manipulate organisms in ways that enhanced their economically useful properties. In contrast, in the evolutionary view, the behavior, diets and, later, the physiology and morphology of certain animals changed from that of their wild counterparts in response to the selection pressures of a new ecological niche—a domestic association with human beings. This view holds, first, that knowing the intentions of prehistoric people is beyond the abilities of modern science. Second, and of greater importance, knowledge of people's rational intentions would not provide a scientific explanation for the process of domestication.

Domestication as Human Design

Given the pivotal role of domestication in shaping our present life-style, it is no surprise to find that prehistorians have argued vigorously about what domestication really is, how it originated, and why. Many classic definitions of the concept focus on human subjugation of other organisms. In a commonly drawn scenario, people isolated individuals of a particular species from their wild counterparts and then selectively bred them to exaggerate desirable traits and eliminate undesirable ones in a process known as artificial selection.

Such a scenario grows out of a combination of common-sense reflection on the conditions under which many modern domesticates live, with the presumption that those ends were sought, at least in rudimentary form, by people of the past. According to this view, people turned to the domestication of plants and animals when increases in human population or environmental changes reduced the availability of wild foods. Given these pressures, people invented or otherwise made a decision to experiment with domestication, though not necessarily as a well-organized plan.

Theories that assume intentionality, however, may be rooted more in the biases of modern culture than in any objective measure. Life in the 20th century without domesticates is virtually unimaginable to us, so it is tempting to presume that people who lived without domesticates during the late Pleistocene and early Holocene surely wished to improve their lives.

Figure 1. Relationships between Stone Age people and wolves set the stage for dog domestication. People and members of the dog family have had a long association, as these 11,000-to-12,000-year-old remains attest. A puppy skeleton from either a dog or a wolf can be seen under the human skeleton's left hand. These burials were discovered at Ein Mallaha in northern Israel and were originally reported by zooarchaeologists Simon Davis and François Valla. Early dog remains have been found at sites in other parts of the world, suggesting that dog domestication may have taken place independently in different regions. Prehistorians have disagreed about whether different animals were intentionally domesticated by ancient people, or whether domestication is another example of evolution driven by natural selection. The author argues the latter, and proposes that dog evolution is best viewed as the product of selection pressures in a new ecological niche, in this case a domestic association with human beings. (Photograph by Alain Dagand.)

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Domestic species and probable place of domestication



A second theme, this one anthropocentric, also underlies theories that assume intentionality—that people exercise rational control of their collective destiny. This perspective is appealing, for it places people at the evolutionary helm, charting the course from the start. To borrow anthropologist David Rindos's apt term, a "paradigm of consciousness" is our conceptual anchor, and from it stems the discussion of domestication as invention, decision, idea and so on.

Maybe the shift to economic reliance on domestic species was in some sense necessary, given human population growth and environmental changes in the Holocene. Maybe domestication was indeed a strategy that prehistoric people intentionally implemented. Both propositions are debatable, but my immediate objection stems from a problem more fundamental than the need for better data.

The human beings who participated in the earliest domestic relationships thousands of years ago are all dead. They cannot tell us what was in their minds or what they sought to accomplish. For early domestication, the data required to evaluate scenarios based on human intention are, by definition, unattainable. In other words, models that explain domestication this way cannot be empirically challenged, and on this basis alone, they are not scientific models.

The real issue is whether it is necessary to presume the intentions of prehistoric people to make sense of early domestication. Over the years, some scholars have attempted to describe domestication in more mechanistic terms, focusing on the implications of organisms sharing space and resources in symbiotic relationships. This approach, however, has not led to a uniform perspective. In 1959, for example, zoologist Charles Reed characterized domestication as "beneficial mutualism." At about the same time, in 1963, archaeologist F. E. Zeuner was using the term "slavery" as a virtual synonym for some cases of domestication. Nevertheless, such efforts can be viewed as the foundation for more recent attempts to model domestication as evolution.

Evolutionary perspectives differ from anthropocentric approaches in several

Figure 2. Humankind's best friend was likely also its first. This time line shows the estimated times and probable places of origin for several other important domesticates.

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ways. First, they do not restrict domestic relationships to people. The complex symbiosis between ants and aphids is a handy example, and is even used in my dictionary to illustrate use of the term "domestication." Certain ants herd aphids, providing protection in exchange for the sugary, honey-like liquid they "milk" from the aphids. Second, domestic relationships involve two species. Focusing solely on the human role in domestication ignores the evolutionary stakes for participating animals and plants. The ubiquity of dogs, for example, suggests they have profited well from the domestic arrangement. Their wolf ancestors, on the other hand, have been extirpated from most of their formerly vast range, and many subspecies are now extinct. From a Darwinian perspective, wolves who took up residence with people a few thousand years ago made a smart move-at least from today's vantage point.

Finally, an evolutionary perspective discourages an assumption that changes in an animal's size or shape during domestication must be products of human selection.

Ancient Associations

If one is to eliminate rational intention as a scientific explanation for early animal domestication, one must conclude that the process originated with a natural association between people and the wild ancestors of dogs. Skeletal remains of early dogs from various archaeological sites around the world place the beginnings of their domestication in the late Pleistocene era, possibly as far back as 14,000 years ago. The data therefore indicate that canid domestication took place among people who still pursued a hunting-and-gathering way of life.

The ancestor of these early dogs can be identified with confidence as the wolf Canis lupus. This assertion rests on a growing body of molecular data and is buttressed by the striking physiological and behavioral similarities between the species. It is not currently possible to identify which subspecies of wolves gave rise to domestic dogs (although new advances in comparative DNA analyses to establish relatedness between species may soon change that). For now, scholars simply recognize the wolf as the dog's ancestral progenitor, and many people suspect that canid domestication involved several wolf subspecies in different parts of the world.



Figure 3. Dogs served a number of economic purposes in past human societies, the variety of which makes it difficult to glean a primary benefit that people derived from the animals during early domestication. This dog bone from Qegertasussuk, a small island off of the west coast of Greenland, for example, was discarded by people along with large quantities of food debris almost 4,000 years ago. A series of cut marks on the bone indicate that the animal from which it came was skinned or butchered. Another dog bone from the site had been fashioned into what Danish archaeologist Bjarne Grønnow describes as a needle case. Later arctic peoples used dogs to pull sleds, and some skulls from later sites in Greenland and elsewhere in the Arctic bear marks that indicated blows to the head. (Photograph by Geert Brovad.)



Figure 4. Dog effigy vessel was made by a Colima artist. The Colima, who inhabited western Mexico about 2,000 years ago, and some other Precolumbian groups in Mesoamerica apparently used dogs as dietary fare, as did later groups, such as the Aztec. According to a Spanish observer at one Aztec market, 400 dogs were sold on a slow day. (Photograph used with permission from the Appleton Art Museum, Ocala, Florida.)

Wolves and late-Pleistocene hunters and gatherers undoubtedly came into contact regularly, since both were social species who hunted many of the same prey items. Wolves are also opportunistic scavengers; they were likely to have been familiar with human hunting practices and to have hung around human settlements regularly. Let us then assume that the road toward domestication began when some wolf pups became incorporated into a human social and residential setting. One could speculate endlessly about the conscious motivation people had for taking on wolf pups. It seems sufficient, however, to note that different people often kept wild animals for a variety of reasons without attempting to achieve long-term domestication.

Somewhere, at some time, one or more adopted pups managed to survive to adulthood in the new setting. To have a chance in human society, the animals minimally had to adjust to new social rules and to an altered diet.

Socialization, according to studies conducted by J. P. Scott during the 1950s and 1960s, is best achieved early in a dog's life. Scott and his colleagues at the Jackson Laboratory in Bar Harbor, Maine, conducted long-term studies of behavior and socialization in dogs and found that the first few weeks of a puppy's life are crucial for forming primary social bonds with both people and other dogs. Not surprisingly, wolves are similar. Several other studies have shown that young wolf pups also form lasting bonds with people, a process that becomes more difficult for the animals as they mature.

Bonding between people and wolves is facilitated by similarities in social structure and in nonverbal modes of communication. Wolves are organized hierarchically and they communicate status through vocal, facial and postural displays of dominance or submission. These displays involve many cues that are recognizable to people. Dogs use much the same repertoire of cues. Wolves and dogs can also respond appropriately to many human signals.

It is clear that animals living within human settlements had to learn that subordinate status to dominant humans was an inviolable rule. Some wolves were undoubtedly more adaptable than others to human dominance, and those that did not follow the rules were likely either killed or driven away. Some of those that adjusted be-



came tolerated in human society—a phenomenon that must have occurred within many human settlements. Selection for behavioral compatibility in a setting with new social boundaries was a strong force among founding domestic populations.

From the beginning of their domestic life, wolf pups would also have had to adjust to a different diet. Wild wolves take almost all their nutrition from meat. Adults often hunt cooperatively for large prey items, which for modern wolves includes deer, caribou or moose. Young wolves often accompany the adults and learn hunting skills, but that opportunity would be lost to wolf pups living in the domestic setting. Instead, they would have needed to rely more on people to share scraps of their own meals, a mixture of meat and plants. Adeptness at soliciting food from people was surely a valuable skill. To supplement this diet, wolf pups would have had to learn to scavenge competitively and to hunt small animals.

To maintain their toehold in the domestic niche, the domesticated wolves had to succeed in reproducing. One could assume that a male might leave the human setting and mate with wild animals. If he were successful, the progeny would be wild and would therefore not help perpetuate domestic populations.

Alternatively, the domestic setting might have included a male and female whose progeny remained in the human settlement. Although this scenario successfully creates more domestic animals, it also creates a genetically inbred population, which, in the long run, weakens the gene pool of the domestic population.

But a female surely had other options. A wild male that was unsuccessful in breeding within a wild pack might have found a domestic female an easier target. The female would most likely raise her offspring within the do-

Figure 5. DNA sequence comparisons and other lines of evidence allow scientists to establish the evolutionary relationships between members of the dog family. This analysis suggests that the gray wolf was the immediate ancestor of the domestic dog. The two species share so much genetic material in common that some scientists have described dogs as gray wolves with a few genetic alterations. The images do not depict true size relations between the species. Time is shown in millions of years ago. (Adapted from Wayne, 1993.) mestic setting, although a few might attempt to return to the wild with their pups. The continuation of the domestic line requires that only some females raise offspring in a domestic setting.

An irony here is that canid domestication might have foundered if not for the role of wild males finding alternative reproductive opportunities. Still, their strategy ensured that the domestic population was not isolated genetically from wild populations. Genetic input from wild wolves was probably strong for many generations. Even today dogs and wolves are capable of mating and producing fertile offspring.

Evolution in a Domestic Setting

The new population of domestic wolves undoubtedly continued to expand. But at some point the animals began to change physically and behaviorally, evolving toward the form we recognize today as the dog. Early dogs conveniently exhibit consistent morphological changes when compared with wolves. Briefly (and not exhaustively), dogs became smaller overall, and the length of the snout became proportionally reduced. The result was a smaller animal with a shorter face, a steeply rising forehead and proportionally wider cranial dimensions. This general pattern suggests that adult animals retained juvenile characteristics, a phenomenon known as paedomorphosis. Paedomorphic dogs have a somewhat puppylike cranial morphology when compared with adult wolves.

In seeking to explain this pattern, many discussions presume that domestic animals must change in ways that serve people. For example, some discussions suggest that people involved in early canid domestication may have found paedomorphic features endearing and favored animals that retained them. Similarly, it has been suggested that people found smaller animals more manageable and favored them as well. Such suggestions appear reasonable, especially because they reflect common biases in people's present-day choices for good household pets. But these changes were taking place ubiquitously some 10,000 years ago, despite tremendous variability in cultural and geographic settings. It seems unlikely that all these human groups would have selected for exactly the same traits in dogs. Surely, the consistent appearance of these traits in animals living within so many different cultures raises



Figure 6. Gray wolf was almost certainly the ancestor of the domestic dog.

the possibility that some selection pressure other than human preference brought about the changes.

Specialists in life-history studies have developed some tools for probing this issue. The life-history analyst focuses on the entire life cycle of an animal, especially how changes in timing of developmental processes and important life events can have consequences that impact reproductive success. Lifehistory analysts might consider when and how often an animal should reproduce, or how big and how fast it should grow, depending on its situation. Different ecological circumstances pose different selection pressures, and the answers to these kinds of questions depend on the specific conditions faced by the animals.

In addition to selection for social compatibility, I propose that the conditions faced by early domestic canids led to strong selection on reproductive timing and body size. These selection pressures ultimately produced the smaller, paedomorphic animal known as the dog.

J. P. Scott, whose experimental work with dogs has already been noted, point-



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ed out that canid domestication may be regarded as ecological colonization of a new niche. Population models view the hallmark of colonization as rapid population growth. One reason for this is that mortality becomes less dependent on population density compared with more stable conditions. Under these circumstances, a classical prediction of life-history models is that selection should favor lowered age at first reproduction. Increased fertility is at a premium then, and precocious maturation is a remarkably efficient way to achieve this. Evolutionary theory predicts that this change should result in size reduction and paedomorphosis in a descendant species, owing to a truncation of the growth period. In such a case, both consequences are only by-products of selection on reproductive timing. It is tantalizing to note that wild wolves reach sexual maturity at about the age of 2 years, whereas most modern dog breeds achieve maturity between 6 and 12 months. Unfortunately, it is difficult to know when in their history dogs started to reach sexual maturity earlier, and the current observed ages might just be an artifact of modern selective breeding programs.

A consideration of life-history studies also suggests that body size itself was a likely target of selection. An animal's body size plays a crucial role in defining its niche, and studies have shown that adult size is correlated with most life-history traits. Unfortunately, causes can be difficult to disentangle from effects. With early dogs, dietary change had to be pronounced, and I believe this placed smaller animals at a distinct advantage, because of their lower nutritional requirement. Admittedly this idea is difficult to test, and

Figure 7. Natural selection may have brought about many changes in the physiology and overall body size of domesticated wolves and led them eventually to form a separate species-the domestic dog. Skeletal remains show that early dogs were smaller and that adult dogs appeared juvenile in relation to their wolf ancestors. Here a prehistoric adult dog skull (center) is compared with an adult wolf skull (top) and a juvenile wolf skull. The dog skull bears a striking similarity to the juvenile wolf skull and is much less similar to the skull of the adult wolf. These changes suggest that the developmental program of the dog was altered in such a way that it would reach sexual maturity earlier than its wolf ancestors, while other aspects of its physical development were slowed down. (The juvenile wolf skull is enlarged here for the sake of comparison.)

other factors were probably involved.

Different lines of evidence at least suggest that dogs took a very direct route, genetically speaking, to get to smaller sizes. Zoologist Robert K. Wayne of the Zoological Society of London studied DNA sequences in modern canids and concluded that dogs basically are wolves, altered only by simple changes in developmental timing and growth rates. In related studies, Wayne also suggested that reduced fetal growth rates may be an important determinant of adult size in small dogs. Simple changes led to rapid size reduction in early dogs, probably at the cost of problems in the integration of different developmental processes during growth. For example, it is frequently observed that earliest dogs often have crowded teeth, sometimes even overlapping each other in jaws that are not really big enough to accommodate them efficiently. Overall, rapid size reduction with minimal genetic change suggests strong selection for smaller size among early dogs.

Consistent size reduction clearly took place in the early evolution of the dog, although causes are difficult to pinpoint. But evolutionary theory also predicts that the proposed developmental alterations should produce paedomorphic animals, and this requires a close look.

Evolutionary Paedomorphs

It is one thing to note that the cranial morphology of early dogs appears paedomorphic. It is quite another to argue that this pattern sets them apart from other canids or reveals something important about evolution under domestication. Other wild canids might also appear paedomorphic when compared with wolves. Dogs are frequently described as paedomorphic because modern small breeds resemble juvenile forms of larger breeds. But to have evolutionary significance, it is important to determine whether prehistoric dogs were paedomorphic relative to their ancestral species, the wolves.

To tackle these problems, I armed myself with calipers and a notebook and visited several American and European museums to measure canid crania. First, I took measurements from 65 adult prehistoric dog specimens from archaeological sites, the vast majority dated from between 3,000 and 7,000 years ago. Three-quarters of the specimens are from the United States, and the rest come from northern Europe. My choice of samples emphasized sites



Figure 8. Size change is often a consequence of changes in growth rates and timing. This schematic illustrates a hypothetical model to account for differences in size and morphology between the wolf and the dog. This model postulates that the descendant species grows more slowly very early in life and finishes growing sooner than the ancestral species. In this way the dog comes to resemble the juvenile form of its wolf ancestor when it reaches its full size.

where people were still making their living primarily through hunting and gathering at the time corresponding to the age of the sample, and therefore where I had little reason to suspect systematic selective breeding.

Next, I measured crania from 222 modern wild canids representing four species. These are, in descending order of average size, the gray wolf, the red wolf, the coyote and the golden jackal. The wolves and covotes are all North American, from the continental United States or southern Canada. Based on cranial measurements, I determined that most of the prehistoric dogs in my sample were roughly the size of golden jackals or the smaller coyotes. I did not have prehistoric samples of wild canids and must assume that modern samples provide a generally valid approximation of morphological variations in these species.

I was particularly interested in learning how several snout-length and cranial-width dimensions change in relation to the overall length of the skull as one moves from large to small animals. Size changes in animals are almost inevitably accompanied by patterned changes in proportions, a phenomenon known as allometry. Some allometric patterns stem from basic laws of biomechanics. For example, an elephant's mass could not be supported on geometrically scaled-up mouse bones. To begin with, an elephant has to have proportionally thicker leg bones. Shape changes shown by dogs could reflect only this kind of allometry.

My analysis revealed some interesting results. First, it turns out that most dogs share snout-length proportions with comparably sized wild canids. What sets dogs apart is not changes in the length of their snouts, but the width of their palates and cranial vaults. The cranial morphology of dogs is unique and does not conform to allometric patterns among wild canids.

The issue then is whether this cranial morphology reflects evolutionary paedomorphosis. To determine this, I compared dog morphology with the morphology of its ancestral species, the wolf, as it grows. If the dog is in fact a paedomorphic wolf, I would expect to see the greatest similarities between dogs and juvenile wolves and less similarity between prehistoric dogs and adult wolves. Ideally, data for answering this question would include cranial measurements from juveniles of both species. Unfortunately,

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the archaeological record is not that cooperative, and skulls of juveniles are usually nothing more than a pile of fragile, fingernail-sized pieces. Without data from juvenile dogs, it becomes imperative to have data from juvenile wolves, and this cause is not as hopeless. I measured skulls of 64 modern juvenile wolves ranging in age from a few weeks to several months, a sample that includes several North American subspecies. Using the allometric approach again, I compared juvenile wolf proportions with those of the adult wild canids and prehistoric dogs. By plotting snout-length measures against total skull length, I found that as a wolf grows, its snout gets longer at a rate that mirrors increasing snout length in the adult wild canids. These plots showed that all adult canid species, including adult dogs, look something like scaled-down adult wolves, if one



Figure 9. Behavioral alterations seem to accompany physical changes, so that dogs not only look more juvenile than wolves; they also act more juvenile. Behavior and physiology were shown to be linked by breeding experiments conducted by Russian geneticist D. K. Belyaev. Belyaev and his colleagues interbred foxes that responded well to people. After about 20 generations, foxes from this lineage actively sought contact with people, whined and wagged their tails. Like many dogs, some tame foxes had drooping ears and erect tails, features that were decidedly absent from the control fox population in this study. (Adapted from Belyaev 1979.)

considers only the ratio of snout length to total skull length.

When I plotted width-to-total-skulllength proportions, I saw some interesting differences. Adult dogs are distinct in these dimensions from all the adult wild canids. But adult dogs do resemble one wild canid group: juvenile wolves. Of all wild canid species, including adult wolves, the shape of adult dog crania most closely resembles that of juvenile wolves. The issue is not closed, but these data do support the hypothesis that dogs represent a paedomorphic form of their wolf ancestors. If that is true, it is possible that the dogs evolved as the evolutionary model would predict. Developmental changes in these animals might have come about as a response to selection pressures in a new niche, and these changes ultimately gave rise to a paedomorphic form of the ancestral species.

Behavioral Paedomorphosis

Many adult dogs not only appear juvenile, they also act juvenile. They display a sort of behavioral paedomorphosis. Dogs routinely solicit attention, play, grovel, whine, bark profusely and otherwise exhibit behavior that wolves more or less outgrow as they mature. Biologist Raymond Coppinger and linguist Mark Feinstein describe dogs as "stuck in adolescence." They also make the important point that the essence of tameness is the submissive, solicitous behavior style of juveniles. This leads to the question of whether physiological and behavioral paedomorphosis are interrelated.

Experiments directed by Russian geneticist D. K. Belvaev cause one to suspect that the answer is yes. Belyaev's group implemented a strict selective breeding program with silver foxes from a commercial fur farm. Their work sprung from the observation that although a majority of captive foxes were aggressive or fearful around people, a small number, about 10 percent, were less so. More than 30 years ago Belyaev began selectively breeding these calmer individuals only with other such individuals, through successive generations. Selection was for what Belyaev described as domesticated behavior.

The results after only about 20 generations were fascinating. Many foxes in the selected population now actively sought contact with people. The foxes would lick people's hands and faces, whine and wag their tails. Whereas

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Figure 10. Different geographic subspecies of wolves may have given rise to different dog-breed groups. This model shows one interpretation of the ancestry of modern dog breeds. Modern dog breeds are the result of at least 2,000 years of breeding under human control, and no breed is derived solely from one geographic origin. Ultimately, DNA studies may help assess the accuracy of models like this one. The images do not depict the true size relations between breeds. (Adapted from Clutton-Brock and Jewell 1993.)

wild foxes, like wild wolves, breed only once each year, females in the selected population began a shift towards more frequent receptivity, with some later-generation females capable of breeding twice each year. Domestic dogs regularly breed more than once each year. Other changes in the selected population included a much longer moulting time, drooping ears and erect tails. These remarkably dog-like changes were absent in the unselected

fox population and are absent in wild wolves as well.

The experiments do not replicate, even roughly, the conditions of early domestication, but they show how strongly behavior is linked to physiology. Strict selection for certain behavioral traits can disrupt previously stable patterns of physiological development. Oddities of domestication, such as erect tails and drooping ears, make more sense in light of this work. Scientists are still far from understanding precisely how different factors combined to produce the changed animal whose bones begin to turn up in late Pleistocene archaeological sites. Several important factors, however, at least seem to point in the same direction. Whether focusing on social behavior, diet or reproductive tactics, one should find that the evolution of a smaller, paedomorphic canid during domestication presents no surprise.



Figure 11. Canid domestication was undoubtedly helped along by the ability of the animals to form strong social attachments to people. For many modern dogs, social bonding is vital to their individual well-being. This scene, familiar to dog enthusiasts, emphasizes that bonding is a two-way street.

For a long time, early domestic dogs were consistently smaller compared with wolves. In contrast, modern dogs include breeds, such as the Great Dane, that are as large as or even larger than wolves. Given the context of domestication, only one set of circumstances is likely to account for large dogs or can account for the size range of modern breeds. That set of circumstances is selective breeding under human control.

It is important to stress that a domestic relationship does not mean that natural selection has become something other than natural. It is not a process that distinguishes human factors from others in the environment. Natural selection is simply the statistical summation of the reproductive fates of organisms that use their physical and behavioral equipment to compete for genetic representation in the next generation. Dogs are no exception. Tameness and other traits were the currency of competition from the onset of the domestic relationship, regardless of whether people had goals for the animals or were even aware of what changes were unfolding.

Beyond Dogs

A couple of years ago, a colleague commented that I was fortunate to have chosen dogs as my subject, because my perspective would not hold up for other cases of domestication. Naturally, I asked why not. He answered that dogs were first, but after that, the idea of domestication was in place. People then had a model, one they could apply to animals of considerably greater economic importance, for example goats or cattle. The domestication of such animals, my colleague argued, would best be understood as the product of people's purposeful efforts to achieve that goal.

Applying the same logic to Belyaev's experiments, we might just as well explain the evolution of modified, tame foxes as a consequence of Belyaev setting out to accomplish that. Such an explanation is not scientifically meaningful. The mechanistic explanation begins with the observation that foxes with certain heritable traits mated only with foxes bearing similar traits through successive generations.

The issue is not whether prehistoric people engaged in behavior that led to the domestication of goats or cattle. They certainly must have. The issue lies with the presumption that the eventual result-highly modified animals under conscious human subjugation—explains the process that started those animals toward that end. Figuring out what prehistoric people actually did that contributed to the evolution of domestic organisms is hard enough. To presume their purposes, and then proffer that as part of an explanation for evolutionary change, is to flirt with mysticism.

To be fair, my colleague's argument reflects a broader tendency for scholars to treat dogs as a special case because they are not perceived as economically important and therefore provided no compelling reason for people to have sought to domesticate them. Many societies, however, have made regular use of dogs as dietary fare. In addition, dog skins have served as clothing, and bones as raw material for tools, and the living animals have often been used as beasts of burden or as hunting aids.

Ultimately, the present exercise is only a minor part of the much larger issue of how to fit human cultural evolution into a scientific framework. Human culture, not being genetically determined, is widely assumed to supersede the Darwinian processes that explain how other organisms evolve. By extension, domestication is also frequently exempted from Darwinian models of evolution for the simple reason that it arises in a human sociocultural context. In a field hungry for genuine theory, however, anthropologists and archaeologists are currently debating the applicability of Darwinian theory to sociocultural evolution. Biologists should be keenly interested in this debate, for in the exclusion of cultural evolution from the Darwinian model makes it irrelevant to a good portion of life on this planet.

More than a decade ago, archeologist R. C. Dunnell suggested that if archaeology should achieve its widely professed goal of becoming scientific, few people would be pleased with the result. For one thing, there theories about cultural evolution would not be grounded in human intention. Even if we could document people's goals and intentions, they are phenomena to be explained, not explanations in themselves. Consider how difficult it is to take even the seemingly small step of bringing domestic organisms under the Darwinian umbrella. We are a long way from knowing whether Dunnell is right.

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Three of the guys in processing volunteered to help with my sequencing lecture.