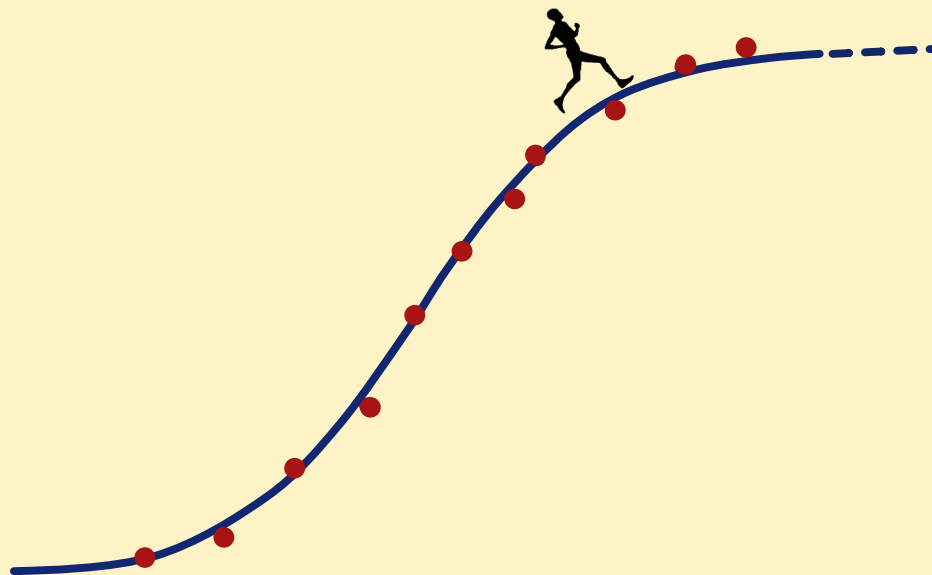


PEAK HUMAN?

THOUGHTS ON THE EVOLUTION OF THE ENHANCEMENT
OF HUMAN PERFORMANCE

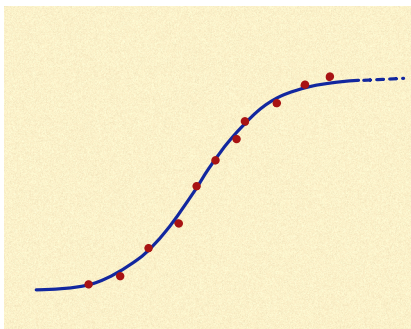
Jesse H. Ausubel and Alan S. Curry



Adapted from the 2022 Nierenberg Prize Lecture
University of California, San Diego
13 October 2022

ABSTRACT

While societies expect cars and computers to continue to improve, what about humans themselves? Is our species near peak human? We provide a four-part framework for considering performance: cognitive achievement such as IQ, physical achievement such as Olympic records, lifetime performance such as height and life expectancy, and immune system education such as resistance to disease. After several centuries of rapid and pervasive enhancement, trends suggest that human performance enhancements may be hard won during the coming decades.



ON THE COVER

An S-shaped logistic curve describes the growth to a limit of many biological processes, from the increase in height of a plant seedling to the spread of disease in a pandemic. What insights can it provide into the further enhancement of human performance?

SUGGESTED CITATION

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Peak Human?

THOUGHTS ON THE EVOLUTION OF THE ENHANCEMENT OF HUMAN PERFORMANCE

Jesse H. Ausubel and Alan S. Curry

The phrase Peak Human resonates with Peak Oil, Peak Stuff, and Peak Farmland, topics our group has researched and written about. Our question is where humanity stands in the great S-curves of performance enhancement, whether our species now nears Peak Human, individually and collectively, particularly in the US. Of course, societies expect improvement in cars (think autonomy) and computers (think quantum computing), but what about humans themselves? This is a peak question for science and society during the 21st century.

The French postman in **Figure 1**, shown on stilts a little more than one hundred years ago, illustrates the question. Stilts did lift mail delivery but less than trucks, planes, and the Internet.

We approach the question with a four-part framework: (1) short-term physical performance such as in Olympic events, (2) lifetime performance such as height, vision, and life expectancy, (3) cognitive performance such as IQ, and finally (4) immune system performance such as resistance to disease. The broad spectrum of ways to achieve performance enhancement spans established means such as ancestry and environment to the less established, such as stilts, Adderall, and vaccines.



Figure 1. Mailman on delivery rounds in Pays de Buch in SW France early 20th century. Stilts enabled rapid movement over boggy and marshy ground.

Source: <https://af.wikipedia.org/wiki/Stelt>

PRELIMINARIES

What are the objectives of enhancement? On the physical side, we should mention boosting strength, agility, beauty, endurance, and longevity and healthy life span. On the mental side, we think of enhancing capacity for work and study, combatting mental fatigue and ego depletion, and increasing social IQ, fellow-feeling and group cohesion.

We are mindful of raising both the peak individual performance and the average or typical performance. Engineers lift the frontier with larger or faster machines, but most of the societal benefit comes from the diffusion of practice, and the repetitious manufacturing of many machines that recently embodied best practices. Peak Human asks not only whether the top individual peaks but whether the group or the average keeps rising too, whether high performance is replicable.

In this regard, it's important to ask how we compare with one another and with machines (**Figure 2**). Considering numerous activities such as cycling, we find that first-class athletes differ from average healthy humans by about 200 watts, or up to four times maximum sustainable power. A lot of headroom for enhancement may exist for many people without lifting the ceiling.

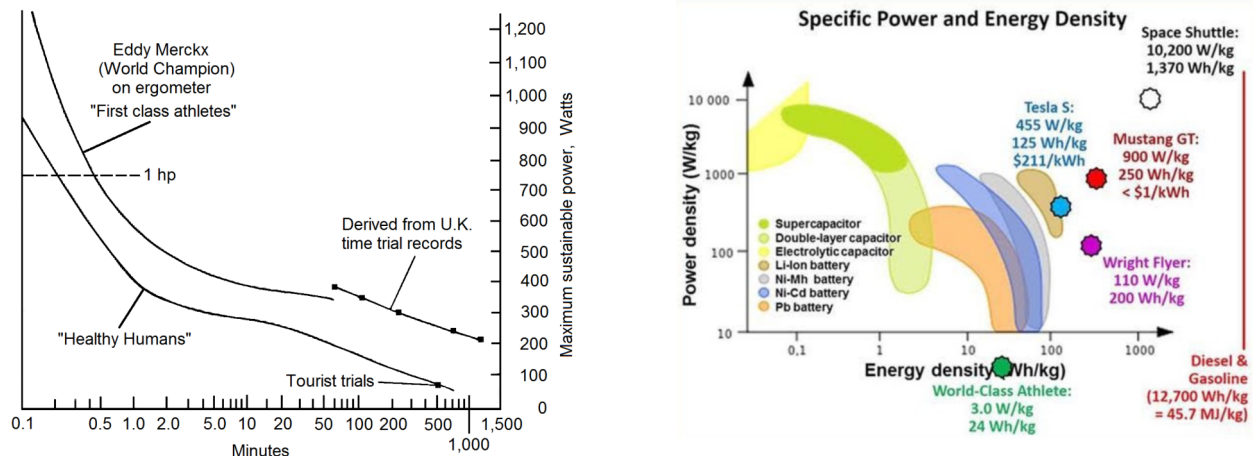


Figure 2. Comparing physical skills of humans with one another and with machines. (Left) Top athletes have up to four times the power of normal humans. (Right) Top athletes have roughly the energy density of a lead battery, one-fifth of a lithium battery, and 1/500th that of gasoline. An athlete's power density is about 1/300th that of a Mustang GT.

Credit: NASA 1964

Gross AC, et al. (1983) "The aerodynamics of human-powered land vehicles," *Scientific American* 249(6), 142–153. <https://www.jstor.org/stable/24969056>

Haugen T, et al. (2018) "New records in human power," *International Journal of Sports Physiology and Performance* 13(6), 678–686. doi:10.1123/ijsp.2017-0441

But even a world-class athlete compares badly in power density to batteries, or in power and energy density to a Mustang, which has about 10 times the energy and 300 times the power density of an athlete. Comparison with a barrel of oil also humbles humans; a barrel of crude equals about nine human years of labor. And machine performance is not standing still.

Thoughts on the Evolution of the Enhancement of Human Performance

A final preliminary point is that efforts to enhance performance go back to our earliest ancestors. Think of the Alpine iceman, Oetzi, and his footwear, six thousand years before Nike's Air Jordans. So-called berserkers a thousand years ago probably achieved their trance-like fighting frenzy by eating *Amanita muscaria* mushrooms containing muscimol, which induces euphoria and delirium. Thirteenth-century Italian monks acquired eyeglasses. Speed, methamphetamine, powered the 1940 Blitzkrieg. Today militaries also struggle with whether to allow or provision performance-enhancing drugs.

PHYSICAL PERFORMANCE

Short-term physical performance is an obvious dimension of enhancement for which data and headlines abound. During the last 40 years, athletes made testosterone and other steroids, erythropoietin (EPO), and other doping products famous. Think of baseball players Barry Bonds and Roger Clemens, cyclist Lance Armstrong, and East German and Chinese swimmers.

When gold medals are at stake, norms adjust. For the Rio de Janeiro Olympics in 2016, 282 US athletes managed to arrange “therapeutic use” exemptions (**Figure 3**).

Doping is only one strategy, or one element of a strategy in this very competitive field. Others include more formal training and professionalism, larger pools of participants from which to draw, better competitive opportunities, and better equipment. Let's quickly review a few trajectories of enhanced performance.

Consider the trajectory of a golf ball in play (**Figure 4**). Top golfers now drive balls 340 yards and pros average almost 300, about twice the distance elite golfers reached a century ago. The enhancements seem to come in pulses, a common pattern, associated with diverse innovations and the lifting of inhibitions.

Figure 4. PGA Tour average driving distance, in yards, 1980–2021. Enhancements are associated with better equipment, such as titanium clubs, the change from wound to multilayer golf balls, physical fitness, and coaching.

Source: trackmangolf.com

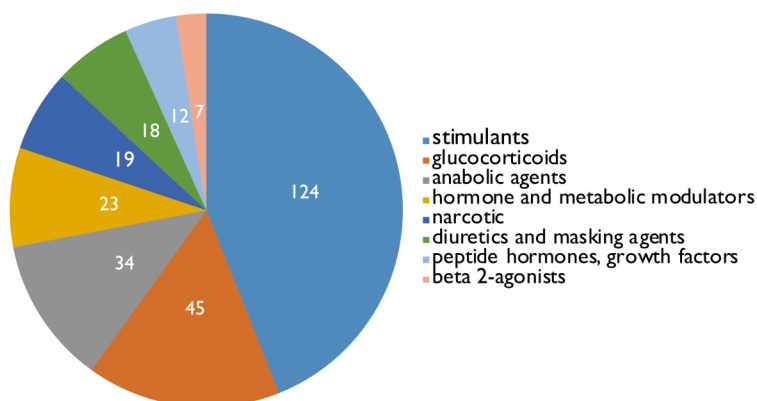
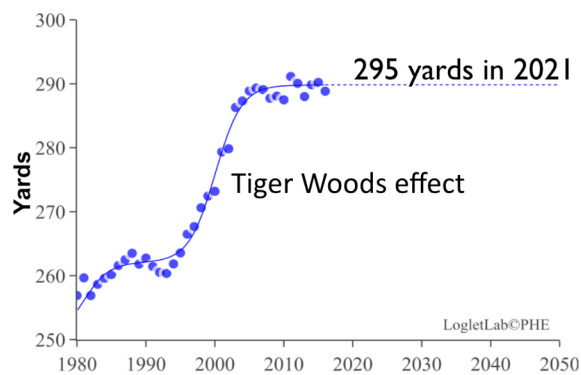


Figure 3. “Therapeutic use” exemptions granted to US athletes in the 2016 Olympics, by class of drug.

Source: Data obtained from the World Anti-Doping Agency illegally and released by the Fancy Bears Hack Team, a Russian hacking group.



Rises in the distance a cyclist covers in an hour have also come in pulses since the invention of the chain-driven bicycle about 1880 (**Figure 5**). The recent pulse comes from improved aerodynamics, in both equipment and rider position. The long trajectories, especially when normalized in the so-called Fisher-Pry transform, show powerfully that societies are learning systems and function as a single cognitive formation extending over generations.

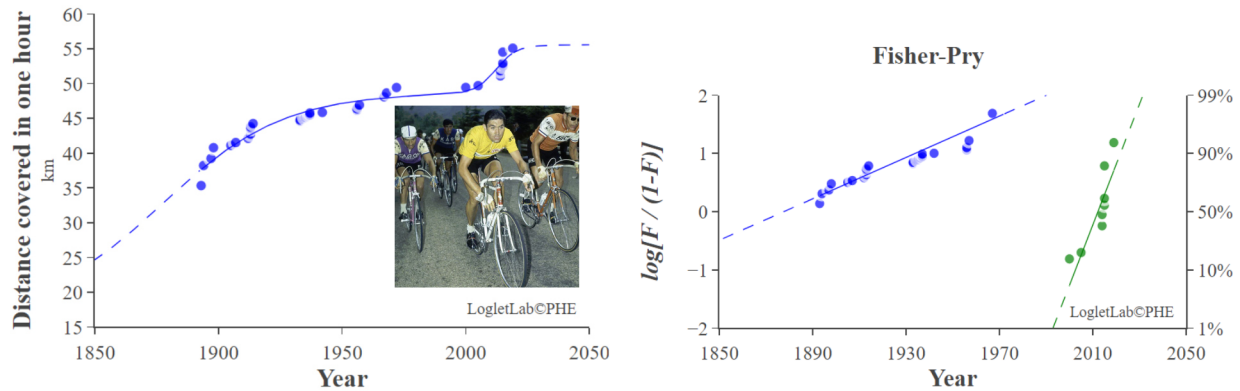


Figure 5. Cycling's world hour record, 1893–2022. (Left) Distances covered in one hour by record-setting cyclists have risen in two pulses or waves to 56 km in 2022 from 35 km in 1893. (Right) The Fisher-Pry transform normalizes and separates the trajectories of the two pulses.

Source: <http://bikeraceinfo.com/records/wrldhour.html>

Swimming offers a case where performance enhancement has been hard won. Stuck at the top of a curve around 2008, swimmers briefly donned polyurethane suits, which enabled a peak before a ban in 2010 (**Figure 6**).

The 100-meter sprint offers a similar picture. Sprinters appear to have exhausted a pulse spanning about 180 years. Innovation is needed (**Figure 7**).

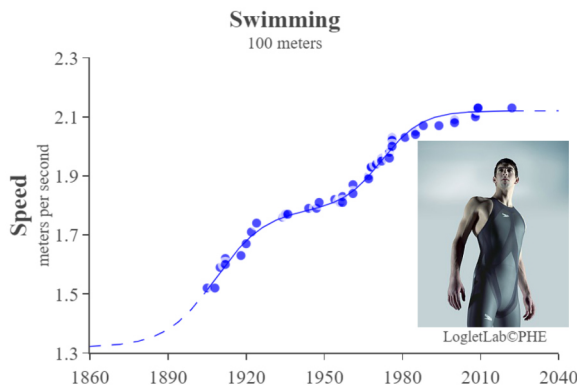


Figure 6. Two waves of enhancement in 100-meter freestyle swimming in world competition, 1904–2022. The second wave reached 90% saturation in 1990. Polyurethane swimsuits, introduced in 2008 and banned in 2010, contributed to 3% improvement in two years and were associated with 89% of medals in the 2008 Beijing Olympics.

Source: en.wikipedia.org/wiki/World_record_progression_100_metres_freestyle

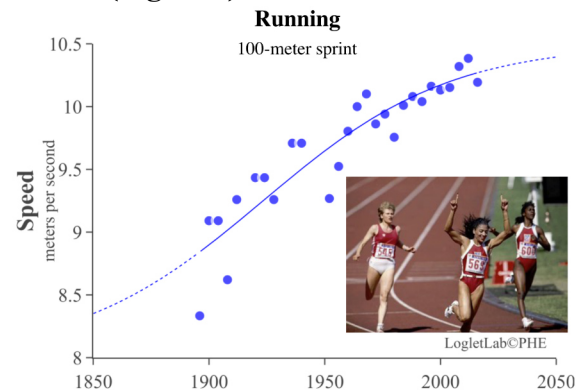


Figure 7. Saturation in 100-meter Olympic sprinting times occurred in 2017. The midpoint of the 178-year pulse was in 1923.

Source: olympic.org

Thoughts on the Evolution of the Enhancement of Human Performance

Marathon records for both men and women show what globalization of the talent pool and lifting of constraints can do (**Figure 8**). They show also some abiding sex or physiology differences, and recently a slowing of rates of improvement.

Marathons show both the improvement of the top performers and, importantly, that many competitors learn successfully to emulate the recent top performers (**Figure 9**). Marathon runners need to run about 6 meters per second, about two-thirds the speed of a sprinter, to finish a 26-mile marathon in under two hours. Maybe by 2030. We will see whether credit goes mainly to high-altitude training, a fast pacesetter, or Nike.

Importantly, teams have been enhanced too. The best and the average National Basketball Association teams today would defeat their counterparts of 25 years ago and embarrass those of 50 years ago. The same might be true of military platoons.

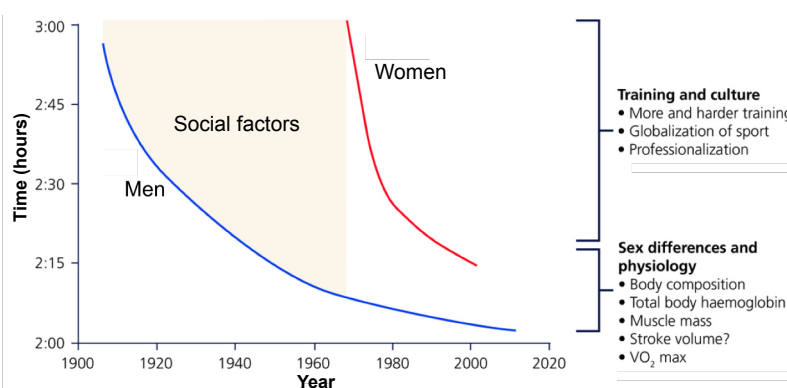


Figure 8. Marathon running, a “market basket” of human performance enhancement.

Credit: Joyner MJ (2016) “Physiological limits to endurance exercise performance: Influence of sex,” *The Journal of Physiology* 595(9), 2949–2954. <https://doi.org/10.1113/JP272268>

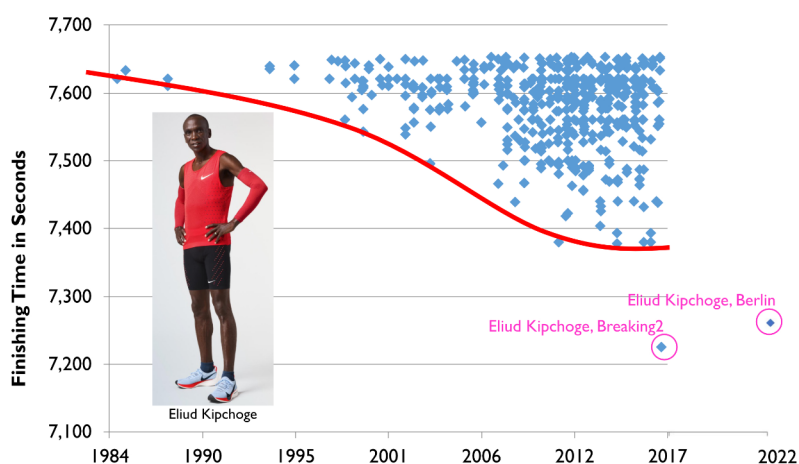
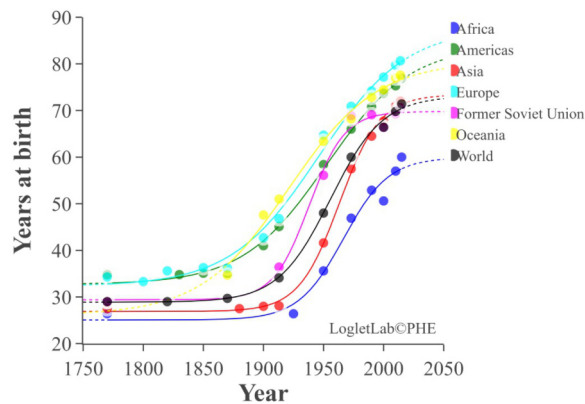


Figure 9. Top 400 Marathon finishers, 1984–2017. Breaking2, a 2016 private competition sponsored by Nike to challenge the 2-hour marathon barrier, was won by Kenyan runner Eliud Kipchoge with a time of 2 hours, 25 seconds. Kipchoge set a world record in the 2022 BMW Berlin Marathon in a field of nearly 35,000 finishers.

Source: International Amateur Athletic Foundation, via marathonguide.com

LIFETIME PERFORMANCE

Before considering life expectancy, regard height. We know from tombs, clothing, and beds that in almost all societies our ancestors were small by 21st century standards. During the 19th century many nations began measuring height for soldiers and then more broadly in their populations. By 1900 men and women in most European nations as well as the USA and Canada began to grow taller, and the phenomenon diffused to almost all populations during the 20th century. Fitting S-curves to many nations, we find that by about 2050, populations should on average attain a height of about 185 cm, or 6 feet. Diet surely accounts for the largest share of the foot-high enhancement, but minor



Saturation	Duration
88 years (Europe)	161 years (Europe)
84 years (Americas)	161 years (Oceania)
81 years (Oceania)	154 years (Americas)
73 years (Asia)	95 years (World)
73 years (World)	82 years (Africa)
70 years (former USSR)	74 years (Asia)
	65 years (former USSR)

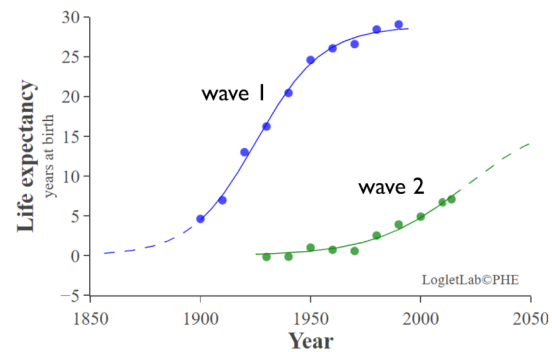
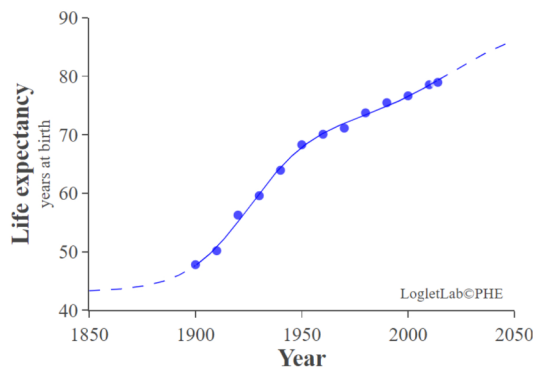
Figure 10. Global life expectancy in number of years that an average person is expected to live from a given year of birth.

Data source: World Health Organization

contributions might come from other factors, even exposure to electrical fields, which can stimulate bone growth.

The S-curves for growth in life expectancy took off about the same time as height. Everyone has gained three to four decades (Figure 10).

Americans seem to have enjoyed two pulses of greater longevity (Figure 11). One might speculate that the first pulse pairs closely with improvements in public health measures for air and water affecting disease transmission and reduction in infant mortality, while the second associates more with modern medicine's treatments of heart disease, cancer, and other causes of adult death, as well as reductions in smoking.



Saturation: 73 years (wave 1), +6 years (wave 2)
 Midpoint: 1922 (wave 1), 1994 (wave 2)
 Duration: 78 years (wave 1), 41 years (wave 2)
 $R^2 = 0.98$
 wave 2 90% saturated in 2060

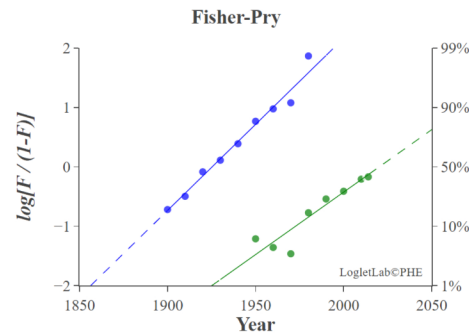


Figure 11. US life expectancy has risen in two pulses. (Left) Composite curve; (Right) Component analysis.

Source: US Census Bureau

Thoughts on the Evolution of the Enhancement of Human Performance

A ferocious literature debates evidence for a hard limit of human life span of, say, 120 years. Whether or not the limit exists, winning each new month of life expectancy seems likely to become harder. A long list of strategies earns research, from caloric restriction to physical activity and activation of sirtuins.

Regardless of life expectancy, the rising performance of older adults is among the astonishing developments of recent decades. For many sports, men at 70 still perform at 70% of what they did at 30. Between 1973 and 2013, improvements in times for running and swimming, for example, are especially good for those over 70 (**Figure 12**). Quarterback Tom Brady, Super Bowl winner at 43, is America's poster boy for adult performance.

Overall, we can summarize neatly the change in lifetime performance with the word "Rectangularization," exemplified by survivorship curves for cohorts born in different decades of the 20th century in India (**Figure 13**). More people remain healthier longer. Yoga and yogurt and scores of other products and services compete for the credit. While the terminal phase of life has remained three to five years, it forms a smaller fraction of life and could probably be compressed, but medicine keeps offering new ways to extend it.

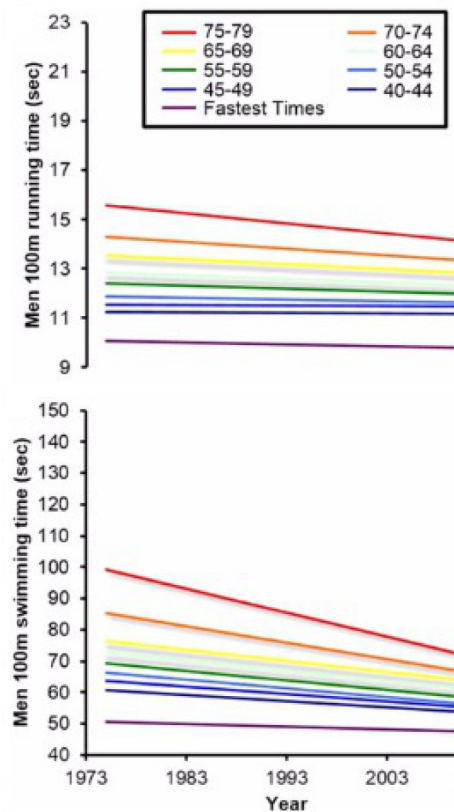


Figure 12. Older athletes are getting faster as physical performance of older adults rises. Male "masters" in running and swimming show the biggest gains in age brackets 70–74 (shown in orange) and 75–79 (shown in red).

Credit: Akkari A, Machin D, Tanaka H (2015) "Greater progression of athletic performance in older Masters athletes," *Age and Ageing* 44(4), 683–686. <https://doi.org/10.1093/ageing/afv023>

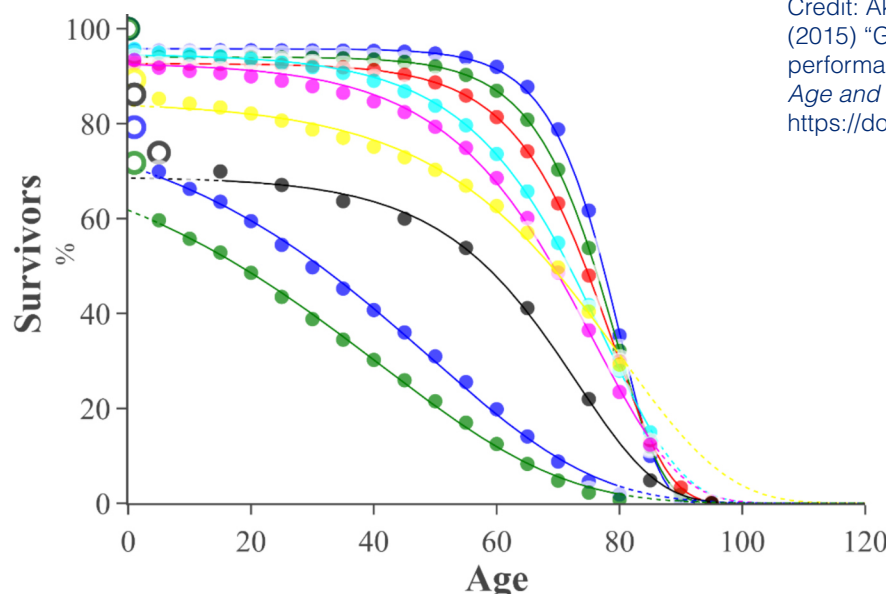


Figure 13. Life expectancy in India. Survivorship curves become rectangular as more people live longer, healthier lives. Curves reflect census data for 1901, 1931, 1957, 2000, and 2010. The topmost curves are estimates for 2025, 2035, and 2045.

Credit: Burg and Ausubel
Source: Census of India

The gold goals of performance enhancement include not only health and longevity but also youth and beauty. The global cosmetic surgery market in 2020 was about \$50 billion, with about half that in the US. Americans underwent more than 4 million procedures here. Brazil, Mexico, and Germany are the largest markets after the US.



Nancy Pelosi and Enrico Berlusconi have this much in common with the Kardashians (**Figure 14**). As with many forms of enhancement, the outcomes do not always match the promises of the vendors.

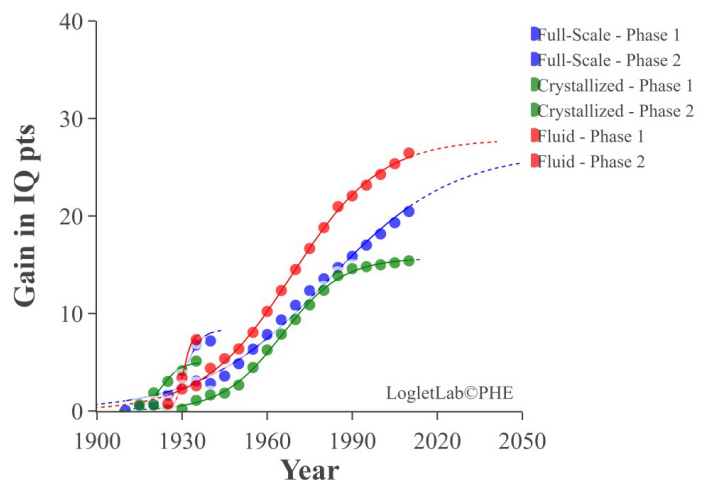
Figure 14. In search of youth and beauty. Politicians and Hollywood have much in common.

COGNITIVE PERFORMANCE

To the extent we believe the results of standardized intelligence testing, we find substantial, sustained gains during the 20th century, the so-called Flynn effect, in all regions, as with life expectancy, and apparently in a pair of pulses (**Figure 15**). Secular gain in crystallized IQ among Asians reached almost 30 points, the difference between borderline mental disability and above average or bright. Attribution studies quarrel about possible contributions from diet and nutrition, schooling, nighttime illumination,

Figure 15. Cognitive performance has risen by 3 IQ points per decade (Flynn effect), but gains are now stagnating globally. Fluid intelligence (red) measures problem solving and analytic reasoning. Crystallized intelligence (green) measures verbal comprehension and memory. Full scale measures overall level of general cognitive and intellectual functioning.

Source: Pietschnig J, Voracek M (2015) "One century of global IQ gains: A formal meta-analysis of the Flynn effect (1909–2013)," *Perspectives on Psychological Science* 10(3), 282–306.
<https://www.jstor.org/stable/44290081>



Thoughts on the Evolution of the Enhancement of Human Performance

a generally more stimulating environment, and other social, cultural, and environmental factors.

Preceding and accompanying IQ growth is diffusion of literacy. Initially a great competitive advantage for the Netherlands and Great Britain, more than 120 countries now approach 100% literacy. While about 70 countries remain below 90%, globally humans have attained about 95% literacy saturation.

A third cognitive measure is educational attainment. For Americans now between 20 and 29, high school diplomas appear to have nearly saturated the susceptible population, but two- and four-year college degrees remain on growth trajectories for a few more decades (**Figure 16**). Alas, the Collegiate Learning Assessment (CLA+) shows that for many students, attendance at college fails to improve critical thinking skills.¹

Returning to high school and to standardized tests, SATs in this case, we find since 1972 mild declines in verbal scores and mild rises in math for college-bound Americans (**Figure 17**). By traditional means and measures, mental as well as physical education in our country seems to have run much of its course.

Relapsing to drugs, ketamine is the new fashion for stress relief, even on Wall Street. From 2010 to 2016, one of us followed the Reddit chat on stacks of nootropics, which Wikipedia defines as a “wide range of natural or synthetic supplements or drugs and other substances that are claimed to improve cognitive function or to promote relaxation, particularly boosting mood, executive functions, attention, memory, creativity, or motivation in healthy individuals.” A lot of experimentation goes on unapproved by the Food and

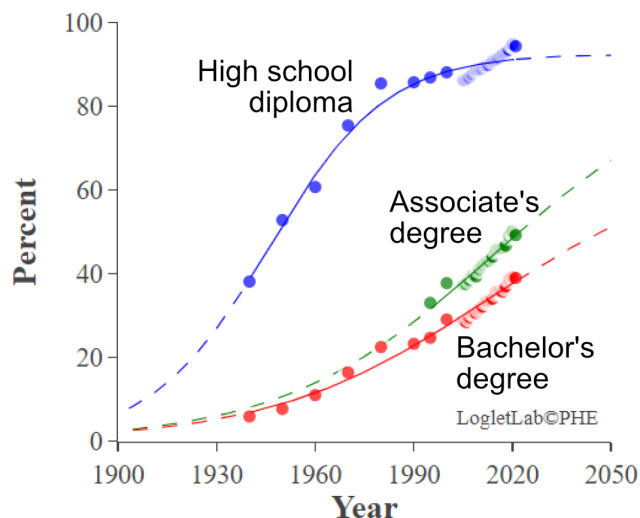


Figure 16. US educational attainment. High school diploma numbers stagnate while growth in numbers of associate's and bachelor's degrees continues.

Saturation: 89% (high school), 37% (bachelors)

Midpoint: 1955 (high school), 1981 (bachelors)

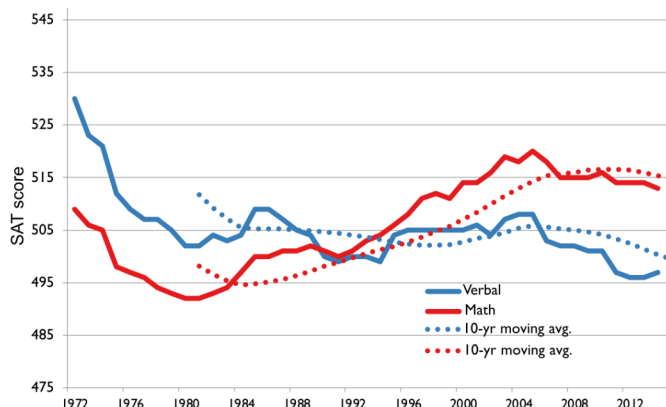
Duration: 89 years (high school), 37 years (bachelors)

$R^2 = 0.9$, 90% saturated in 2019

Source: National Center for Education Statistics

Figure 17. Average math (M) and verbal (V) SAT scores for college-bound seniors, and 10-year moving averages, 1972–2014. SAT scores since 1972 provide weak evidence of population-level cognitive enhancement among US college-bound students.

Source: College Board



Drug Administration (FDA) or other organizations concerned with safety and efficacy. See the detailed advice from the “theficklemonk” for slideshow presentations (**Figure 18**).²

Piracetam
Caffeine
Modafinil
Noopept
Phenibut
Tianeptine
L-theanine
Coffee
Adderall
Nicotine
Semax
Melatonin
Amphetamine
Bacopa
Placebo
Memantine
Adrafinil
Baclofen

Figure 18. Most often discussed nootropics in Reddit chat, 2010–2016. Reddit contributor “theficklemonk” writes: “For something like a presentation, my go-to combo is phenibut and 4F-MPH, an rc analogue similar to Ritalin. The phenibut takes away any nerves and puts me in a great mood, and the 4F offers a bionic, analytical thought process that lets me move through talking points in a clear and concise manner.”

Source: https://www.reddit.com/r/Nootropics/comments/4e74g8/top_10_nootropics/

With regard to FDA-approved products, the popularity of the psychotropic drugs overwhelms. Humans want performance enhancement, especially the easy way. A 2018 study by Dr. Susan Kennedy reported up to 20% of college students use Adderall, Ritalin, or other stimulants, and the rise of “study drugs” in high schools, both prescribed and illicit, is widely reported as well. While sales of Ambien sleeping pills fell between 2003 and 2013, sales of attention enhancers Adderall and Provigil multiplied 11 and 15 times, respectively, and mood-stabilizer Abilify, 112 times. Effecting another form of enhancement, Viagra rose 165%. Drugs targeting different classes of neurotransmitters will emerge from a busy pharmaceutical industry pipeline, and they will also form powerful combinations with existing medications.

Ritalin, by the way, got its name back in 1944 when the inventor’s wife, Rita, took the drug before playing tennis to ward off low blood pressure.

IMMUNE SYSTEM PERFORMANCE

A steep increase in allergic and autoimmune diseases now affects perhaps one billion people worldwide. Studies based at the University of Chicago comparing Amish and Hutterite children suggest that modernity worsens immune system education (**Figure 19**). The Amish have less asthma and fewer allergic diseases than the old order Mennonites. Otherwise very similar, the Amish have much more direct contact with farm animals.³

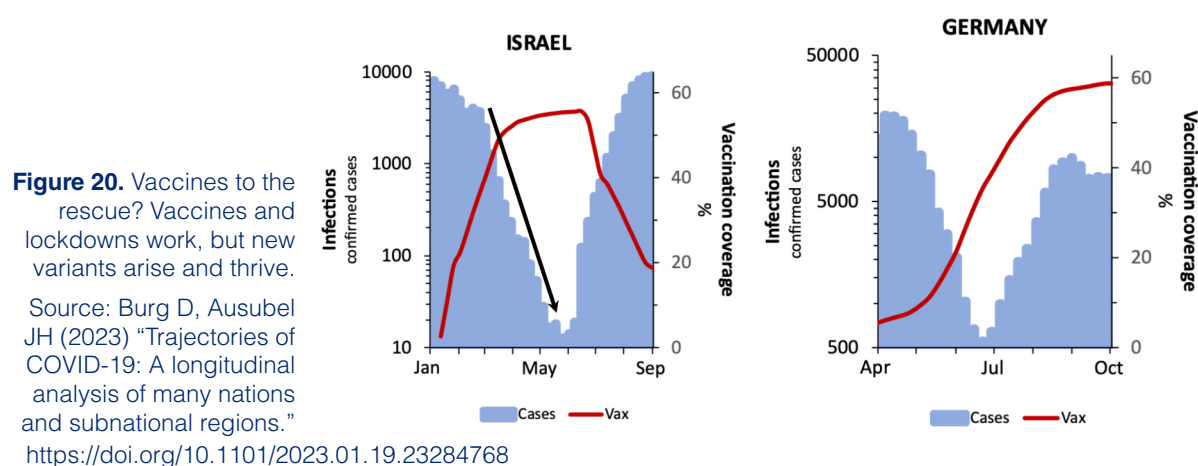


Figure 19. Amish children (*left*) have more contact with animals and fewer allergic diseases than Hutterite children (*right*).

Source: <https://news.uchicago.edu>

A big literature debates the so-called Hygiene Hypothesis, which proposes that children's immune systems learn a lot from mud and dirt, dogs and cats. A new descendant theory suggests that the decline may come from damage we do to our epithelial barriers in part through overuse of detergents and other chemicals. Extreme cleanliness may not be next to godliness.⁴

COVID has taught the world about the role of vaccines in immune system education. If we do not learn as children playing in the mud, we can stage a rehearsal through inoculation. We can also isolate and lock down, as in China's Zero-COVID policy. Combinations of the pair of strategies work, as data from Israel and Germany show, until lockdown unlocks or a new variant arises (**Figure 20**). As the late geneticist Joshua Lederberg remarked with regard to immune system education, "It's our wits versus their genes." Since 2020 the viral genes have been winning.



But our wits keep working in biomedical research institutions and companies in academia and elsewhere. Among other emerging therapies, in September 2022 a team published a promising study about treatment of the autoimmune disease lupus with CAR T cell therapy. This and other gene-editing therapies could bring drug-free remission of certain chronic, life-threatening diseases.⁵

INTEGRATING THE ELEMENTS OF HUMAN PERFORMANCE

To begin forming an integrated picture of human performance enhancement, let's revisit performance with regard to life expectancy, in which humanity has excelled. Other primates such as chimps and gorillas live about 20 years. Life expectancy in hunter-gatherer societies is 30 to 40 years. Most human societies have doubled that over the past couple of centuries and keep adding a month or so every year, a slowing rate of enhancement but still welcome.

Alas, in the USA and some other societies, we find blinking amber lights during the past decade. Life expectancy dropped in the US during 2015 and 2016 and then again during COVID (**Figure 21**). COVID contributed, but took mostly very elderly people, and did not grab huge numbers of life years as did the 1918–1919 influenza pandemic,

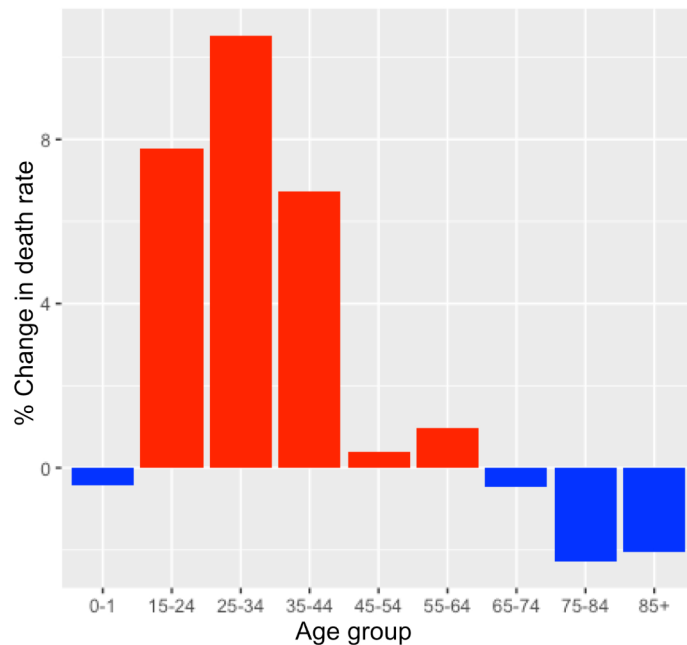


Figure 21. Change in US death rates by age group, 2015–2016.

Source: Centers for Disease Control

Credit: B Gardner, theincidentaleconomist.com

which killed lots of 20-somethings. But substance abuse, especially with fentanyl and other opioids, has stolen scores of life years with sharp rise of death rates of Americans between 18 and 44. About 100,000 Americans died of overdoses in 2021.

Globally the annual rate of elimination of years lost to illness (morbidity) has dropped from 2.1 billion to about 1.6 billion. We may be running out of good targets. And the diseases of the rich, particularly heart disease, stroke, and cancers, are becoming diseases of the poor or formerly poor, as sedentary lifestyles and abundant calories spread.

American men and women both fit the pattern of reaching some kind of limit to gains against morbidity (**Figure 22**). And we see the COVID uptick. Why? As hinted, Americans and the

world have been both enhancing and degrading human performance.

Consider first obesity in the USA for both men and women. In 1950 about 60% of women were of normal weight, while now about 80% are overweight, obese, and severely

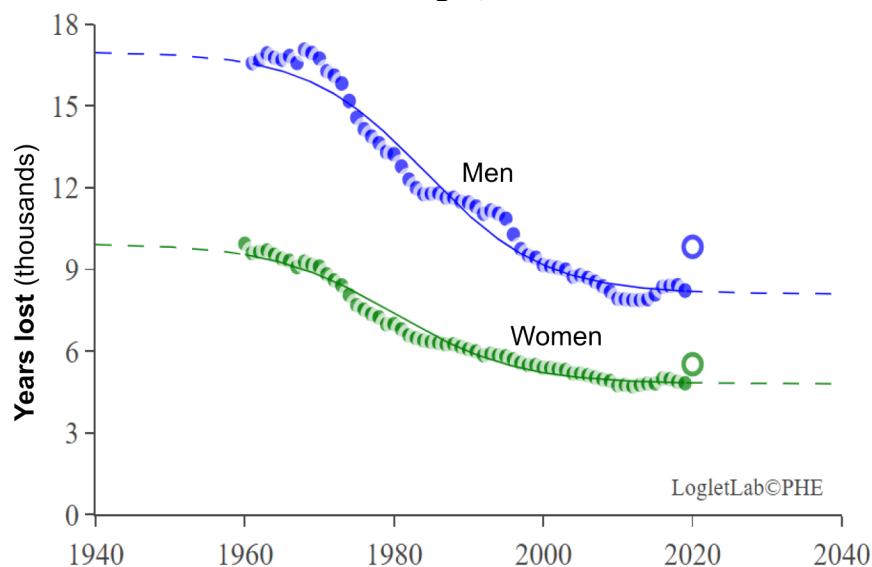


Figure 22. Years of life lost “prematurely” (before age 70) to illness in the US. Approaching a limit?

Data source: Organisation for Economic Co-operation and Development

obese. Men follow roughly the same paths (**Figure 23**).

We are not only fatter, but may be less clever as well. As we have seen, the grand era of cognitive enhancement may be ending for many societies. A UK study of simple reaction times even claims that general intelligence may have declined since Victorian times.⁶

We may also be weaker, at least unsupplemented. One study reports successive

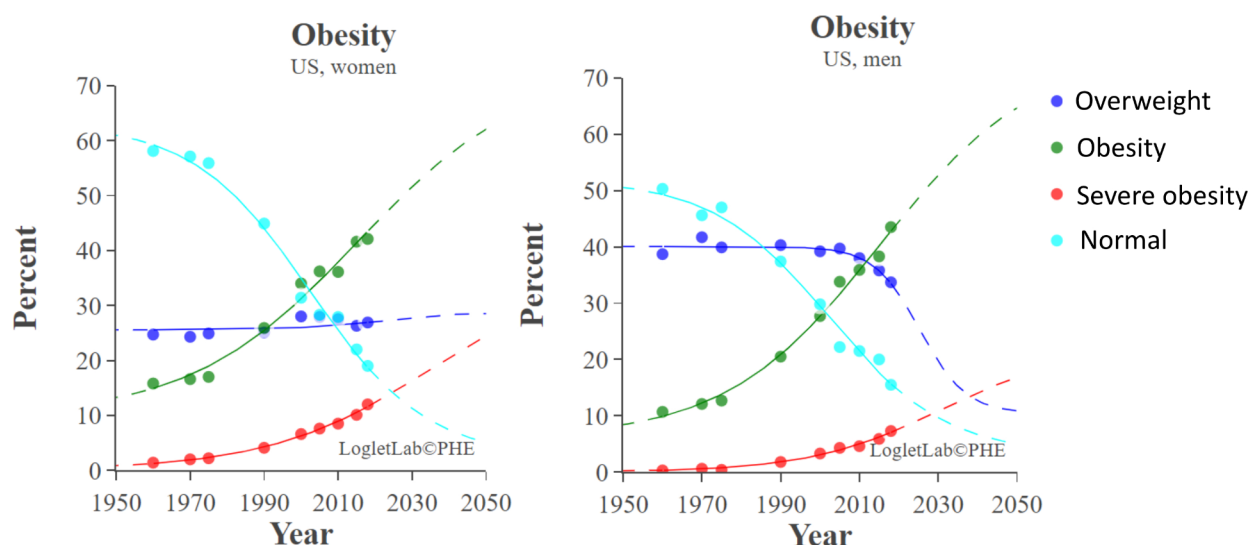


Figure 23. Obesity among US men and women. The fat majority.

Data source: Centers for Disease Control

declines in serum testosterone in cohorts of American men born in 1915 through 1945 (**Figure 24**). Studies from several countries report declining sperm counts.

Our vision is also fainter. Consider increases in myopia in Hong Kong, Taiwan, Singapore, South Korea, and Japan (**Figure 25**). While diagnoses may have become more widespread and sensitive, some of the trend very likely withstands elimination of biases.

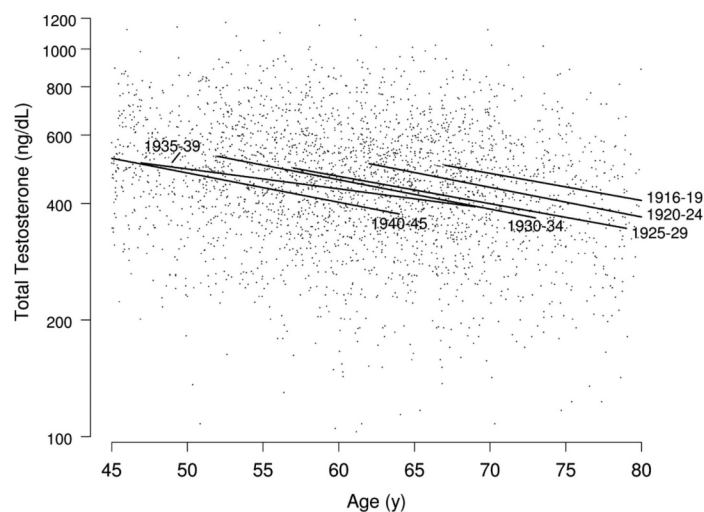


Figure 24. Massachusetts Male Aging Study decline in serum total testosterone concentrations in the analysis sample vs. age by 5-yr birth cohort. The approximately parallel lines indicate that the age-matched decline over time is consistent across age groups.

Source: TG Travison, et al. (2007) "A population-level decline in serum testosterone levels in American men," *The Journal of Clinical Endocrinology & Metabolism* 92(Jan), 196–202.
<https://doi.org/10.1210/jc.2006-1375>

The leading hypothesis is that young children's vision suffers from spending too little time in the bright outdoors, where eyes range over long distances, and too much time in dim schoolrooms and homes staring at books and video screens.

And we are sicker, at least men in Massachusetts as judged by the prescription medications used in 2002 versus 1987.⁷ Aging, more aggressive diagnostic practices, and more treatable conditions surely explain much of the difference, and the net outcome may be enhanced performance by this population, but it also suggests a worrisome dependency on pills.

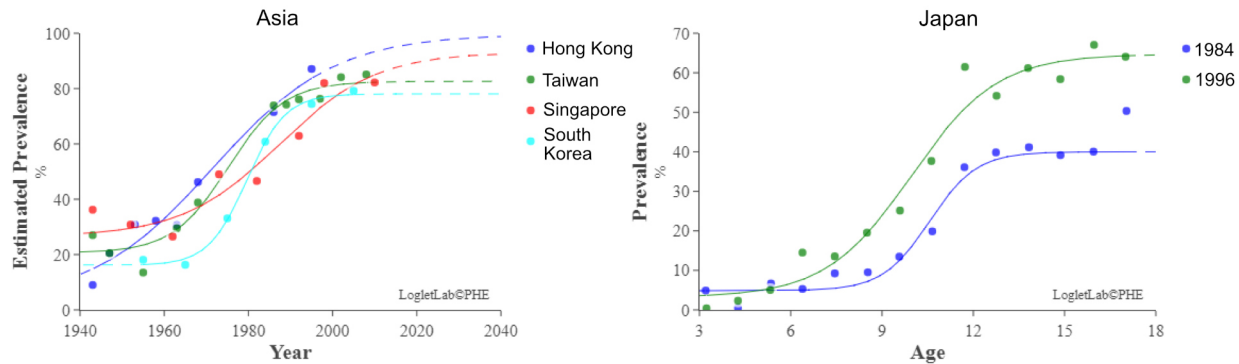


Figure 25. Increasing short-sightedness in Asian children.

Source: <https://www.bbc.com/future/article/20220927-can-you-prevent-short-sightedness-in-kids>

Why would humans now be degrading after centuries of spectacular gains? A sympathetic answer is that we are victims of our own success. The late geneticist William Hamilton worried that our success is creating a “planetary hospital.” Better survivorship and relaxation of natural selection bring a price, including a requirement for better ongoing health care. Moreover, some of our behavior, such as delaying children, may create on average more illness-prone children; in chimps and humans, germline mutations increase with father’s age.⁸

A complication, at least in the USA, is a rise in so-called assortative mating. Americans of similar background increasingly marry each other (**Figure 26**). For example, surges have occurred in doctors marrying other doctors and in those with no high school diplomas marrying partners also without diplomas. From an economic point of view, this kind of mating would tend to make the rich richer.

Any discussion of Peak Human must of course consider our total number. Since about 1950 we have grown from 2 to 4 to 8 billion, and only a few decades ago,

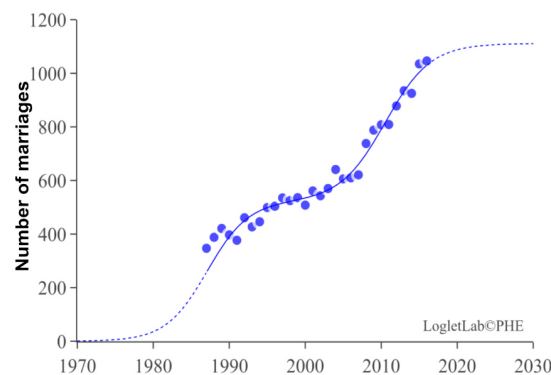


Figure 26. Number of marriages between physicians entering residency together in US, 1970–2018, an example of assortative mating. Americans of similar educational background increasingly marry one another.

Source: nrmp.org

projections of 20 billion humans were common. Now the highest UN projections barely graze 12 billion, and respected demographers, including Wolfgang Lutz, forecast a top below 10 billion before the year 2070 (**Figure 27**). We have probably passed Peak Baby, and most of those below the age of 30 today may well experience Peak People.

What about the USA? The US population is very likely to keep growing, even with fertility well below replacement, because of immigration. While Peak Italy, Peak Japan, Peak Russia, and Peak China may occur this decade, Peak USA seems many decades in the future.

Thoughts on the Evolution of the Enhancement of Human Performance

For the rest of Nature, the peaking of human numbers very likely offers relief, but for human performance the larger pool has its attractions. In any case, the extreme positive outliers in a world of 9 or 10 billion are likely to be truly exceptional, whether at basketball or mathematics or music.

HIGHLIGHTS AND OUTSTANDING QUESTIONS

First, whatever the causes or contributors, the Rectangularization of lifetime and physical performances is a huge enhancement of human performance. The survivorship curves for US Olympians from six different Olympics resemble the pattern of the entire population of India discussed earlier (**Figure 28**). Even among these high performers, performance kept extending and rising.

Second, the global secular diffusion of many enhancements emphasizes the large roles of protein and other basics such as electrification in many of the improvements. Vendors sell a lot of snake oil. Or, to quote Coco Chanel, “I do not sell perfume, I sell hope.” A lot of products and services have few or short-lived benefits, or offsetting fallout, physical and social. Still, with so many inventors and entrepreneurs searching for means of enhancement, the 21st century is sure to invent many successful ones. But they may be niche products compared with the sweeping markets for food and footwear. The “Flynn effect” may be seen in retrospect as a result of “therapeutic” elimination of nutritional and environmental

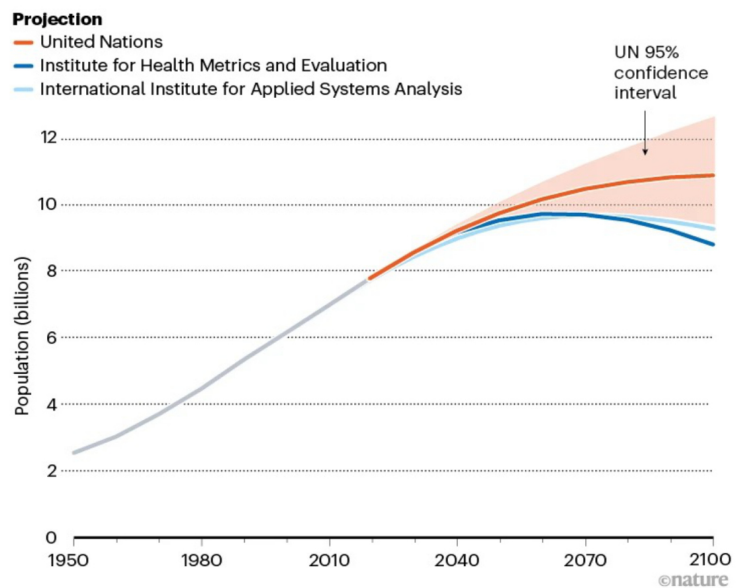


Figure 27. Peak People. The United Nations projects that global population will reach close to 11 billion by 2100, significantly higher than estimates from two other organizations.

Sources: UN Population Division, Institute for Health Metrics and Evaluation, and International Institute for Applied Systems Analysis. Credit: Nature

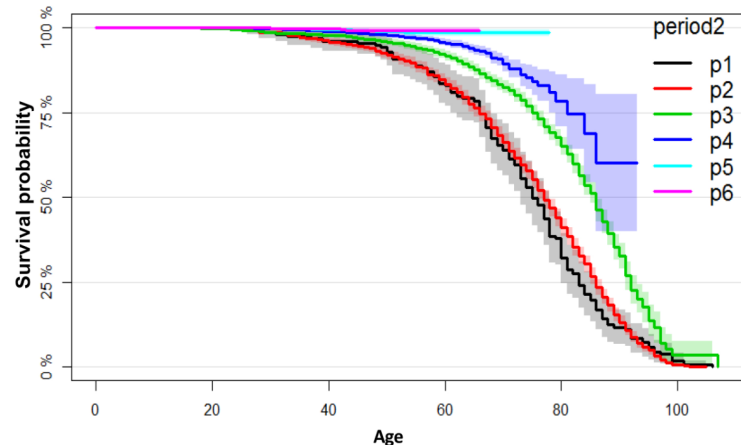


Figure 28. US Olympians survival probability by age in six historical periods: p1 1912; p2 1920–1936; p3 1948–1964; p4 1968–1984; p5 1988–1996; p6 1998–2012.

Credit: Antero J, et al. (2020) “Female and male US Olympic athletes live 5 years longer than their general population counterparts: A study of 8124 former US Olympians,” *British Journal of Sports Medicine* 55(4), 206–212. <https://bjsm.bmj.com/content/bjsports/55/4/206.full.pdf>

deficits, rather than evidence of “enhancement” of healthy or average performers (**Figure 29**).

But how much higher can enhancements take humans? At the outset we recognized machines have surpassed humans in matters of horsepower and other once-crucial aspects of physical performance. A comparable overtaking now occurs in cognition. Until 2018, the Electronic Frontier Foundation maintained a website showing competition between humans and machines in numerous cognitive tasks like playing chess and recognizing images. The EFF abandoned the project because the machines were surpassing us in every task tracked. The growth of machine learning and artificial intelligence puts in question the full range of human cognitive achievement.

The question thus becomes to what extent and how humans, or human groups, will ally with new kinds of machines. Will we give up competing with each other and with machines? Explicit hybrids such as car racing and E-sports may portend the future. For many individuals, motivation may prove the final frontier.

Obviously, different cultures may respond differently, spanning fatalism and celebration, regulation and machine-smashing. An important question is how diverse national cultures respond to the opportunities. While almost everyone who can afford them may adopt titanium golf clubs, what about new kinds of implants and deep brain stimulation? On a national level, acceptance could bring commercial and other forms of competitive success, as literacy lifted the Dutch and English. Corporations, militaries, and other organizations, including universities, which compete for prestige and power, all face ethical choices about what to allow and encourage. National and international sports organizations already wrestle with these choices. How many will hold out like the Amish?

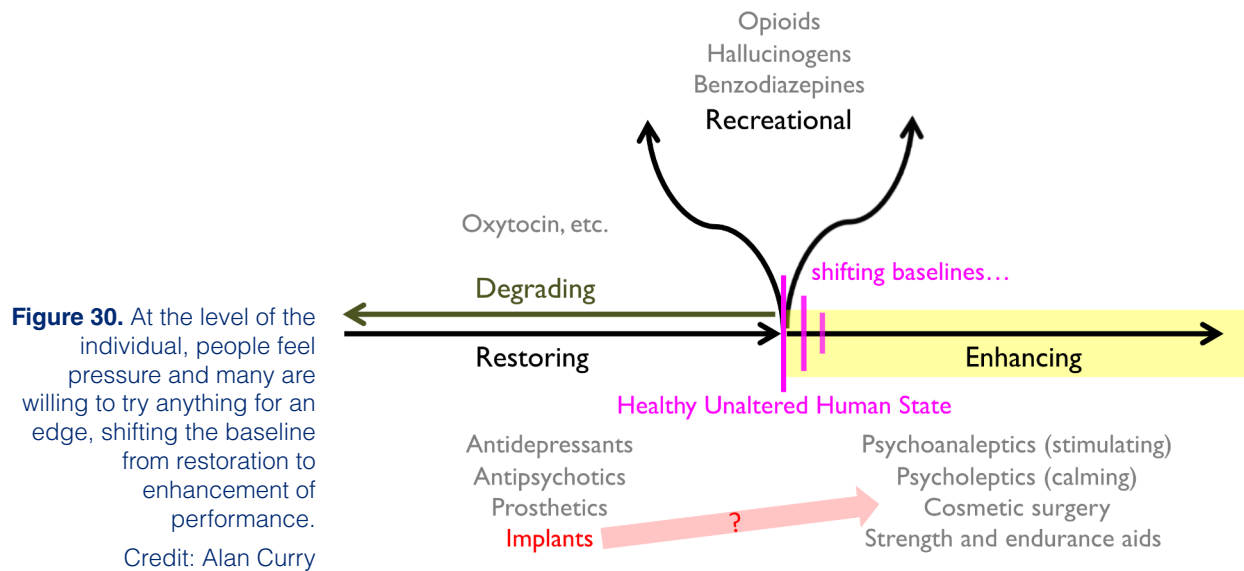
How will performance enhancement feel at the level of the individual or family? What does it look like from the bottom up? If opportunities to enter Peking University or other elite schools are one in a thousand and to play professional sports one in ten thousand, then the pressure to swallow many forms of enhancement will be enormous for anyone who enters the concourse, and for their parents (**Figure 30**). As already in Hollywood and in the market for nootropics, an increasing fraction of an individual’s encounters with the biomedical enterprise will relate to performance enhancement rather than restoration of health, except in that final steep decline during a rectangular life.



Figure 29. Kim Jong-un inspects protein sources. Many factors enhance performance, including historic gains from basics such as nutrition and public health.

Credit: Reuters

Thoughts on the Evolution of the Enhancement of Human Performance



A BRIEF RECAPITULATION

With regard to physical performance, at least at the envelope, where most data are collected, humans seem close to saturation or peak in measures of aerobic and anaerobic fitness. However, the performance of older adults continues to improve with postponement of age-related deterioration.

With regard to lifetime performance, maximum life span globally could continue to grow slowly, though Russia, America, and other countries have experienced recent admonitory reversals. Peak height should come in a few more decades, while peak vision may be past—peak testosterone and peak sperm, too.

With regard to cognition, performance (as measured by IQ) is close to saturation in most of the developed or advanced world, and flat or flattening by other measures as well.

With regard to immune system performance, at least as summarized by morbidity, we find years of life lost to illness still slightly improving, but offsetting degradation in many measures, most famously in prevalence of asthma and allergies and frequency of auto-immune conditions.

Overall, we see a broad stagnation in measures of human performance. However, high headroom exists for averages to rise toward top performers. Elite performers, whether shooting three-point baskets or resisting COVID, show ways for the rest of society to improve its functioning, as the right tail lends a hand to the general distribution. Of course, science aggressively seeks ways to move outliers to new frontiers, and commerce looks for profitable ways to diffuse the innovations. But, with Siri, Alexa, and other machines still in their adolescence, and enhancing their own performance steeply, many humans may choose to delegate the work to unfettered machines and rest on the plateau we appear to be reaching, very high compared to 5 or 10 generations ago.

In sum, Peak Human and Peak Humans seem a real possibility for the 21st century, Peak American too. Even as special forces become more special, the bigger questions may be how much societies lift the average in all dimensions of performance, which tends to linger at a quarter to half of the top in emblematic domains, and how fast societies can replicate near-peak performances, while minimizing unwanted fallout.

Surveying the spectrum of human performance enhancements from stilts and eyeglasses to personal trainers and vaccines also evokes, without irony, the Biblical declaration of Pontius Pilate when speaking of Jesus crowned with thorns, “Ecce homo,” behold the man (**Figure 31**). As humanity rides a trajectory of enhancement, let us not forget to ask, “Who is the real me?”

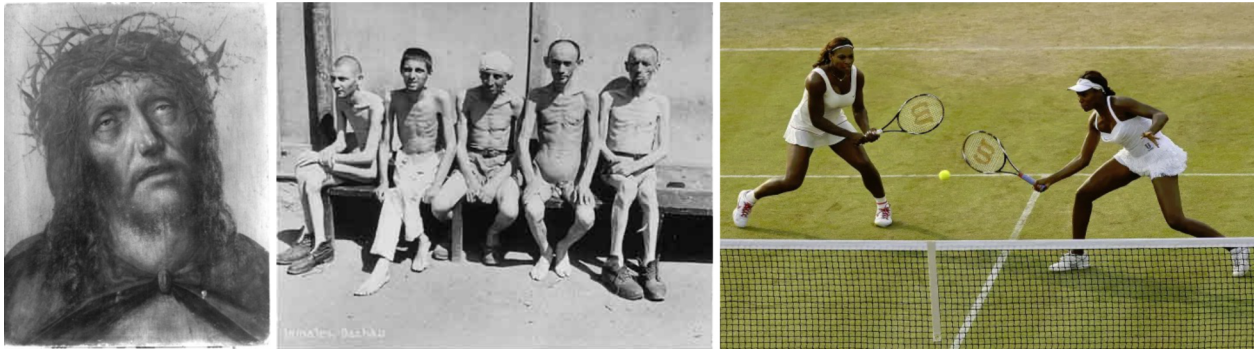


Figure 31. Who is the real me? From left, Ecce Homo by Albrecht Dürer (Source: Bavarian State Painting Collections, Public domain, via Wikimedia Commons); Survivors at Dachau Concentration Camp (Source: <https://www.jewishvirtuallibrary.org/holocaust-survivors>); Venus and Serena Williams at Wimbledon, 2010 (Source: Glyn Kirk/AFP/Getty Images).

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