The End of Darwinism:

How Humans Are Overriding Evolution

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Abstract

The natural selection theory of Charles Darwin is based upon a few concepts: Species naturally reproduce in overabundance, with genetic variation and mutations that are generally harmful, but sometimes beneficial. The more adaptable offspring have higher survival rates than the less adaptable offspring, so that the minority of surviving populations genetically evolve to be better adapted to their (often changing) environments across generations.

Human technology has often overridden these basic premises. Humans themselves today have almost a 100% survival to reproductive age. Domesticated animals and plants are artificially bred, with targeted survival rates, helped along by agricultural methods that include feeding and protection of animals, with herbicides and pesticides to protect crops, etc. Wild animal and plant populations are encroached by these developments. Since genetic evolution is usually a slow process, wild species are unable to adapt to the human caused rapidly changing environment with loss of habitat, climate change, pollution, etc. Thus, the Darwinian process breaks down, especially for domesticated animals and plants, for wild animals, and to some extent for wild plants. Although humans may still naturally reproduce, we too are no longer genetically evolving to better adapt, but instead are much more quickly adapting through technology and culture, e.g. by dramatically lowering fertility rates to offset surging population.

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Introduction

In 1859, Charles Darwin published one of the greatest scientific works of all time, *On the Origin of Species*, which posited a theory of evolution that came to be known as Darwinism. The theory starts with reproduction by natural selection, with offspring inheriting genetic variations along with occasional mutations, with only a minority of the offspring surviving to reproduce themselves. The offspring that are better adapted to their environment have higher survival rates than the less adaptable offspring. In this way, species continually evolve in ways to better adapt to their changing environment. Genetic evolution is a slow process, especially for species that have a substantial time span from birth to reproduction. However, over many millennia, dramatic changes in species can and do take place.

We see the results of evolution all around us. Our Earth was formed about 4.5 billion years ago, with first life estimated to start about 3.5 billion years ago. Life started with single celled species, evolved into multi-celled creatures, and eventually into the vertebrates of fishes and insects, then into amphibians, reptiles, and winged insects. The first animals lived about 600 million years ago, while the first mammals and dinosaurs appeared about 250 million years ago. Then birds evolved from dinosaurs and mammals evolved into many species including hominines which eventually evolved into humans.

Although humans have only been in their current form for about 250,000 years, we are the species that have come to dominate our planet. Humans dominate not so much from a biomass perspective, but rather from their huge impact on so many of the other species on the planet. And humans are a remarkable species themselves, as we are the only species that can easily accumulate knowledge across generations, recording their own history as well as coming to scientifically understand the history of the origins of the Earth, our solar system, and the universe. Humans, in fact, have been able to land on the moon and with their spacecraft visit other planets in the outer reaches of our solar system. In addition, humans through their telescopes and various detection devices have been able to observe other galaxies, planets, and look back through time.

Of course, Charles Darwin was a human, and his theories of evolution have helped us to understand how the multitude of species on Earth have evolved. However, we will argue in this essay that humans have come to so dominate the planet that we have affected the theory of "Darwinism" itself, by impacting natural selection and the statistical survival rates of the species

that enabled them to adapt. Thus, humans have come to override the workings of Darwinism. Humans have domesticated a wide variety of animals and plants, eliminating natural selection with their own selective breeding and genetic coding techniques. Humans also altered the survival rates of the various species offspring, seeds, etc., by providing protection for the domesticated species, while using pesticides, herbicides, and hunting to control weeds, insects, and other "nuisance" species. Perhaps our biggest impact on other species is by dramatically changing their habitat through agriculture, pollution, climate change, etc.

Rather surprisingly, humans are also impacting our own evolution. Although our selection of sexual partners is still mostly natural, what has dramatically changed over time is the survival rate of our offspring. In antiquity, and until rather recently, the typical woman birthed about seven children over her lifetime. Of these, only about two or three survived to adulthood. This was not surprising, for it is a standard part of Darwinism. Statistically, the more adaptable members of a species tend to survive, allowing the species to continually adapt better and better to their changing environment. However, in today's world, over 95% of human offspring survive to an age in which they are capable of their own reproduction. Thus, we have reached an inflection point, in that we are no longer genetically adapting across generations. Nonetheless, humans are adapting. We are adapting through our own accumulated knowledge, with science, technology, economics, social development, etc. In fact, humans are replacing genetic evolution with a scientific, industrial, and digital evolution, in which humans come to evermore not only adapt ourselves, but are changing the ways that the world's species evolve. Thus, we are ending Darwinism, and replacing it with our own "creative design." However, this design is not coming from some higher power, but rather from ourselves.

We start with the description of Darwinism and what it is, with the concepts of natural selection, slow evolution with variation and mutations, and statistical survival rates. Through an economic lens, we organize this into inputs, process, and outputs. We can think of the Darwinian input, in which species naturally mate, divide, etc. to form the offspring of each new generation. The offspring are produced in overabundance. Each new generation encompasses genetic variation and mutations, which are on average harmful, but are sometimes beneficial. The process is the life of the offspring to its own reproduction. The key Darwinism assumption is that only a small minority of offspring survive. In particular, the more adaptable offspring are more likely to survive,

because they have higher statistical survival rates. The output is evolution itself, in which species better and better adapt across generations to their environments. Evolution is a slow process, especially for species with longer reproductive cycles. But across the many millennia, species change and adapt in dramatic ways, resulting in the wide variety of species that we see today.

Humans have done very well at genetically adapting, developing large brains, very mobile legs and feet, dexterous hands, a wide-ranging diet, tremendous stamina, and long lives. But, as we shall see, humans are no longer genetically adapting in any Darwinian sense. Rather, we are adapting by technology, with our accumulated knowledge base, communication and social skills, and the building of infrastructure which is dramatically changing the planet. One of the most important ways that we are adapting is by lowering our fertility rates. Humans are also more and more dominating the other species on the Earth. Humans have not only discovered how Darwinism works, but they have also learned how to override the Darwinian process, both intentionally and unintentionally.

Perhaps, the most dramatic way that humans have dominated other species is through domestication. Humans have domesticated animals both in agriculture and as pets. We have created artificial species through selective breeding for centuries. Few domesticated species could survive on their own. Instead, we have protected and nurtured the members that we wish to survive, mostly to serve our own purposes. Similarly with plants, we have created hybrids and other artificial selection methods, both for consumption and pleasure, while protecting them with herbicides, pesticides, plowing, and pruning. We have developed a symbiotic relationship with these plants and animals. One example familiar to all of us is lawn grass, which dominates our urban and suburban environments.

Wild animals and plants have been heavily impacted by rapid environmental changes and loss of habitat. Many of the species have not been able to adapt quickly enough to their new circumstances. Evolution is usually a slow process, especially for longer lived species with long evolutionary cycles. Mass extinctions are taking place, often with imported (by humans) invasive species taking over increasing shares of both the land and the ocean. Insect populations are falling dramatically, the Earth is becoming deforested, and the oceans are becoming polluted. The Earth's temperature is rising while the climate is becoming more volatile, and scientists generally agree

that humans are the cause. Natural selection for animals and plants is ongoing, but it is too slow a process to allow many species to adapt to their rapidly changing environments.

Although humans have changed the planet in so many easily observable ways, we have not yet heavily impacted the overall biomass of the Earth. For example, humans have not much impacted the deep subsurface, and it contains far more biomass than the polluted marine life does, even though the oceans cover more than 70 % of the Earth's surface. The animals with the highest collective biomass are arthropods (insects, etc.), fish, annelids (worms, etc.), and mollusks (snails, etc.). But animals make up only a small portion of the Earth's biomass, which is dominated by plants, the overwhelming proportion of which are still wild. Bacteria and fungi also make up a larger portion than animals.

Thus, in this essay, we will describe the major tenets of Darwinism and show how humans manage domesticated animals and plants, including how we influence our own genetics. We have also impacted wild animals and plants by rapidly changing their environment faster than they can adapt to it. We haven't changed everything yet, but we are on the way to ending Darwinism for the more developed species of the world.

Darwinism

Charles Darwin was very aware that humans had been practicing "artificial selection" in breeding domesticated species. In contrast, he popularized the term "natural selection" as the evolution that was the result of the random acts of nature, rather than an intentional result. Darwin recognized how controversial his concept of evolution was, because one implication was that humans evolved from a more primitive ancestor. This was the reason why he delayed for decades in publishing his theory. It was only after other contemporaries were about to publish, most notably Alfred Russel Wallace, that Charles Darwin rushed in 1859 to get his book *On the Origin of the Species* in print. His theory of evolution was both simple and elegant, since it rested on only a few plausible assumptions, most of which were directly observable. Although natural selection was based on heredity, the theory was developed before we understood genetics, but was nevertheless compatible with most new scientific developments.

Since we will look at Darwinism from an economic perspective, we classify the theory of evolution into inputs, process, and outputs. The primary input is that the breeding is natural. This

can take the form of sexual selection, cell division, or any of the other methods of reproduction. But in the Darwinian theory, the reproduction occurs naturally in nature, without artificial breeding by humans, or without the guiding hand of some higher deity. The breeding is typically self-selected. An important assumption is that most species engage in massive overproduction of offspring, although this is less true for the higher order animals, including humans. The offspring have considerable variation from the combined genome of the parents. In addition, mutations take place, which can result in dramatic changes from parents to offspring.

Darwin's process assumptions are the key part of the theory. The variations and mutations are on average harmful, but a few of them may be beneficial. Variations of the offspring are inherently harmful because they change a genome which in most cases was already well adapted to its environment. However, each species' parents overproduce a large number of offspring, with only a minority surviving to their own reproduction stage. And each offspring genome has a different statistical survival rate. Since the offspring with the more adaptable genomes have higher survival rates in a competitive environment, the population of each surviving generation tends to be more adaptive to its environment than its parents, despite the overall average being less adaptable. These small differences accumulate in the populations over multi-millenniums, as a wide variety of species adapt to their changing environments.

The output is evolution itself. We started with the most primitive one-celled forms of life, and we end up with a tremendous variety of plant, animal, and other forms of life. These include species that are able to survive and grow to huge populations on land, in the seas, within the Earth's subsurface, and even to some extent in the atmosphere. Darwinism proclaims that this variation and evolution takes place through random occurrences, rather than through "intelligent design." An important assumption of evolution is that life occurred over eons of time, allowing for very sophisticated adaptations. Thus, even elaborate innovations such as "the eye" can occur through intermediate stages, starting with light detection, reaction to impulses, connections to the central nervous system, ability to focus and observe depth perception, etc. In Darwinism, all species of organisms arise and develop from small, inherited variations that statistically increase each member's ability to survive, compete, and reproduce.

Darwin made it clear that humans were included in his theory of natural selection with *The Descent of Man*, published in 1871. Humans have evolved from earlier species i.e., various

hominids. The human population of the Earth has grown dramatically and has now surpassed 8 billion people, growing from about 1 billion people in 1800. As we will be discussing, humans have become so dominant that we are undermining the basic genetic premises of Darwinism for many species, including our own.

In Exhibit 1 below, we list the inputs, process, and outputs of the main species categories. These include humans, domesticated animals, domesticated plants, wild animals, and wild plants, along with other categories such as fungi, bacteria, viruses, and other single-celled organisms. We summarize the input that humans have had on overproduction, including birth control, selective breeding, manual pollination, etc. We then summarize the human impact on the process including a near 100% survival rate of human offspring as well as the polarized survival rates of desired domesticated animals and plants. Wild animals and plants are impacted by habitat destruction, pesticides, herbicides, climate change, etc. In terms of the output, humans are able to thrive and adapt technologically, instead of through genetic evolution. Domesticated animals and plants are designed to meet human needs and preferences. Meanwhile, wild animals and plants struggle to survive in the rapidly changing human impacted environment. It is only the "last" category that humans have not yet affected very much.

Exhibit 1: Reproduction, Life, and Evolution

	Input **reproduction activity, variation, overproduction**	**Process** **life to reproduction, competition, survival, adaptability**	**Output** **species evolution**
Humans	- birth control - global fertility: 2.3 - most developed countries below replacement fertility: 2.1	- near 100% survival rates - high child investment - technology: medicine, sanitation, education, cumulative learning	- inflection point with humans no longer genetically adapting -humans adapting through technology and cultural changes
Domesticated animals	- birth control - artificial insemination - selective breeding	- humans choose survival rates for domesticated species	- species evolve to meet human needs and preferences
Domesticated plants	- GMO and selected seeds - human determined location and proximity - homogeneity	- crops with high survival rates - weeds restricted	- industrialized agriculture produces abundant inexpensive food - agriculture less than 2% of US economy
Wild animals	- variety and proximity of mates may be limited	- pesticides, hunting, etc. - habitat destruction, pollution, plastics - geographic isolation	- evolution cannot keep up with human induced environmental change; especially for higher order species
Wild plants	- habitat destruction	- herbicides, degraded soil - invasive species - climate change	- relative proportions of species altered
Fungi, bacteria, viruses, single celled organisms	- frequent and efficient overproduction, especially for asexual reproducers	- humans have limited control of populations, e.g. bacteria and viruses	- species evolve mostly as they would without human interference - some species transported by humans across continents

Descriptions under Input, Process, and Output are authors' interpretations.

Humanity

We as humans are the highest order species on the planet, and we have thrived over the last several thousand years, especially over the last few hundred years. Most of us no longer wonder where our next meal is coming from, nor where we will shelter for the night. We supplanted other hominid species (e.g. the Neanderthals), started wearing clothes so we could survive in a variety of climates, learned to speak languages, migrated from a hunter-gatherer society to developing agriculture (over 10,000 years ago), and started moving into cities and towns where we invented writing (several thousand years ago). Various countries went through industrial revolutions over the last 200 years, dramatically raising the standards of living of our global population. In Exhibit 2 below, we summarize our view of the major ways that humans have adapted since the first humans appeared. Note that this adaptation is not inherited genetically, nor do we share these accomplishments with any other species.

Exhibit 2: Major Innovations and Cultural Adaptations

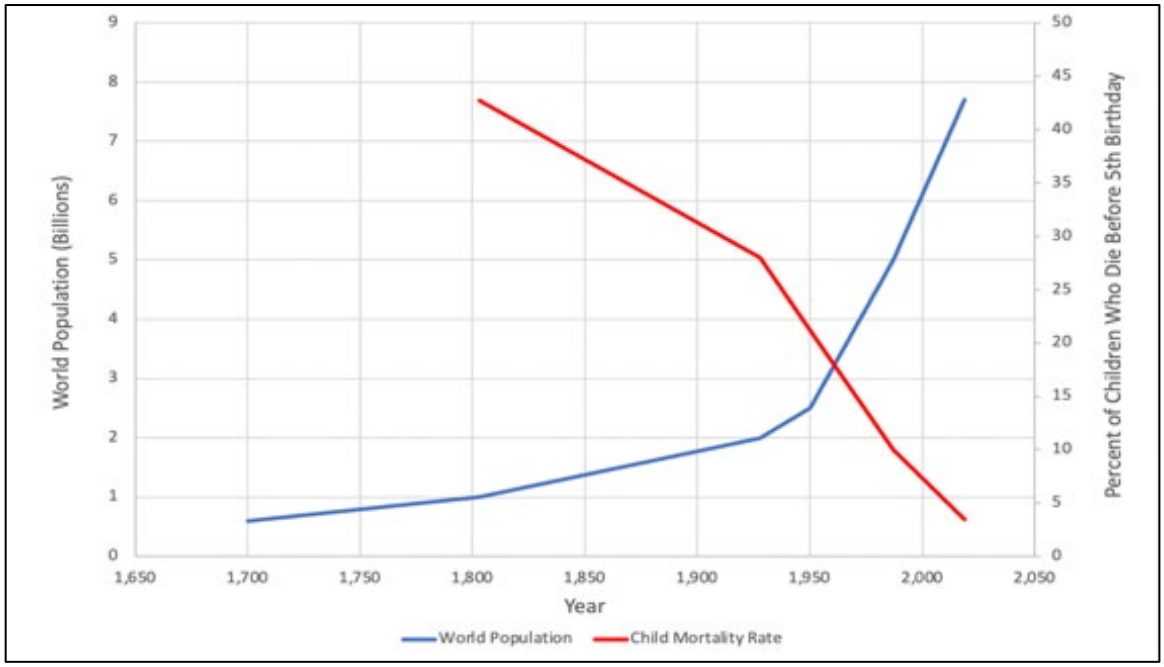
- About 250,000 years ago: first humans, subject to Malthusian trap
- Clothes, shelter, fire, cooking, language
- Transition from hunter-gatherer to agricultural food sufficiency
- Civilization, urbanization, warfare, religion, writing, education
- Economic development, trade, money, wealth creation
- Infrastructure, transportation, automation, computers, space exploration
- Public health, medical advances, child mortality drops, longevity
- Women's empowerment, choosing fertility, heavy investment per child

From an economic perspective, humans' numerous adaptations have been described by Joseph Schumpeter (1942) as "creative destruction." Each generation builds on the last generation by replacing older technology. This has some similarity to Darwinism, but it is no longer the survival of an evolving genome. Rather, it is technology that adapts, stranding less productive economic structures and systems.

Perhaps one of our greatest achievements is a reduction in child mortality rates. We can see by Exhibit 3 below that the percent of children that died before their fifth birthday had fallen from

about 43% in 1800 to about 2.5% today. In earlier times, more than half of children did not survive to age 5, and an even lower percentage did not survive to an age in which they were capable of reproduction. Our success at reducing infant and child mortality is the primary cause for increased longevity over the past two centuries.

Exhibit 3: World Population vs Child Mortality (1650-2050)



Max Roser (2013) - "Future Population Growth." Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/future-population-growth

Max Roser, Hannah Ritchie and Bernadeta Dadonaite (2013) – "Child and Infant Mortality." Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/child-mortality

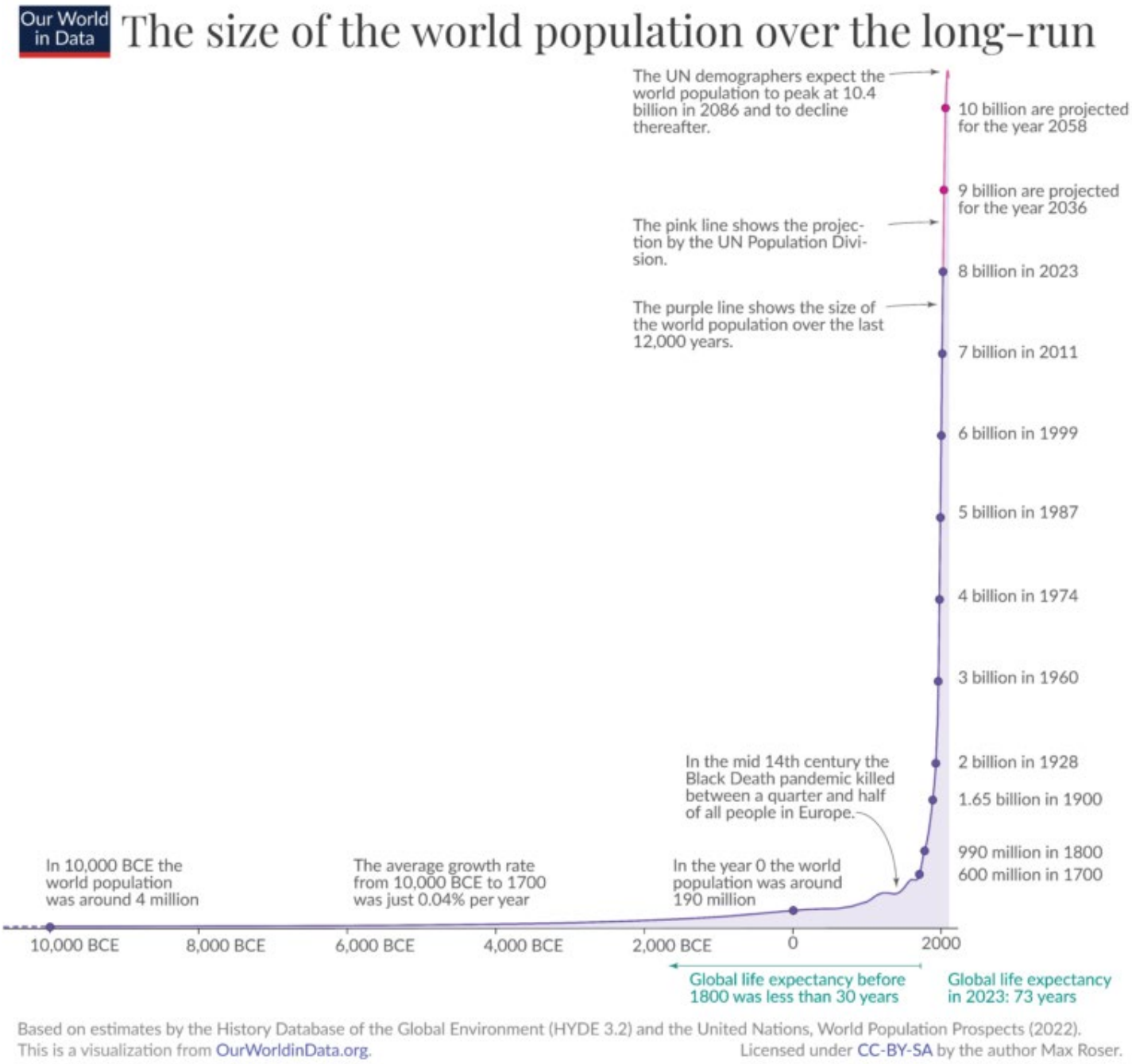
We have clearly benefitted from having our children survive. Nowadays, it is hard to imagine how painful it would be to lose most of our children before they reach adulthood. But, the low survival rates of offspring are a major tenet of Darwinism. These low survival rates have historically been applied to humans and still apply to most of the other species on the planet.

Darwinian evolution of generational adaptation is based upon the idea that the more adaptable members of a species have more offspring and/or that the more adaptable offspring have higher

survival rates. Neither of these tenets appear to be true for humanity today. In general, the less developed countries have the highest fertility rates, as do the poorest within each county. As we have seen, almost all offspring survive today. As child mortality rates began to drop, human fertility rates did not initially fall. This caused the world population to grow exponentially.

Exhibit 4 graphs the world population over the last 12,000 years. Here we can see the full impact of the drop in child mortality over a long time period. The graph is not logarithmic, in which the slope would illustrate the rate of growth. Rather, it plots the level of population, which at even a 1% yearly growth rate would double in about 70 years. (The Rule of 72 gives an approximation of the number of years to double by dividing 72 by the growth percentage). During the 20th century, the world's population grew even faster than 1% a year. As a result, the human population exploded! After first reaching 1 billion people in the early 1800s, we reached 2 billion in 1928, 3 billion in 1960, 4 billion in 1975 with the United Nations Population Division estimating that we reached 8 billion people in late 2022, and that we will peak out at 10.4 billion near the end of this century.

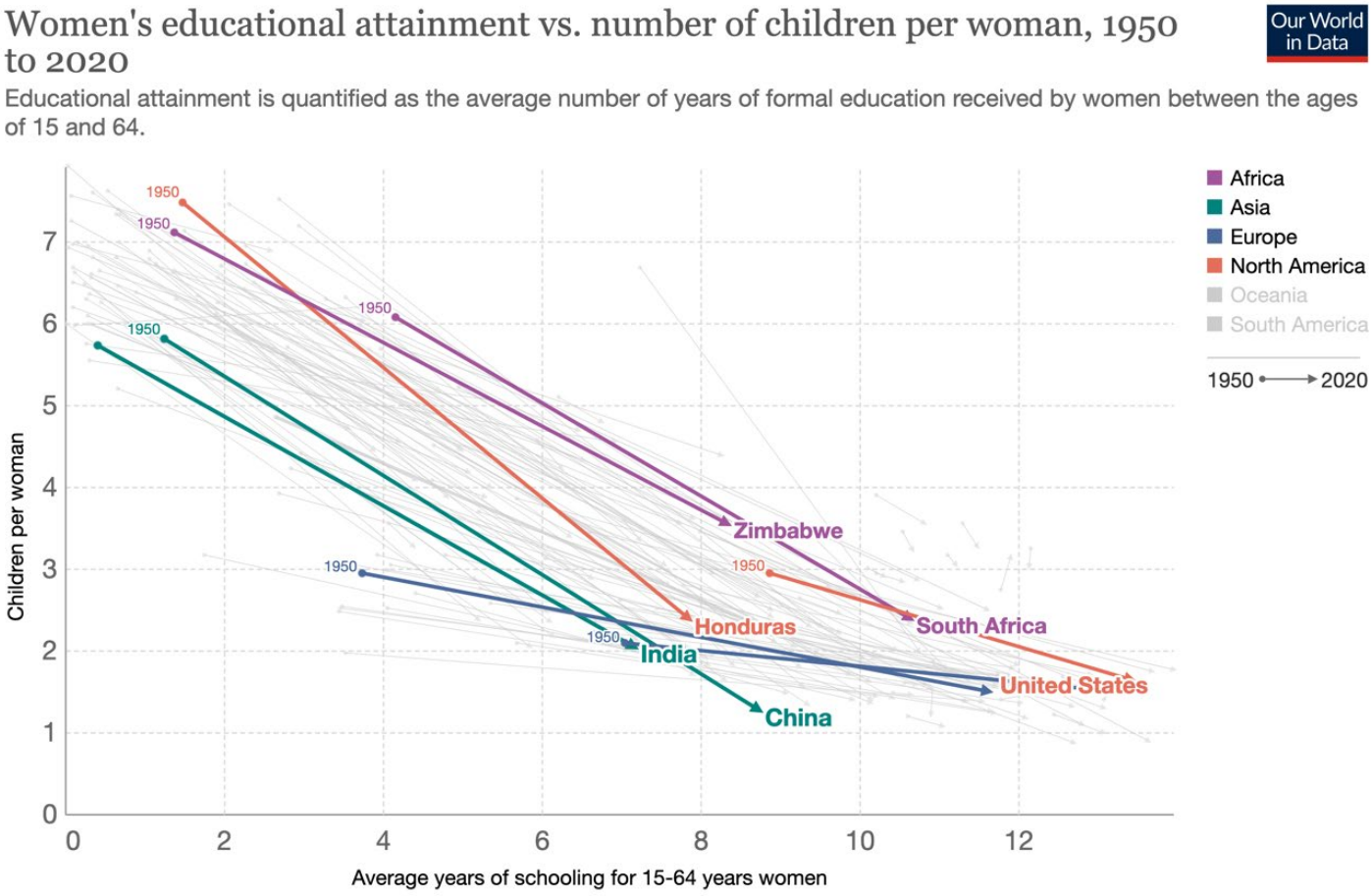
Exhibit 4: World Population Since 10,000 BCE



Child mortality rates are now approaching zero, and almost 100% of our children today survive to reproductive age. Because fertility decline lagged behind mortality decline, the 20th century experienced explosive exponential growth in the human population, quadrupling over the last 100 years. Had our species not reacted by beginning to lower our fertility rates over the past half-century, our current population would be even larger than today's 8 billion, and our future population would still be growing at an explosive rate.

Fortunately, humans are adapting to keep from crowding ourselves out. But this adaptation does not primarily have a genetic origin. Rather, it comes from new technologies and a change in culture. We have been able to separate sexual and romantic activities from pregnancy and birth by the use of various family planning methods. And perhaps most important of all, women have become more empowered to control their own reproduction. This can be seen in Exhibit 5 showing women's years of educational attainment vs. fertility rates across various continents and countries. After our amazing drops in child mortality and increases in longevity, perhaps our most important human accomplishment is our dramatic decrease in human fertility rates. By having fewer children, humans have been able to invest far more in each child's health, education, and well-being. In 1965, the world's fertility rate was just over 5.0 children per woman. The current world's fertility rate is 2.3 and is still dropping. Long-term replacement level fertility is 2.1 (assuming a 95% survival rate to reproduction). We may reach the replacement level within a few decades, but the world's population isn't projected to peak until near the end of the century. Although long-term population projections are difficult to make, the United Nations recently estimated that today's population of 8 billion could grow by the year 2100 to about 10.4 billion, plus or minus a couple billion.

Exhibit 5: Women's Educational Attainment vs Fertility Rate



From the perspective of this essay, this historical data illustrates a number of important findings. The near 100% survival rate of human offspring violates the Darwinian process. In natural selection, there is a wide variety of offspring resulting from combined male and female genetics, as well as from mutations that take place. As we have emphasized, on average these variations are harmful, because the parents had already been well adapted to their environment. For each new generation to adapt better than its parents, only a minority of the better adapted offspring can survive. As an exercise in logic, there is good reason to believe that if all the offspring survive, humans are no longer becoming better suited to our environment through genetic adaptation. As a species approaches a 100% survival rate, it encounters an inflection point in its

evolution, wherein net positive genetic adaptions become increasingly unlikely to be passed on to subsequent generations. With high survival rates, humans no longer genetically adapt.

Humanity's increased potential for negative genetic adaptation might suggest that the long-term human trajectory is not positive. However, we believe this is *not* the case. Humans have developed other, far more effective ways to adapt. We are accumulating knowledge, technology, and changing culture across our generations at an astonishing pace! If human productivity increased by 1 % a year per capita, our standard of living would double in about 70 years. And this seems to be happening! Not only are we developing technologies that might dramatically improve our lives, we are also developing approaches that might mitigate the huge impact we are having on the planet. As we have seen from the earlier exhibits, our biggest impact has come from our explosive population growth. But as our child mortality rates approach zero, and our lives get longer, we are reacting by lowering our world fertility rate, which may soon approach the 2.1 replacement level.

Thomas Malthus (1798) proposed a theory that the human condition was predisposed to subsistence and poverty because any increases in food production, well-being, or productivity would be absorbed by population growth. This may have been empirically true in the years prior to his publication. It is still probably true today for most of the other species on Earth. But humans have in fact become much better off in the last few centuries, despite explosive population growth.

Our technological progress works far faster than population growth or genetic evolution. As we can see from Exhibit 6 below, it has been estimated that the real (inflation adjusted) per capita annual income has grown over the last millennium at a rate of 0.23% in China and 0.35% in the UK. These may not seem like fast rates of growth, but over the period, the GDP per capita of China increased over 10 times, and that of the UK increased over 35 times. Over the last 200 years, the estimated world GDP per capita increased 14.2 times for the annual growth rate of 1.34%. In recent times, growth has been accelerating, with GDP per capita growth exceeding 2% per year. Meanwhile, our wealth has been growing at a substantially higher but more variable rate. A much smaller proportion of people are without food or shelter, and the world's poverty rates have dropped dramatically. In recent times per capita GDP growth has far exceeded genetic adaption rates. Technological adaptation rates easily overwhelm human genetics. Our human genome has not changed that much over the last 250,000 years. But economically, humans have

not only continually adapted to our environment, but we have changed the environment to meet our purposes, and we are likely to continue to adapt at exponential rates.

Exhibit 6: Long Term Estimated Growth Rates in GDP per Capita

	China	UK	World
Start Year	1000	1000	1820
Start Year GDP per Capita	$1,225	$1,151	$1,102
End Year	2020	2020	2020
End Year GDP per Capita	$13,370	$41,250	$15,678
Ratio	10.9	35.8	14.2
Annual Growth Rate	0.23%	0.35%	1.34%

Calculations created using data from The Madison Project Database, 2020 version, with authors' update

None of our recent adaptation methods are a result of Darwinism. In fact, humanity's near 100% survival rate would on its own lead to less genetic adaptation across generations, since there would no longer be survival of only the most adaptable. However, humans have survived and thrived by violating the basic principles of Darwinism, replacing them with human devised technological and cultural changes.

Domesticated Animals and Plants

Humans have dramatically changed the way animals and plants evolved through domestication. We were domesticating animals and plants long before Charles Darwin developed his theories. This was done primarily in agriculture, but also in developing a symbiotic relationship with our pets, e.g. dogs and cats. By its very nature, agriculture involves the breeding, seeding, and nurturing the type of animal and plant life that is most useful to humans. Thus, we encourage the plants that are most edible, or create the most aesthetic or recreational environments, such as lawns and gardens. We focus on the animals that are also most useful to us, such as those that provide meat, eggs, and dairy, or that can do work for us, help us hunt, protect us from other species, or provide companionship.

Most of the animals that we have domesticated would have a tough time surviving on their own. We have created cows with large udders, chickens that lay the most eggs, and animals that grow quickly to maturity. These animals are fed by humans, medically treated, and given protection from natural predators. Thus, while there is a long-term genetic cost to a species, there is an on-going symbiotic relationship with humans. The animals are bred typically to have one feature desired by humans, often to digest really fattening food, or grow so big and fast that they can hardly stand. The less desired animals are culled, while the more desired animals have high survival rates, at least until they are consumed or otherwise no longer of use to humans. Humans decide which animals reproduce, and often this is done through artificial insemination. There is no natural selection in these domesticated animals, neither in the breeding inputs, nor in the statistical survival rates that are mostly determined by humans. The animals evolve by “artificial selection,” rather than by natural selection.

Much of the domestication of animals has occurred through industrialized agriculture. In the preindustrial era, humans provided livestock a safer and often longer life than they would experience in the wild. However, small farms have morphed into large-scale industrial enterprises, wherein animals such as chickens and dairy cows are suffering both genetic and quality of life degradation in comparison to their undomesticated counterparts. In the short-term, industrialized agriculture provides domesticated animals with protection, but in the longer term, the species are genetically altered to benefit humanity. Thus, most domesticated animals are totally dependent on humanity and cannot survive without us.

The impact on the world animal population has been dramatic, especially for mammals. It is estimated that human's amount to 36% of the biomass of all mammals, while domesticated livestock, mostly cows and pigs, account for 60%, with wild mammals only accounting for 4%. Thus, domesticated mammals make up 96% of mammalian biomass! Avians are also mostly domesticated. It is estimated that the biomass of poultry is about three times higher than that of wild birds. Our fish consumption is increasingly coming from farmed populations. Even insects are affected, as we domesticate bees and use pesticides to reduce wild insect populations. Our world animal population is rapidly becoming domesticated, with a smaller and smaller population left in its original Darwinian state.

Humans have also dramatically domesticated plants, although domesticated plants make up a minority of the plant biomass on the planet. Our biggest domestic arena is in industrialized agriculture, where we focus on a few high-yielding crops, such as corn, grains, rice, potatoes, soybeans, sugar, etc. We also have standardized our fruit and vegetable production. We have accomplished this by carefully selecting the appropriate seeds, creating hybrids, and using other methods to select plant species that are especially edible, cheap to produce, and resistant to the herbicides and pesticides that we use to protect them. Thus, domestic agriculture controls the inputs as to what gets planted, continues the control the process through the harvest, and ultimately evolves agricultural plant life in human designed artificial ways.

The following Exhibit 7 categorizes the world's land use by percent of acreage. Although domesticated plant life (cropland and grazing pastures) makes up a relatively low percentage of total world acreage, this acreage has been purposely selected because it has been the most productive farmland. Although deserts and tundra make up a relatively large percentage of the acreage, they host a relatively small percentage of the plant biomass. Oceans are not listed on this chart—they make up about 70% of the surface of the Earth but a much smaller percent of the biomass.

Exhibit 7: Land Area

	Land Type	Percent of Earth's Land
Domesticated (35%)	Grazing pastures	27
	Cropland	7
	Towns, cities, infrastructure	1
Wild (65%)	Temperate forest	20
	Deserts and barren land	19
	Glaciers	10
	Savanna, grassland, shrubland	8
	Tropical forest	6
	Freshwater	1
Total:		**100%**

Authors' estimates from multiple sources; may not sum to 100% due to rounding

Although our gardens and lawns make up a far smaller portion of the overall acreage, these urban and suburban environments are also clearly dominated by human design. In fact, we usually regard as "weeds" any plant that naturally arises in our gardens. We typically use herbicides and pesticides to control these weeds, or just manually pull them out or dig them up. In any event, our garden plants are just one more example of us deviating from natural selection.

Domesticated animals and plants are the most clear-cut departure from Darwinism. They break the Darwinian assumptions of natural breeding and the statistical survival rates that would be found in nature. Most agricultural species have been designed or clearly altered by humans. Our gardens have been carefully crafted. Our pets often deviate substantially from what is found in nature. Domesticated animals and plants are increasingly designed by humans, not by natural selection.

Wild Animals and Plants

In the wild, in a strict sense, Darwinian evolution still takes place. Animals continue to breed naturally, statistically surviving according to those most able to adapt. Plants also reproduce in natural ways, with the more adaptable plants effectively competing in their environment. However, one of the tenets of Darwinism is that evolution is a slow process, taking place over many generations. Species continually adapt to their changing environment, but even in the wild, evolution can break down when the environment changes faster than species can adapt.

There are many reasons to believe the environment is quickly changing. We are continually experiencing habitat loss, decreased ice cover, rising sea levels, and forest fires. Human pollution is impacting us on the ground, in the air, and in the seas. In particular, the oceans are becoming filled with minute plastic particles, and agricultural land is being threatened by falling freshwater tables. Global warming is changing our climate, not only warming the Earth, but also making weather far more variable. The inability of animals and plants to quickly adapt is leading to mass extinctions. The current era has been called the "Sixth Extinction" (Anthropocene Epoch).

Most plants are either perennials or annuals. It is generally easier for the annuals to adapt to a changing environment because they produce new offspring each year, usually in high quantities. The perennials are longer lived and can be easily threatened by changing environments. Trees, in particular, are impacted by lumber production, loss of habitat, forest fires, and a changing climate. Meanwhile, invasive species are particularly good at adapting, as they move into new environments with less competition.

When it comes to animals, their ability to adapt is tied to their time to sexual maturity and the number of offspring they produce. Species that have short lifecycles, such as fruit flies, can quickly go through many generations in short periods of time. Even more important to genetic adaptation is having a large number of offspring with a small number of survivors, because the higher statistical survival rates of the most adaptable members is a key to Darwinian evolution. In contrast, higher order mammals have long periods until sexual maturity and produce relatively few offspring, making them more vulnerable to a rapidly changing environment. Various animal species are shown in Exhibit 8, which summarizes the time to sexual maturity, lifespan, and number of offspring for selected species. The various species have a variety of time to sexual

maturity, with fish usually creating a large number of offspring, while the wild mammals, birds, and other higher order species produce fewer offspring.

Exhibit 8: Animal Reproductive Capacity

Animal	Time to sexual maturity	Number of offspring	Lifespan
Fruit fly	24-48 hrs	20 eggs, up to 500 eggs lifetime	40-50 days
Blue Jay	3 weeks	2-7 eggs, 1-2 times per year	7 years
Bald Eagle	4-5 years	1-3, 1 time per year	20 years
Atlantic Bluefin Tuna	4-5 years	5 million – 25 million per year	20 years
Sockeye Salmon	5 years	500-1000 per nest, 2000-5000 eggs lifetime	5 years
Spotted Salamander	2 years	1-10 masses of 125 eggs each	20 years
Saltwater Crocodile	10-16 years	50 eggs, 1 time per year	70 years
Whale	5-14 years	1 every 1-6 years	30-90 years
Rabbit	5 months	5 per litter, 11 times per year	9 years
Housecat	7-9 months	4 per litter, 5 times per year	13-17 years
Dog	1 year	6 per litter, 2 times per year	10-13 years
Cow	15-18 months	1 every 1+ years for 18 years	20 years
Elephant	8-13 years	1, up to 12 throughout lifetime	50-70 years
Human	12-16 years	1 every 1+ years for 20 years	72 years

Authors' estimates from multiple sources

Humans are a special case. We have a long time to sexual maturity and reproduce a relatively small number offspring during our lifetimes. But as we have already shown, humans no longer rely on genetic evolution to adapt to their environment. Instead, we change the environment to suit our purposes and then we use technology to adapt to the world that we have created.

Other species also have ways of adapting which do not include evolving genetics. These include migration, bet-hedging (overproducing to include populations which have not adapted well to the current environment but which might adapt better in changed environments), and phenotypic plasticity. As the natural environment changes, some species are plastic in that they can change their phenotypes, so that the same genetics can have different phenotypic expressions. An example is an iguana, which can change its color to match different backgrounds. Another example is a bee which through a super diet can become a queen bee, very different from the infertile female worker bees.

These non-genetic ways of adapting are different from traditional Darwinism. Yet they are "natural" in that they occur in nature. Species may in fact evolve to include these extra forms of adaptability to changing environments. However, even these other forms of adaptability are often insufficient to protect a species when the environment is undergoing very rapid change. Humans are changing the environment at a much faster pace than any time in recorded history. These changes include climate change, land and water pollution, habitat destruction, extensive use of pesticides and herbicides, and heavy use of fertilizers and other chemicals.

Darwin Fights Back

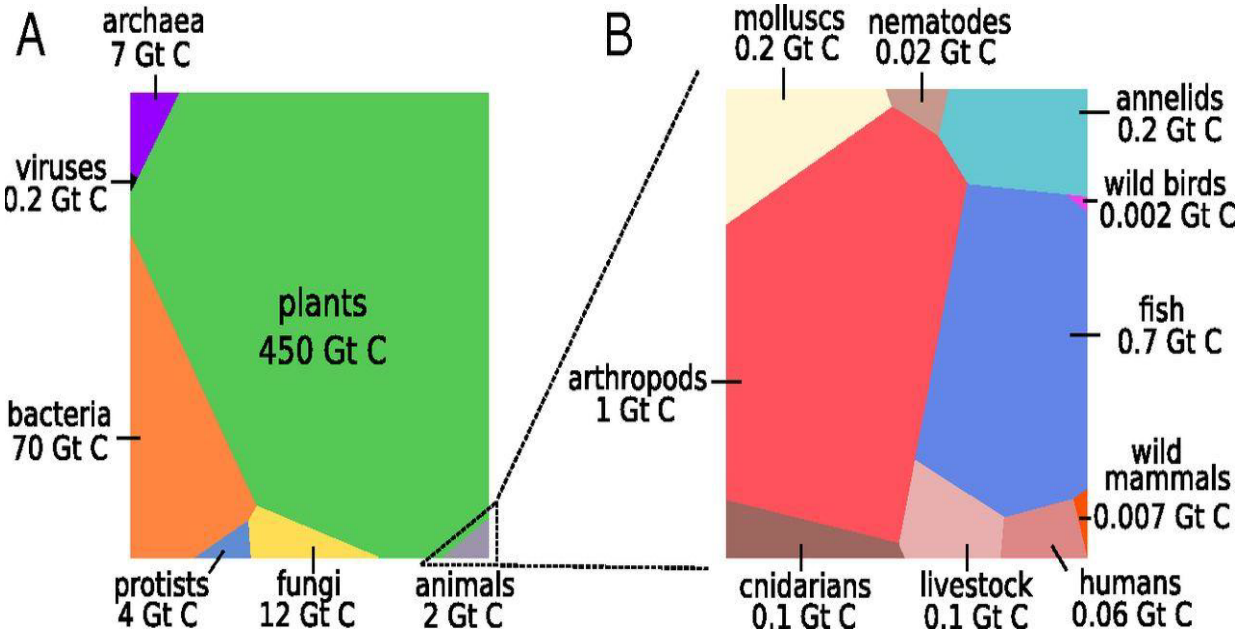
As we have seen, humans are surviving at rates of nearly 100% while adapting by dramatically reducing their fertility rates through technology and cultural change. Humans are also changing the environment to fit their needs through urbanization, industrialized agriculture, infrastructure, and technological developments. Humans are domesticating animals and plants for their own use, while encroaching on wild animal and plant populations through habitat destruction, pollution, climate change, etc. In all these ways, we are replacing the Darwinian process either directly or indirectly. Humans are especially impacting the higher order animal species and the larger plant life species. But when we look at the Earth from a biomass perspective, we see a different picture.

Animals make up only a small proportion of the biomass of the planet. Mammals and birds are the highest order type of animals, but they make up very little of the total animal biomass. The largest portions of animals are arthropods (insects, etc.) and fish. The other major categories of animals are mollusks (snails, etc.), annelids (worms, etc.), and cnidarians (aquatic invertebrates). For the most part, these species have short reproduction cycles and produce a large number of offspring. These species likely have the ability to quickly genetically adapt to their changing environment.

Exhibit 9 shows the proportions of biomass across the various categories of species. The scientific names for many of these categories may be unfamiliar, but they are clarified in a later exhibit. The largest category of biomass by far is plant life, estimated to make up 82.6% of our biomass, only a small proportion of which is domesticated. The next largest category is bacteria, making up 12.8% of our biomass. As seen in the exhibit, other relatively large categories are fungi, archaea, and protists. Although animals may first come to mind, they make up only a tiny 0.3% of total biomass. Humans, however, make up an even smaller portion of the biomass (approximately 0.01%!). It is remarkable that such a minor species (from a biomass perspective) has garnered the power to override much of traditional Darwinian evolution.

Exhibit 9: Biomass by Category of Species

i: Graphical Representation of Biomass Proportions



The categories are measured in gigatonnes of carbon, but what is relevant are the numeric proportions, which are displayed to approximate scale.

Bar-On, Y. M., Phillips, R., & Milo, R. (2018, June 19). The Biomass Distribution on Earth. *PNAS*. https://www.pnas.org/content/115/25/6506.

ii: Biomass Breakdown Across Terrestrial, Ocean, and Subsurface

	Terrestrial	Ocean	Subsurface	Total biomass
% of total biomass	86.20%	1.21%	12.59%	100%
Plants	95.60	13.60	0	82.57
Bacteria	1.34	21.15	90.82	12.84
Fungi	2.50	3.63	0	2.20
Archaea	0.08	4.23	9.18	1.28
Protists	0.37	33.83	0	0.73
Animals	0.09	23.56	0	0.37 (0.01 humans)
	100%	100%	100%	100%

Authors' calculations based on above Graphical Representation and data from:
Hannah Ritchie and Max Roser (2021) - "Biodiversity." Published online at OurWorldInData.org.
Retrieved from: 'https://ourworldindata.org/biodiversity'

Plants especially dominate the terrestrial biomass of the planet, with most of the remaining plant life in the ocean. Humans impact a relatively small minority of the plant biomass, as well as having little impact on the terrestrial fungi and bacteria. Other big categories of biomass are in the subsurface of our land mass. Humans are not likely to have a big impact on bacteria or archaea, but we are degrading the Earth's soil. While we humans have had a substantial impact on higher order species, we have not changed the Darwinian process that much when considering the overall biomass of the planet. We summarize the human impact on the various categories in Exhibit 10.

Exhibit 10: Human Impact on Selected Categories

Selected Categories	Description	Human Impact
Animals:		
Mammals	96% domesticated; humans, cattle, pigs, etc.	very high
Birds	Mostly domesticated; chickens, turkeys, etc.	very high
Fish	Overfishing, pollution, global warming, farming	medium-high
Mollusks	Pollution harms mussels, octopi, snails, etc.	medium
Arthropods	Pesticides & pollution impact insects, crustaceans	medium
Annelids	Industrial agriculture impacts worms, etc.	medium-low
Plants:		
Domesticated	Agriculture (grains, corn), grass, gardens etc.	very high
Wild	Global warming & herbicides impact wild plants	medium-low
Other:		
Bacteria	Single-celled microorganisms found throughout nature	low
Fungi	Primarily terrestrial; mushrooms, mold, etc.	low
Archaea	Primarily subsurface single-celled microorganisms	low
Protists	Oceanic & terrestrial single-celled protozoa, algae, etc.	low

Authors' interpretations

Saving Darwinism

Although Darwinism is natural and evolution allows species to continually adapt to their environments, it is not necessarily a desirable process. Humans have overridden the Darwinian process by having fewer children with high survival rates. We are not just adapting to our environment, but also changing the environment to adapt to us. This behavior has dramatically improved our standard of living. There is no other species that has had similar technological and cultural adaptation success, even at the most primitive levels e.g. wearing clothes, cooking, using complex language, etc. Humans have clearly benefited from overriding the evolutionary process.

Domesticated animals and plants have also clearly departed from Darwinian evolution, with industrialized agriculture. We choose which species survive and which ones are eliminated. This has mixed affects. It is positive in the sense that some species are protected and may in some circumstances flourish. It can also be positive in that agriculture is becoming increasingly productive, so that it takes less land and resources to feed us. But it is negative in that we may distort animal and plant genetics to fit our own purposes, reducing the diversity of both animals and plants. Domesticated animals may be subject to overly quick growth, overcrowding, and generally uncomfortable conditions, often making their lives miserable.

Agriculture and food production is a declining portion of our GDP, but it has a relatively high negative impact on animal welfare and the environment. It may be possible to reduce the harm done to animals and the environment, while not impacting the costs of food very much. For example, we can treat animals better, reduce or substitute meat consumption by choice, utilize water more judiciously, and use less harmful fertilizers, herbicides, pesticides, etc. In the U.S, a major food exporter, agriculture is a major cause of environmental damage despite making up less than 2% of our GDP. Most of the cost of our food is not from agriculture, but rather from processing, packaging, distribution, and branding. We do not necessarily want to bring natural selection back, but rather be better stewards of the animals and plants that we domesticate. This could potentially be achievable without great cost to our food budgets, but it would involve making difficult political choices.

Wild animal and plant kingdoms benefit from Darwinism. In order to diminish the impact that humans are having on wild species, we must reduce greenhouse gas emissions, pollution, habitat

destruction, hunting, and the use of pesticides, herbicides, fertilizers, etc. A simple equation can help us to focus our efforts:

Environmental Damage = Human Population x Damage per Capita

Thus, there are two ways to tackle the problem, and both are relevant. One way is to continue to slow our population growth, eventually stabilizing the total world human population. It is the less developed countries that have the highest fertility and population growth rates. Some argue that rapid population growth in the less developed countries is not that damaging because the average environmental footprint of people in low-income countries is relatively small. However, as the standard of living in less developed economies increases, it is likely that their environmental damage per capita will also grow. Thus, population stabilization through voluntary family planning is a crucial component of development initiatives in low-income countries, where high fertility and unmet need for contraception are both exceedingly high.

The other way is to lower the impact on the environment per individual. It is in the more developed nations that each of us has a higher negative environmental footprint. There are a multitude of ways to accomplish this, including lowering our fossil fuel use, implementing carbon capture, restricting use of plastics, recycling, and improving trash removal strategies. These strategies do require short term economic tradeoffs. The overall goal should be to maintain our standard of living while using less resources more efficiently.

We are making progress both by lowering fertility rates and slowing the growth rate of per capita damage. Saving Darwinian diversity benefits not only the wild kingdom, but also humans. We are the dominant species, and there have been great benefits to us by overriding the Darwinian process, but there may also be great costs to displacing it too widely. The costs have mostly been borne by the domesticated and wild species on the planet.

Conclusions

The natural selection theory of Charles Darwin is based upon a few concepts: Species naturally reproduce in overabundance, with genetic variation and mutations that are generally harmful, but sometimes beneficial. The more adaptable offspring have higher survival rates than the less adaptable offspring, so that the minority of surviving populations genetically evolve to be better adapted to their (often changing) environments across generations.

Humans have not only evolved into the Earth's highest order species, but also into an extremely successful species. Human evolution itself has reached an inflection point, with its near 100% survival rates, so that we are no longer adapting genetically. Rather, we are adapting in a much quicker way through technology and cultural change. We first learned how to help our children survive, and then we learned to live to old age. This caused explosive population growth, but we have been able to adapt by cutting our fertility rates in half in a little more than 50 years. We are accomplishing this as women become better able to make their own choices.

We have also become the dominant species, so much so that we have often overridden Darwinism. The result is that we have either eliminated or domesticated most of the higher order animals. We have domesticated large portions of plant life for timber, agriculture, or gardens. We choose and adapt the species that we want to survive and flourish, overriding natural selection.

Humans have also impacted wild animals and plants. We have changed the climate, dammed the rivers, polluted lands and oceans, over-irrigated, hunted and trapped, restricted habitats, and introduced invasive species. All of this has changed the environment so rapidly that many species have been unable to adapt. Genetic evolution is a slow process, especially for higher order and long-lived species.

Our impact on Earth's overall biomass has not been that great so far. Our planet's biomass is primarily made up of wild plants, bacteria, fungi, etc. Agricultural land is still a minority of the Earth's land, and grazing land is still largely natural. Darwinism is still at work, but human technology is growing at an explosive rate and wild forms of biomass, which make up the majority of Earth's biomass, might be threatened in the future.

Humans have greatly benefited from overriding Darwinism, with our high child survival rates, longevity, and our dramatically increasing standard of living. The benefits to domesticated animals and plants have been mixed and can be potentially improved at not great overall costs. The impact on wild animals and plants has been severe, especially the higher order species that have long reproduction cycles and/or few offspring. Fortunately, humans are adapting by lowering population growth and attempting to lower the environmental damage per individual. We are starting to react to our circumstances, but we may not be reacting fast enough. Wild animals and plants adapt through the slow multiple generational Darwinian process. It is up to humans to reduce, or at least slow, our impact on the natural environment.

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