Selective Breeding: Unraveling the Methods, Motivations, and Implications

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Selective breeding, also known as artificial selection, allows for the passing on of traits deemed desirable by breeders to subsequent generations. Without human interference, populations of plants, animals, and other living organisms reproduce under natural selection where the environment determines which traits are passed down.

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From the juicy kernels on an ear of corn to the floppy ears of the basset hound, plants and animals today look very different from their wild counterparts. This is due to selective breeding, by which humans have altered thousands of plant species and about [40 animal species] from their original form over multiple generations. Humans can increase the frequency of desirable traits in future generations of a population by only allowing individuals with those traits to reproduce.

In the pursuit of more efficient or aesthetically pleasing plants and animals, selective breeding has developed over time, integrating with new technology and evolving demands. Selective breeding has resulted in sweeter fruits, plumper chickens, and fluffier puppies, utilizing a broad range of practices and yielding varying outcomes for its subjects.

What is Selective Breeding and How Does it Work?

Selective breeding, also known as artificial selection, allows for the passing on of traits deemed desirable by breeders to subsequent generations. Without human interference, populations of plants, animals, and other living organisms reproduce under natural selection where the environment determines which traits are passed down.

Through natural selection, individuals who are well-suited to their environment are more likely to survive and reproduce, leading to offspring that share those well-suited traits. Those who are less suited to the environment are more likely to die before reproducing. This results in the next generation having a higher proportion of individuals with traits suited to the environment compared to their parents' generation. This cycle repeats over and over through changing environments, resulting in the diversity of life seen today.

Selective breeding uses a similar mechanism of passing on traits, but rather than the environment determining which individuals are "well-suited," breeders decide. Breeders identify individuals with desired traits and have them reproduce with each other while preventing those without the trait from reproducing. This process yields changes in a population faster than natural selection by greatly reducing the chance that an organism with a desired trait fails to reproduce or the chance one without the trait successfully reproduces. Artificial selection allows humans to dramatically change the appearance, behavior, and health of organisms in just a few generations.

Are Selectively Bred Plants and Animals GMOs?

While selective breeding and genetic modification share some similarities, selectively bred organisms are not GMOs. All organisms are made of a genetic code that determines their traits. Genetically modified organisms refer to individuals who have had their genetic code altered through genetic engineeringwith tools such as CRISPR. Like selective breeding, genetic modification can result in the expression of desirable traits decided by humans. However, while genetic modification relies on direct manipulation of genetic code, selective breeding uses an organism's existing reproductive mechanism. Another difference between the two processes is that genetic modification can introduce new traits into an organism, including traits from other species, while selective breeding can only increase the frequency of an existing trait.

Why is Selective Breeding Done?

The most common application of selective breeding is for agriculture. Plants have been selectively bred to produce larger fruits, have increased resistance to pests and harsh weather, and taste better to consumers. Similarly, animals raised for food have been selectively bred to be heavier or to produce more eggs or milk. Selective breeding has resulted in corn yields increasing from 40 bushels per acre to 150 bushels per acre in the last hundred years, and modern hens laying 300 eggs per year, compared to the wild jungle fowl they were bred from who lay about 10-15 per year.

Selective breeding, and other forms of genetic modification, can also be used for conservation purposes. Endangered species can be bred to increase their population size and to make them better adapted to their shifting environment. One example of selective breeding for conservation was when scientists propagated coral reef colonies that were known to be resistant to temperature fluctuations, resulting in heat-tolerant coral.

Humans have also selectively bred animals for aesthetic or sporting purposes. Selective breeding has led to smaller dogs, furrier cats, and faster horses that humans enjoy for companionship or entertainment.

While all dogs and cats are selectively bred to some extent, many people seek out companion animals that have been meticulously bred to fit the specific criteria of a particular breed.

Selective Breeding Methods

Artificial selection can be accomplished by selecting desired individuals to breed or by preventing undesired individuals from breeding. When practicing selective breeding, breeders must decide if they want to use inbreeding, linebreeding, or crossbreeding to balance efficiency with health outcomes.

Inbreeding

Two individuals who share the same desirable traits are more likely to be related than others. This results in many instances of selective breeding considered inbreeding. While definitions of inbreeding vary between breeders, many people who breed cows consider inbreeding to be mating between parents and offspring, between siblings, or between cousins. Inbreeding can be risky as it increases the likelihood of genetic diseases and also limits the gene pool. Diverse gene pools are important for populations because different genes increase the likelihood that at least some individuals will survive in difficult or changing environments.

Linebreeding

Due to the risks of close inbreeding, many breeders engage in a selective breeding method called linebreeding. Through linebreeding, breeders take calculated risks to maximize offspring with desired traits while minimizing the adverse effects of inbreeding. The differentiation between inbreeding and linebreeding is not formally defined and one of the most popular forms of linebreeding in cows raised for meat is between a half-brother and half-sister.

Crossbreeding

The opposite of inbreeding is crossbreeding. Also known as outbreeding, this method involves mating two unrelated individuals, but can still be a form of selective breeding. Crossbreeding is a form of inbreeding avoidance that is also seen in some animals in the wild. For example, rats have the ability to detect their relatives based on the smell of their urine and avoid mating with them, decreasing their risk for genetic diseases.

Culling

While selective breeding is often thought of as a way to maximize desirable traits, it is also used to eliminate undesirable traits. This process is called culling, and it can take many forms. Breeders can remove individuals from the population physically by selling them or killing them. They can also cull a population by spaying or neutering individuals deemed unfit to reproduce. Some examples of animals that would be culled include goats raised for dairy whose udders sag, pigs that cannot gain enough weight, and dogs considered too aggressive.

Examples of Selective Breeding

Dogs

Humans have been practicing artificial selection in animals for about 9,000 years, with dogs being among the first to be selectively bred. Compared to their ancestors (gray wolves), modern dogs are more trusting of humans, more omnivorous, smaller, and more physically diverse due to selective breeding. Today, dogs have been linebred into 360 different breeds as recognized by the World Canine Organization with varying traits. While many of these traits are beneficial to both dogs and humans such as adaptations to a cold climate or swimming, others have negative consequences on the dogs' health.

Some breeds that have been artificially selected for flat faces, like pugs and French bulldogs, experience lifelong breathing problems and are more at risk of eye injuries. Other selectively bred traits that have led to negative health outcomes in dogs include floppy ears leading to infection, large heads leading to difficulties giving birth, and long backs leading to spinal deformities.

Other Companion Animals

Like dogs, other companion animals like cats, horses, rabbits, rodents, birds, reptiles, and fish have been selectively bred to be better suited for domestication and human aesthetic preferences. These animals are often bred to have variations in color and pattern or to excel at specific tasks or sports. Similarly to complications seen in dogs, selective breeding in some breeds of cats and rabbits with long fur has led to increased rates of matting and skin infections, and selective breeding for stockier horses has led to bone issues. Today, breeders of companion animals have been making strides to prevent negative health outcomes in artificially selected animals, such as avoiding inbreeding and genetic testing.

Farmed Animals

In 2014, Vox News published a popular article called, "Chickens have gotten ridiculously large since the 1950s," accompanied by an image comparing a slim chicken from 1957 and one four times as heavy from 2005. This change has been accomplished not only by feeding the chickens more, but through selective breeding. One of the most sought-after traits by chicken breeders is their "breast conversion rate," or the ratio of how much breast tissue the chicken can grow compared to how much he or she eats. Breeders also value how fast the chickens can put on weight, with slaughter dates decreasing from 112 days to 47in the last century.

Different lines of chickens are bred depending on whether the animal's meat or her eggs are being sold. Hens who are selectively bred to lay eggs almost always fail to meet industry standards for meat, due to the two types of chickens belonging to different lines. Therefore, when hens are no longer able to lay eggs, their bodies are sent to landfills or processed into other products. Similarly, when dairy cows can no longer produce industry-standard quantities of milk, their bodies can only be used for ground beef or other processed meat because of their inferior quality to consumers.

Due to an increase in demand for pork, selective breeding in China has led to a new line of pigs that can weigh over 1000 pounds or 454 kgs. In addition to growing large fast, female pigs are also bred to have as many offspring as possible. Since traits related to fertility are hard to pass down, scientists have used computer-based tools such as "best linear unbiased prediction" to increase litter sizes.

The Disadvantages of Selective Breeding

Selective breeding has astronomically increased agricultural productivity, allowing billions of people to be reliably fed, but it has not been without consequences. Artificial selection has resulted in hundreds of billions of animals in farms around the world living with complications from inbreeding and selection that neglects their health in favor of maximizing their bodies' capacity to produce commodities.

One negative outcome of selective breeding that utilizes inbreeding is an increased risk of recessive genetic diseases. Animals receive genes from both their parents that result in different traits. If an organism inherits a recessive gene from both of their parents, they will display a recessive trait, such as a genetic disease. When closely related individuals are bred, there is a higher chance that both parents will have the same recessive genes and pass them down to their offspring, resulting in recessive traits. Recessive traits are often harmful to the animal, with examples of recessive diseases in beef cattleincluding osteopetrosis and dwarfism, which are more common in inbred animals.

Even in animals who have not been inbred, selective breeding for production can lead to inherent health consequences. For example, chickens who have been bred to lay hundreds of eggs a year have higher rates of bone fractures and brittleness because the egg shells require calcium to produce that is leached from their bones. Likewise, animals that are extremely efficient at converting food into muscle and fat are susceptible to heart failure due to increased physical pressure on their internal organs.

Another oversight of selective breeding that has drawn attention from breeders is lower rates of fertility in highly specialized lines. In nature, living beings evolved to make trade-offs between growth, maintenance, and reproduction, with increased energy in any of the three leading to a decrease in the other two. This balance is why animals that grow large like elephants or humans typically have long development periods with fewer offspring, compared to smaller animals like insects reaching reproductive age quickly and having hundreds or thousands of offspring. Thus, the hyperfocus on breeding animals that can grow rapidly has resulted in lower fertility rates in dairy cows, pigs, and other animals.

Throughout the process of selective breeding, human breeders control which animals can and cannot breed, often through physical means. When pigs are deemed uneconomical, the most common culling methods include blunt-force trauma delivered by a human or machine, electrocution, or carbon dioxide gas chambers. While many companion animals are culled through sterilization under general anesthesia, this option is not used on farmed animals due to economic inviability.

For animals who have been deemed fit for breeding, many reproduce through artificial insemination. Artificial insemination refers to collecting sperm from male animals and manually impregnating female animals using human hands or mechanical tools. While artificial insemination was initially developed to prevent sexually transmitted diseases, today its primary function is to ensure effective selective breeding since the ejaculate of the chosen breeding male can be divided and used to inseminate multiple breeding females. This allows for just 1% of bulls with highly desirable traits to father an entire generation of cattle. However, if the father has genetic diseases, hundreds of calves can become afflicted.

Selective Breeding Facts

- Humans have been selectively breeding plants and animals for about 10,000 years
- There are 53 breeds of chickens used for meat, egg production, and sport
- Selective breeding was one of the practices that Charles Darwin studied to develop his theory of natural selection

- Due to selective breeding, milk production in dairy cows has quadrupled in a century
- Modern breeders use a blend of traditional breeding and genetic modification tools
- Fish, such as rainbow trout, have been selectively bred for color for sport fishing
- Efficient selective breeding requires the mass culling of unfit individuals through slaughter or sterilization, with the former being more economical in animal agriculture
- Selective breeding can lead increased disease susceptibility in plants and animals due to smaller gene pools and lack of selective pressure

Conclusion

Due to high demand for rapidly maturing livestock and designer pets, breeders are empowered to meet consumer demands with artificial selection. However, in this process, those selectively bred for such traits frequently suffer from health issues, such as brittle bones and reduced reproductive abilities. These pitfalls of conventional selective breeding have gained the attention of not only those concerned with animal welfare, but also those who breed, raise, and sell selectively bred animals. Breeders are increasingly turning to genetic modification tools and other technologies to reap the benefits of selective breeding while minimizing the need to cull sick or inefficient animals. Still others are utilizing selective breeding to increase welfare, such as crossbreeding in pugs to improve their breathing. Both the rise of genetic engineering technologies and growing concern for the well-being of highly selected animals call into question the continued existence of selective breeding. Does the process, with its shortcomings, still have a place in modern agriculture and other industries? Can selective breeding be reformed to take into consideration the needs of the animals, rather than solely the preferences of consumers? As long as humans desire specific traits in others, ranging from taste to personality, these questions will drive the future of selective breeding and evolving methods of genetic manipulation.

Parker Do is a senior at the University of California Los Angeles studying human biology and society with a minor in anthropology. They are a seasoned organizer, having hosted animal welfare demonstrations across Los Angeles and coordinated a 2300 attendee academic conference with a plant-based default, BruinMUN 31.