# Artificial Selection: How Humans Have Shaped Evolution

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### 20 March 2024

All living things are governed by the rules of evolution. Since the beginnings of life on Earth, the principle of natural selection has driven the origin and diversification of all species, based on three key principles:

1. organisms produce more offspring on average than their environment can sustain
2. Genetic variation means that those offspring are not exact copies of their parent
3. Therefore the ‘fittest’ offspring survive and reproduce.

This process though, is not restricted to natural evolution. Indeed, any process, natural or otherwise, that exerts a selective pressure on organisms can drive evolutionary change.  Nowhere is that better evidenced than in the enormous impact that humans have had on other species during the brief period of our existence on this planet. As we have spread around the globe, humans have shaped the evolutionary trajectory of other species ranging from invisible bacteria to enormous trees.

## Agricultural Evolution

Sometimes that shaping process has been deliberate, something that is particularly evident in species that we rely on to improve our own survival. We see this most dramatically in the crops that we have domesticated in the 10,000 or so years during which humans have been farmers. Prior to the agricultural revolution, humans are likely to have collected and consumed seeds from a wide variety of plants.  But as we transitioned to a sedentary lifestyle, we inadvertently selected for specific traits in the crops that we domesticated.  For instance, if we look at the ancestral relatives of wheat, then we can see a rapid increase in grain size in the period immediately following the origins of agriculture. Such a process is easy to explain. Humans are likely to have collected larger seeds wherever possible from the wild and therefore when such seed was scattered, either deliberately or inadvertently, when they returned to villages then the wheat that ended up growing around these settlements would be more likely to carry genetic variants contributing to larger grain size, therefore driving the evolution of ever larger grains in these early domesticated lineages.

We see a similar change in the morphology of seed heads. The purpose of seeds, of course, is to create new plants. Consequently, seeds are designed for dispersal and most plants either actively or passively aid this process - for example via a trait known as ‘shattering’, in which seeds are released from the seedhead and blown by the wind.  However, shattering is a disadvantageous trait to farmers, especially if one gathers the grain by cutting the whole wheat plant - there is no benefit in bringing back sheafs of wheat from which all of the seed has fallen. Fortunately for early farmers, there are a number of mutations that disrupt the process of shattering and thereby produce a plant that retains seed within the seat head. Such mutations would be extremely deleterious in the wild, since seed dispersal would be strongly inhibited. But since the loss of shattering dramatically increases grain yield during farming, we see in the archaeological record a rapid increase in non-shattering types of grain in the early years of the agricultural revolution. Interestingly exactly the same evolutionary process is visible in a totally different crop species - rice - and in a very different part of the world - Far East Asia rather the fertile Crescent of the Middle East. This human-imposed selective process for non-shattering traits is therefore a remarkable example of parallel artificial selection occurring in multiple species.

## Shaping Man’s Best Friend

Human imposed selection is evident in almost all of the crops that we consume today. Similarly, humans have shaped the evolutionary trajectory of the many animal species that we rely on for food, often in ways that are diametrically opposed to ‘natural’ selection. For instance, domesticated chickens lay eggs that will never become new chickens, whilst dairy cattle produce far more milk than their calf requires, and indeed have been deliberately selected to lose many of their maternal instincts, enabling those calves to be separated from their mothers immediately after birth.

But the impact of human selection reaches far beyond the species that we eat. Many of us share our homes with one of the best examples of the power of artificial selection: the domestic dog. Based on genetic data, it appears that humans began to domesticate European wolf puppies between 30,000 and 50,000 years ago. However, for the vast majority of the time since then, the domestic dog remained very similar in appearance to its wolf ancestor.

The first reliable accounts of what we might recognise as different breeds of dog come from around the time of the Roman Empire. Even then, most dogs belonged to one of only a handful of breed types. It is only in the last few centuries that the hundreds of modern dog breeds have come into existence. This extraordinary rate of evolution has, of course, being driven by an incredibly intense process of selection. As a result, domestic dogs represent a unique resource for our understanding of evolutionary genetics. By sequencing the genomes of different dog breeds and mapping them against physiological traits, such as size or shape, or against behavioural traits, such as aggression for intelligence, we have been able to learn much about the genetic control of these features. In some cases, by studying these canine traits we have also been able to learn about genetic influences on human health – for instance, in metabolism or, more controversially, in mental health.

## Accidental Selection

The profound impact of human selection on crops, livestock and domestic pets has, for the most part, being a deliberate process. But there are many other species whose evolution has been fundamentally shaped by humans entirely inadvertently. An obvious example are the very many species that have been driven to extinction by humans. Their genes have now been lost forever from the global gene pool and instead other species have occupied the ecological niche that they vacated.

More directly, however, human-driven processes have shaped genetic change in many of the species that exist alongside us. In the 1950s the discovery of warfarin, a drug that inhibits blood clotting, created a new generation of rodent poisons. Warfarin acts by binding to, and inhibiting, an enzyme that is critical for the blood clotting process. Consequently, small mutations that change the shape of the enzyme can block warfarin binding, rendering the enzyme insensitive to inhibition. The enthusiastic adoption of warfarin for pest control produced a huge selective pressure on the urban rodent population and so it should have come as no surprise when warfarin-resistant rats started to appear in the 1960s, followed by warfarin-resistant mice a few years later.

Today, of course, one of the most well-known and potentially catastrophic examples of such inadvertent selection is that of antimicrobial resistance. Even as the first set of antibiotics were being developed in the early part of the 20th century, scientists were warning that their widespread use would impose an evolutionary pressure that was likely to select for resistant pathogens. Such a scenario has, of course, proven only too true. Over the course of the 20th century, almost every major new class of antibiotic that was introduced to the market was followed, a few years later, by reports of bacteria that had evolved resistance to it. As a result, clinicians started to move away from monotherapy to more complex multi-drug therapies. But such approaches only reduce, rather than eliminate, the probability of resistant mutations occurring and it was only a matter of time before laboratories started identifying bacterial strains that were resistant to two, three or even more frontline antibiotics; so-called ‘multidrug resistant’, or MDR, strains. Now that the world has woken up to the threat that such pathogens pose, there is renewed interest in developing antimicrobial approaches that may be less vulnerable to rapid evolution of resistance.

## Selecting Ourselves

The impact of ‘artificial selection’ by humans on other species is evident all around us. Far less obvious, but arguable no less influential, has been the effect we have had upon our own evolutionary trajectory.

In animals, one of the most potent forces for ‘within species’ evolution is sexual selection. Individuals compete for mating opportunities with one sex, often the female, ‘choosing’ mates which display positive fitness characteristics. Such characteristics can either be directly beneficial (e.g. strength, in the case of competing red deer stags) or ‘proxy’ measures of fitness (such as the peacock’s tail - a so-called ‘handicap’ trait).

Attempts to identify similar sexually-selected traits in humans have had very limited success, perhaps because we lack the overt breeding season or courtship rituals of other mammals. But one trait that has been proposed to be under sexual selection is breast size. Female humans are unique amongst the primates in having prominent breasts. Previous work has shown that breast size does not correlate with any meaningful direct fitness benefit, such as lactation or milk quality. However, there is some evidence that breast size and, in particular, symmetry is a so-called ‘honest signal’ of fecundity. In other words, larger breasts in proportion to body size may have evolved in humans as a way of individuals signalling their own fitness status in the same way that plumage colouration signals fitness in many birds.

## Engineering Selection

For around 3.5 billion years, evolution has been quietly (or sometimes not-so-quietly) shaping the form and function of life on Earth. As far as we know, though, humans are the only species to have realised this and therefore the only species with the ability to deliberately manipulate evolutionary trajectories. Until very recently, the only tools available to achieve this were the same ones that occur naturally – elimination of individuals with ‘undesirable traits’ and successful reproduction of those with favourable phenotypes. But the genetic revolution has transformed this process and opened up powerful new ways to influence evolution. Now, it is possible for prospective parents to test themselves and their embryos for inherited genetic diseases. In some cases, this has started to remove particular genetic variants from populations at a rate far faster than natural selection can achieve, creating huge health benefits for the individuals but also reshaping population genetics in a highly targeted way.

And now we stand on the cusp of a revolution that is likely to not just accelerate evolution, but in some senses to actively reverse it. By applying genetic technologies such as CRISPR, it is possible to ‘edit’ the genetic code, correcting damaged genes back to their functional form or potentially even introducing new traits. And whilst international law currently forbids doing this in a way that would create heritable changes in humans, the first ‘genome edited’ individuals have already been born – an event that landed its architect in jail, but has nonetheless broken new ground in terms of the evolution of our species. Only time will tell how influential such attempts at ‘evolutionary engineering’ will be for the future of our species…

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