Singularity
Definition

"The Singularity" redirects here. For other uses, see Singularity (disambiguation).

The **technological singularity** is a hypothetical event in which an upgradable intelligent agent (such as a computer running software-based artificial general intelligence) enters a 'runaway reaction' of self-improvement cycles, with each new and more intelligent generation appearing more and more rapidly, causing an intelligence explosion and resulting in a powerful superintelligence whose cognitive abilities could be, qualitatively, as far above humans' as human intelligence is above ape intelligence.[1][2][3] More broadly, the term has historically been used for any form of accelerating or exponential technological progress hypothesized to result in a discontinuity, beyond which events may become unpredictable or even unfathomable to human intelligence.[4]

Historically, the first documented use of the term "singularity" in a technological context was by Stanislaw Ulam in his 1958 obituary for John von Neumann, in which he mentioned a conversation with von Neumann about the "ever accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue".[5] The term "technological singularity" was popularized by mathematician, computer scientist and science fiction author Vernor Vinge, who argues that artificial intelligence, human biological enhancement, or brain–computer interfaces could be possible causes of the singularity.[6] While some futurists such as Ray Kurzweil maintain that human-computer fusion, or "cyborgization", is a plausible path to the singularity, most academic scholarship focuses on software-only intelligence as a more likely path.

In 2012, a study of artificial general intelligence (AGI) predictions by both experts and non-experts found a wide range of predicted dates, with a median value of 2040.[7] Discussing the level of uncertainty in AGI estimates, study co-author Stuart Armstrong stated: "my current 80% estimate is something like five to 100 years."[8] Kurzweil predicts the singularity to occur around 2045[9] whereas Vinge has predicted some time before 2030.[10]

1 Manifestations

1.1 Intelligence explosion

Main article: Intelligence explosion

Strong AI might bring about an intelligence explosion, a term coined in 1965 by I. J. Good.[11] Although technological progress has been accelerating, it has been limited by the basic intelligence of the human brain, which has not, according to Paul R. Ehrlich, changed significantly for millennia.[12] However, with the increasing power of computers and other technologies, it might eventually be possible to build a machine that is more intelligent than humanity.[13] If a superhuman intelligence were to be invented—either through the amplification of human intelligence or through artificial intelligence—it might be able to bring to bear greater problem-solving and inventive skills than current humans are capable of. It might then design an even more capable machine, or re-write its own software to become even more intelligent. This more capable machine could then go on to design a machine of yet greater capability. These iterations of recursive self-improvement could accelerate, potentially allowing enormous qualitative change before any upper limits imposed by the laws of physics or theoretical computation set in.[14][15][16]

1.2 Emergence of superintelligence

Main article: Superintelligence

Many of the most recognized writers on the singularity, such as Vernor Vinge and Ray Kurzweil, define the concept in terms of the technological creation of superintelligence. They argue that it is difficult or impossible for present-day humans to predict what human beings' lives will be like in a post-singularity world.[9][10][17] Vernor Vinge made an analogy between the breakdown in our ability to predict what would happen after the development of superintelligence and the breakdown of the predictive ability of modern physics at the space-time singularity beyond the event horizon of a black hole.[17]

1.3 Non-AI singularity

Some writers use "the singularity" in a broader way to refer to any radical changes in our society brought

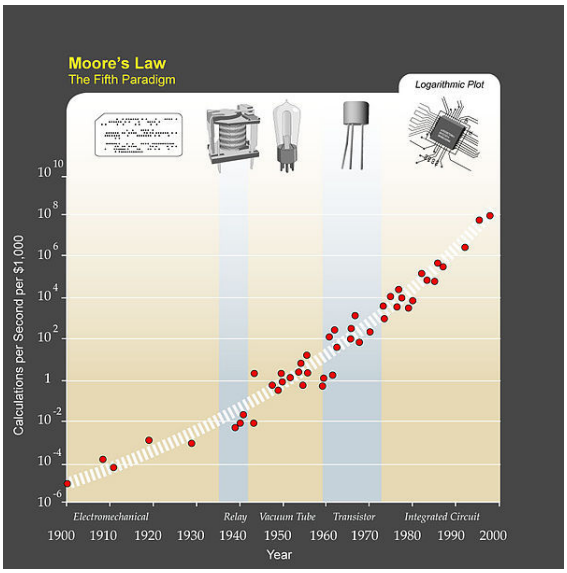
about by new technologies such as molecular nanotechnology,[18][19][20] although Vinge and other prominent writers specifically state that without superintelligence, such changes would not qualify as a true singularity.[10] Many writers also tie the singularity to observations of exponential growth in various technologies (with Moore's Law being the most prominent example), using such observations as a basis for predicting that the singularity is likely to happen sometime within the 21st century.[19][21]

2 Plausibility

Further information: Intelligence explosion § Plausibility

Gary Marcus claims that "virtually everyone in the A.I. field believes" that machines will one day overtake humans and "at some level, the only real difference between enthusiasts and skeptics is a time frame."[22] However, many prominent technologists and academics dispute the plausibility of a technological singularity, including Paul Allen, Jeff Hawkins, John Holland, Jaron Lanier, and Gordon Moore, whose Moore's Law is often cited in support of the concept.[23][24][25]

2.1 Likely cause: exponential growth



Ray Kurzweil writes that, due to paradigm shifts, a trend of exponential growth extends Moore's law from integrated circuits to earlier transistors, vacuum tubes, relays, and electromechanical computers. He predicts that the exponential growth will continue, and that in a few decades the computing power of all computers will exceed that of ("unenhanced") human brains, with superhuman artificial intelligence appearing around the same time.

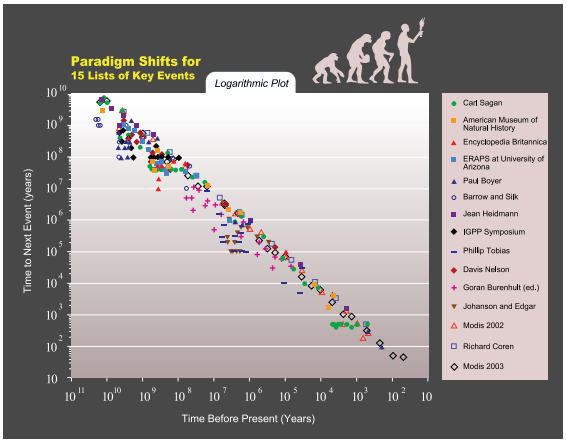
The exponential growth in computing technology suggested by Moore's Law is commonly cited as a reason to expect a singularity in the relatively near future, and a number of authors have proposed generalizations of Moore's Law. Computer scientist and futurist Hans Moravec proposed in a 1998 book[26] that the exponential growth curve could be extended back through earlier computing technologies prior to the integrated circuit. Futurist Ray Kurzweil postulates a law of accelerating returns in which the speed of technological change (and more generally, all evolutionary processes[27]) increases exponentially, generalizing Moore's Law in the same manner as Moravec's proposal, and also including material technology (especially as applied to nanotechnology), medical technology and others.[28] Between 1986 and 2007, machines' application-specific capacity to compute information per capita has roughly doubled every 14 months; the per capita capacity of the world's general-purpose computers has doubled every 18 months; the global telecommunication capacity per capita doubled every 34 months; and the world's storage capacity per capita doubled every 40 months.[29] Like other authors, though, Kurzweil reserves the term "singularity" for a rapid increase in intelligence (as opposed to other technologies), writing for example that "The Singularity will allow us to transcend these limitations of our biological bodies and brains ... There will be no distinction, post-Singularity, between human and machine".[30] He believes that the "design of the human brain, while not simple, is nonetheless a billion times simpler than it appears, due to massive redundancy".[31] According to Kurzweil, the reason why the brain has a messy and unpredictable quality is because the brain, like most biological systems, is a "probabilistic fractal".[31] He also defines his predicted date of the singularity (2045) in terms of when he expects computer-based intelligences to significantly exceed the sum total of human brainpower, writing that advances in computing before that date "will not represent the Singularity" because they do "not yet correspond to a profound expansion of our intelligence."[32]

2.1.1 Accelerating change

Main article: Accelerating change

Some singularity proponents argue its inevitability through extrapolation of past trends, especially those pertaining to shortening gaps between improvements to technology. In one of the first uses of the term "singularity" in the context of technological progress, Stanislaw Ulam (1958) tells of a conversation with John von Neumann about accelerating change:

> One conversation centered on the ever accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue.[5]



According to Kurzweil, his logarithmic graph of 15 lists of paradigm shifts for key historic events shows an exponential trend

Hawkins (1983) writes that "mindsteps", dramatic and irreversible changes to paradigms or world views, are accelerating in frequency as quantified in his mindstep equation. He cites the inventions of writing, mathematics, and the computer as examples of such changes.

Kurzweil's analysis of history concludes that technological progress follows a pattern of exponential growth, following what he calls the "Law of Accelerating Returns". Whenever technology approaches a barrier, Kurzweil writes, new technologies will surmount it. He predicts paradigm shifts will become increasingly common, leading to "technological change so rapid and profound it represents a rupture in the fabric of human history".[33] Kurzweil believes that the singularity will occur before the end of the 21st century, setting the date at 2045.[34] His predictions differ from Vinge's in that he predicts a gradual ascent to the singularity, rather than Vinge's rapidly self-improving superhuman intelligence.

Presumably, a technological singularity would lead to rapid development of a Kardashev Type I civilization, one that has achieved mastery of the resources of its home planet.[35]

Oft-cited dangers include those commonly associated with molecular nanotechnology and genetic engineering. These threats are major issues for both singularity advocates and critics, and were the subject of Bill Joy's *Wired* magazine article "Why the future doesn't need us".[36]

The Acceleration Studies Foundation, an educational non-profit foundation founded by John Smart, engages in outreach, education, research and advocacy concerning accelerating change.[37] It produces the Accelerating Change conference at Stanford University, and maintains the educational site Acceleration Watch.

Recent advances, such as the mass production of graphene using modified kitchen blenders (2014) and high temperature superconductors based on metamaterials, could allow supercomputers to be built that, while using only as much power as a typical Core I7 (45W), could achieve the same computing power as IBM's Blue Gene/L system.[38][39]

2.2 Criticisms

Some critics assert that no computer or machine will ever achieve human intelligence, while others hold that the definition of intelligence is irrelevant if the net result is the same.[40]

Steven Pinker stated in 2008,

> (...) There is not the slightest reason to believe in a coming singularity. The fact that you can visualize a future in your imagination is not evidence that it is likely or even possible. Look at domed cities, jet-pack commuting, underwater cities, mile-high buildings, and nuclear-powered automobiles—all staples of futuristic fantasies when I was a child that have never arrived. Sheer processing power is not a pixie dust that magically solves all your problems. (...)[23]

Martin Ford in *The Lights in the Tunnel: Automation, Accelerating Technology and the Economy of the Future*[41] postulates a "technology paradox" in that before the singularity could occur most routine jobs in the economy would be automated, since this would require a level of technology inferior to that of the singularity. This would cause massive unemployment and plummeting consumer demand, which in turn would destroy the incentive to invest in the technologies that would be required to bring about the Singularity. Job displacement is increasingly no longer limited to work traditionally considered to be "routine".[42]

Joan Slonczewski and Adam Gopnik argue that the Singularity is a gradual process; that as humans gradually outsource our abilities to machines,[43] we redefine those abilities as inhuman, without realizing how little is left. This concept is called the Mitochondrial Singularity.[44] The idea refers to mitochondria, the organelle that evolved from autonomous bacteria but now powers our living cells. In the future, the "human being" within the machine exoskeleton may exist only to turn it on.

Jared Diamond, in *Collapse: How Societies Choose to Fail or Succeed*, argues that cultures self-limit when they exceed the sustainable carrying capacity of their environment, and the consumption of strategic resources (frequently timber, soils or water) creates a deleterious positive feedback loop that leads eventually to social collapse and technological retrogression.

Theodore Modis[45][46] and Jonathan Huebner[47] argue that the rate of technological innovation has not only ceased to rise, but is actually now declining (John Smart, however, criticizes Huebner's analysis[48]). Evidence for

this decline is that the rise in computer clock rates is slowing, even while Moore's prediction of exponentially increasing circuit density continues to hold. This is due to excessive heat build-up from the chip, which cannot be dissipated quickly enough to prevent the chip from melting when operating at higher speeds. Advancements in speed may be possible in the future by virtue of more power-efficient CPU designs and multi-cell processors.[49] While Kurzweil used Modis' resources, and Modis' work was around accelerating change, Modis distanced himself from Kurzweil's thesis of a "technological singularity", claiming that it lacks scientific rigor.[46]

Others propose that other "singularities" can be found through analysis of trends in world population, world gross domestic product, and other indices. Andrey Korotayev and others argue that historical hyperbolic growth curves can be attributed to feedback loops that ceased to affect global trends in the 1970s, and thus hyperbolic growth should not be expected in the future.[50][51]

In a detailed empirical accounting, *The Progress of Computing*, William Nordhaus argued that, prior to 1940, computers followed the much slower growth of a traditional industrial economy, thus rejecting extrapolations of Moore's law to 19th-century computers.[52] Schmidhuber (2006) suggests differences in memory of recent and distant events create an illusion of accelerating change, and that such phenomena may be responsible for past apocalyptic predictions.

Andrew Kennedy, in his 2006 paper for the British Interplanetary Society discussing change and the growth in space travel velocities,[53] stated that although long-term overall growth is inevitable, it is small, embodying both ups and downs, and noted, "New technologies follow known laws of power use and information spread and are obliged to connect with what already exists. Remarkable theoretical discoveries, if they end up being used at all, play their part in maintaining the growth rate: they do not make its plotted curve... redundant." He stated that exponential growth is no predictor in itself, and illustrated this with examples such as quantum theory. The quantum was conceived in 1900, and quantum theory was in existence and accepted approximately 25 years later. However, it took over 40 years for Richard Feynman and others to produce meaningful numbers from the theory. Bethe understood nuclear fusion in 1935, but 75 years later fusion reactors are still only used in experimental settings. Similarly, quantum entanglement was understood in 1935 but not at the point of being used in practice until the 21st century.

Paul Allen argues the opposite of accelerating returns, the complexity brake;[25] the more progress science makes towards understanding intelligence, the more difficult it becomes to make additional progress. A study of the number of patents shows that human creativity does not show accelerating returns, but in fact, as suggested by Joseph Tainter in his *The Collapse of Complex Societies*,[54] a law of diminishing returns. The number of patents per thousand peaked in the period from 1850 to 1900, and has been declining since.[47] The growth of complexity eventually becomes self-limiting, and leads to a widespread "general systems collapse".

Jaron Lanier refutes the idea that the Singularity is inevitable. He states: "I do not think the technology is creating itself. It's not an autonomous process."[55] He goes on to assert: "The reason to believe in human agency over technological determinism is that you can then have an economy where people earn their own way and invent their own lives. If you structure a society on *not* emphasizing individual human agency, it's the same thing operationally as denying people clout, dignity, and self-determination ... to embrace [the idea of the Singularity] would be a celebration of bad data and bad politics."[55]

In addition to general criticisms of the singularity concept, several critics have raised issues with Kurzweil's iconic chart. One line of criticism is that a log-log chart of this nature is inherently biased toward a straight-line result. Others identify selection bias in the points that Kurzweil chooses to use. For example, biologist PZ Myers points out that many of the early evolutionary "events" were picked arbitrarily.[56] Kurzweil has rebutted this by charting evolutionary events from 15 neutral sources, and showing that they fit a straight line on a log-log chart. *The Economist* mocked the concept with a graph extrapolating that the number of blades on a razor, which has increased over the years from one to as many as five, will increase ever-faster to infinity.[57]

3 Ramifications

3.1 Uncertainty and risk

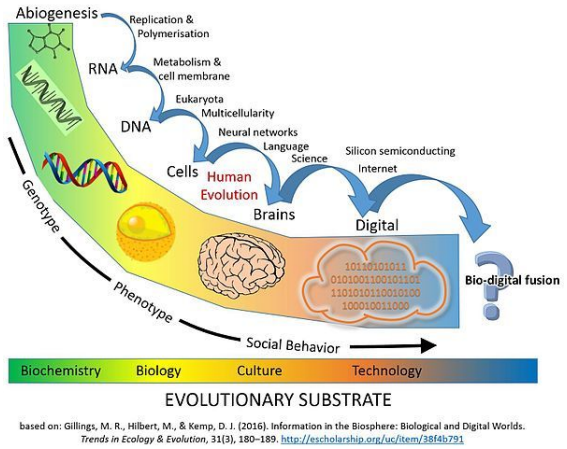
Further information: Existential risk from artificial general intelligence

The term "technological singularity" reflects the idea that such change may happen suddenly, and that it is difficult to predict how the resulting new world would operate.[58][59] It is unclear whether an intelligence explosion of this kind would be beneficial or harmful, or even an existential threat,[60][61] as the issue has not been dealt with by most artificial general intelligence researchers, although the topic of friendly artificial intelligence is investigated by the Future of Humanity Institute and the Singularity Institute for Artificial Intelligence, which is now the Machine Intelligence Research Institute.[58]

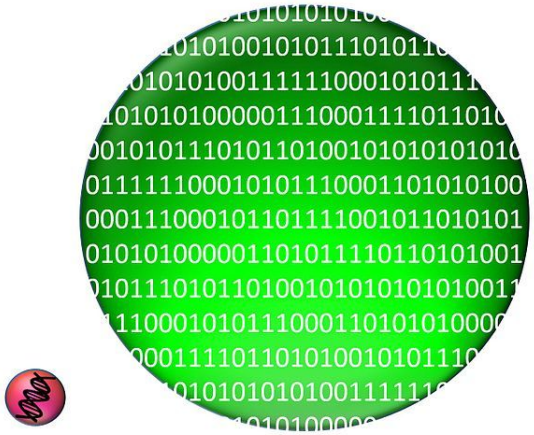
3.2 Next step of sociobiological evolution

Further information: Sociocultural evolution

While the technological singularity is usually seen as a



Schematic Timeline of Information and Replicators in the Biosphere: Gillings et al.'s "major evolutionary transitions" in information processing.[62]



Amount of digital information worldwide (5x10^21) versus human genome information worldwide (10^19) in 2014.[62]

sudden event, some scholars argue the current speed of change already fits this description. In addition, some argue that we are already in the midst of a major evolutionary transition that merges technology, biology, and society. Digital technology has infiltrated the fabric of human society to a degree of undisputable and often life-sustaining dependence. A 2016 article in Trends in Ecology & Evolution argues that "humans already embrace fusions of biology and technology. We spend most of our waking time communicating through digitally mediated channels... we trust artificial intelligence with our lives through antilock braking in cars and autopilots in planes... With one in three marriages in America beginning online, digital algorithms are also taking a role in human pair bonding and reproduction". The article argues that from the perspective of the evolution, several previous Major Transitions in Evolution have transformed life through innovations in information storage and replication (RNA, DNA, multicellularity, and culture and language). In the current stage of life's evolution, the carbon-based biosphere has generated a cognitive system (humans) capable of creating technology that will result in a comparable evolutionary transition. The digital information created by humans has reached a similar magnitude to biological information in the biosphere. Since the 1980s, "the quantity of digital information stored has doubled about every 2.5 years, reaching about 5 zettabytes in 2014 (5x10^21 bytes). In biological terms, there are 7.2 billion humans on the planet, each having a genome of 6.2 billion nucleotides. Since one byte can encode four nucleotide pairs, the individual genomes of every human on the planet could be encoded by approximately 1x10^19 bytes. The digital realm stored 500 times more information than this in 2014 (...see Figure)... The total amount of DNA contained in all of the cells on Earth is estimated to be about 5.3x10^37 base pairs, equivalent to 1.325x10^37 bytes of information. If growth in digital storage continues at its current rate of 30–38% compound annual growth per year,[29] it will rival the total information content contained in all of the DNA in all of the cells on Earth in about 110 years. This would represent a doubling of the amount of information stored in the biosphere across a total time period of just 150 years".[62]

3.3 Implications for human society

In February 2009, under the auspices of the Association for the Advancement of Artificial Intelligence (AAAI), Eric Horvitz chaired a meeting of leading computer scientists, artificial intelligence researchers and roboticists at Asilomar in Pacific Grove, California. The goal was to discuss the potential impact of the hypothetical possibility that robots could become self-sufficient and able to make their own decisions. They discussed the extent to which computers and robots might be able to acquire autonomy, and to what degree they could use such abilities to pose threats or hazards.

Some machines have acquired various forms of semi-autonomy, including the ability to locate their own power sources and choose targets to attack with weapons. Also, some computer viruses can evade elimination and, according to scientists in attendance, could therefore be said to have reached a "cockroach" stage of machine intelligence. The conference attendees noted that self-awareness as depicted in science-fiction is probably unlikely, but that other potential hazards and pitfalls exist.[63]

Some experts and academics have questioned the use of robots for military combat, especially when such robots are given some degree of autonomous functions.[64] A United States Navy report indicates that, as military robots become more complex, there should be greater attention to implications of their ability to make autonomous decisions.[65][66]

The AAAI has commissioned a study to examine this issue,[67] pointing to programs like the Language Acquisition Device, which was claimed to emulate human in-

teraction.

Some support the design of friendly artificial intelligence, meaning that the advances that are already occurring with AI should also include an effort to make AI intrinsically friendly and humane.[68]

Isaac Asimov's Three Laws of Robotics is one of the earliest examples of proposed safety measures for AI. The laws are intended to prevent artificially intelligent robots from harming humans. In Asimov's stories, any perceived problems with the laws tend to arise as a result of a misunderstanding on the part of some human operator; the robots themselves are merely acting to their best interpretation of their rules. In the 2004 film *I, Robot*, loosely based on Asimov's *Robot* stories, an AI attempts to take complete control over humanity for the purpose of protecting humanity from itself due to an extrapolation of the Three Laws. In 2004, the Machine Intelligence Research Institute launched an Internet campaign called *3 Laws Unsafe* to raise awareness of AI safety issues and the inadequacy of Asimov's laws in particular.[69]

4 Immortality

In his 2005 book, *The Singularity is Near*, Kurzweil suggests that medical advances would allow people to protect their bodies from the effects of aging, making the life expectancy limitless. Kurzweil argues that the technological advances in medicine would allow us to continuously repair and replace defective components in our bodies, prolonging life to an undetermined age.[70] Kurzweil further buttresses his argument by discussing current bioengineering advances. Kurzweil analyzed Somatic Gene Therapy (SGT), which is where scientists attempt to infect patients with modified viruses with the goal of altering the DNA in cells that lead to degenerative diseases and aging. Celera Genomics, a company focused on creating genetic sequencing technology, has already fulfilled the task of creating synthetic viruses with specific genetic information. The next step would be to apply this technology to gene therapy.[71] Kurzweil's point is that SGT provides the best example of how immortality is achievable by replacing our DNA with synthesized genes.

5 Religion

Computer scientist, Jaron Lanier, writes, "The Singularity [involves] people dying in the flesh and being uploaded into a computer and remaining conscious".[72] The essence of Lanier's argument is that in order to keep living, even after death, we would need to abandon our physical bodies and have our minds programmed into a virtual reality. This parallels the religious concept of an afterlife where one continues to exist beyond physical death.

Strong artificial intelligence can also be idealized as "a matter of faith", and Ray Kurzweil is said to have said that the creation of a deity may be the possible outcome of the singularity.[73]

Singularitarianism has been likened to a religion by John Horgan.[74]

6 History of the idea

Nicolas de Condorcet, the 18th-century French mathematician, philosopher, and revolutionary, is commonly credited for being one of the earliest persons to contend the existence of a singularity. In his 1794 Sketch for a Historical Picture of the Progress of the Human Mind, Condorcet states,

> Nature has set no term to the perfection of human faculties; that the perfectibility of man is truly indefinite; and that the progress of this perfectibility, from now onwards independent of any power that might wish to halt it, has no other limit than the duration of the globe upon which nature has cast us. This progress will doubtless vary in speed, but it will never be reversed as long as the earth occupies its present place in the system of the universe, and as long as the general laws of this system produce neither a general cataclysm nor such changes as will deprive the human race of its present faculties and its present resources."[75]

In 1847, R. Thornton, the editor of *The Expounder of Primitive Christianity*,[76] wrote about the recent invention of a four-function mechanical calculator:

> ...such machines, by which the scholar may, by turning a crank, grind out the solution of a problem without the fatigue of mental application, would by its introduction into schools, do incalculable injury. But who knows that such machines when brought to greater perfection, may not think of a plan to remedy all their own defects and then grind out ideas beyond the ken of mortal mind!

In 1863, Samuel Butler wrote Darwin Among the Machines, which was later incorporated into his novel Erewhon. He pointed out the rapid evolution of technology and compared it with the evolution of life. He wrote:

> Reflect upon the extraordinary advance which machines have made during the last few hundred years, and note how slowly the animal and vegetable kingdoms are advancing. The more highly organised machines are creatures not so much of yesterday, as of the last

> five minutes, so to speak, in comparison with past time. Assume for the sake of argument that conscious beings have existed for some twenty million years: see what strides machines have made in the last thousand! May not the world last twenty million years longer? If so, what will they not in the end become?...we cannot calculate on any corresponding advance in man's intellectual or physical powers which shall be a set-off against the far greater development which seems in store for the machines.

In 1909, the historian Henry Adams wrote an essay, *The Rule of Phase Applied to History*,[77] in which he developed a "physical theory of history" by applying the law of inverse squares to historical periods, proposing a "Law of the Acceleration of Thought." Adams interpreted history as a process moving towards an "equilibrium", and speculated that this process would "bring Thought to the limit of its possibilities in the year 1921. It may well be!", adding that the "consequences may be as surprising as the change of water to vapor, of the worm to the butterfly, of radium to electrons."[78] The futurist John Smart has called Adams "Earth's First Singularity Theorist".[79]

In 1951, Alan Turing spoke of machines outstripping humans intellectually:[80]

> once the machine thinking method has started, it would not take long to outstrip our feeble powers. ... At some stage therefore we should have to expect the machines to take control, in the way that is mentioned in Samuel Butler's *Erewhon*.

In his obituary for John von Neumann, Stanislaw Ulam recalled a conversation with von Neumann about the "ever accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue."[5]

In 1965, I. J. Good first wrote of an "intelligence explosion", suggesting that if machines could even slightly surpass human intellect, they could improve their own designs in ways unforeseen by their designers, and thus recursively augment themselves into far greater intelligences. The first such improvements might be small, but as the machine became more intelligent it would become better at becoming more intelligent, which could lead to a cascade of self-improvements and a sudden surge to superintelligence (or a singularity).

In 1983, mathematician and author Vernor Vinge greatly popularized Good's notion of an intelligence explosion in a number of writings, first addressing the topic in print in the January 1983 issue of *Omni* magazine. In this op-ed piece, Vinge seems to have been the first to use the term "singularity" in a way that was specifically tied to the creation of intelligent machines,[81][82] writing:

> We will soon create intelligences greater than our own. When this happens, human history will have reached a kind of singularity, an intellectual transition as impenetrable as the knotted space-time at the center of a black hole, and the world will pass far beyond our understanding. This singularity, I believe, already haunts a number of science-fiction writers. It makes realistic extrapolation to an interstellar future impossible. To write a story set more than a century hence, one needs a nuclear war in between ... so that the world remains intelligible.

In 1984, Samuel R. Delany used "cultural fugue" as a plot device in his science-fiction novel *Stars in My Pocket Like Grains of Sand*; the terminal runaway of technological and cultural complexity in effect destroys all life on any world on which it transpires, a process poorly understood by the novel's characters, and against which they seek a stable defense. In 1985, Ray Solomonoff introduced the notion of "infinity point"[83] in the time-scale of artificial intelligence, analyzed the magnitude of the "future shock" that "we can expect from our AI expanded scientific community" and on social effects. Estimates were made "for when these milestones would occur, followed by some suggestions for the more effective utilization of the extremely rapid technological growth that is expected".

Vinge also popularized the concept in SF novels such as *Marooned in Realtime* (1986) and *A Fire Upon the Deep* (1992). The former is set in a world of rapidly accelerating change leading to the emergence of more and more sophisticated technologies separated by shorter and shorter time-intervals, until a point beyond human comprehension is reached. The latter starts with an imaginative description of the evolution of a superintelligence passing through exponentially accelerating developmental stages ending in a transcendent, almost omnipotent power unfathomable by mere humans. Vinge also implies that the development may not stop at this level.

In his 1988 book *Mind Children*, computer scientist and futurist Hans Moravec generalizes Moore's law to make predictions about the future of artificial life. Moravec outlines a timeline and a scenario in this regard,[84][85] in that robots will evolve into a new series of artificial species, starting around 2030–40.[86] In *Robot: Mere Machine to Transcendent Mind*, published in 1998, Moravec further considers the implications of evolving robot intelligence, generalizing Moore's law to technologies predating the integrated circuit, and speculating about a coming "mind fire" of rapidly expanding superintelligence, similar to Vinge's ideas.

A 1993 article by Vinge, "The Coming Technological

Singularity: How to Survive in the Post-Human Era",[10] spread widely on the internet and helped to popularize the idea.[87] This article contains the oft-quoted statement, "Within thirty years, we will have the technological means to create superhuman intelligence. Shortly after, the human era will be ended." Vinge refines his estimate of the time-scales involved, adding, "I'll be surprised if this event occurs before 2005 or after 2030."

Vinge predicted four ways the singularity could occur:[88]

1. The development of computers that are "awake" and superhumanly intelligent.
2. Large computer networks (and their associated users) may "wake up" as a superhumanly intelligent entity.
3. Computer/human interfaces may become so intimate that users may reasonably be considered superhumanly intelligent.
4. Biological science may find ways to improve upon the natural human intellect.

Vinge continues by predicting that superhuman intelligences will be able to enhance their own minds faster than their human creators. "When greater-than-human intelligence drives progress," Vinge writes, "that progress will be much more rapid." He predicts that this feedback loop of self-improving intelligence will cause large amounts of technological progress within a short period, and states that the creation of superhuman intelligence represents a breakdown in humans' ability to model their future. His argument was that authors cannot write realistic characters who surpass the human intellect, as the thoughts of such an intellect would be beyond the ability of humans to express. Vinge named this event "the Singularity".

Damien Broderick's popular science book *The Spike* (1997) was the first to investigate the technological singularity in detail.

In 2000, Bill Joy, a prominent technologist and a co-founder of Sun Microsystems, voiced concern over the potential dangers of the singularity.[89]

In 2005, Ray Kurzweil published *The Singularity is Near*, which brought the idea of the singularity to the popular media both through the book's accessibility and through a publicity campaign that included an appearance on *The Daily Show with Jon Stewart*.[90] The book stirred intense controversy, in part because Kurzweil's utopian predictions contrasted starkly with other, darker visions of the possibilities of the singularity. Kurzweil, his theories, and the controversies surrounding it were the subject of Barry Ptolemy's documentary *Transcendent Man*.

In 2007, Eliezer Yudkowsky suggested that many of the varied definitions that have been assigned to "singularity" are mutually incompatible rather than mutually supporting.[19] For example, Kurzweil extrapolates current technological trajectories past the arrival of self-improving AI or superhuman intelligence, which Yudkowsky argues represents a tension with both I. J. Good's proposed discontinuous upswing in intelligence and Vinge's thesis on unpredictability.

In 2008, Robin Hanson (taking "singularity" to refer to sharp increases in the exponent of economic growth) listed the Agricultural and Industrial Revolutions as past singularities. Extrapolating from such past events, Hanson proposes that the next economic singularity should increase economic growth between 60 and 250 times. An innovation that allowed for the replacement of virtually all human labor could trigger this event.[91]

In 2009, Kurzweil and X-Prize founder Peter Diamandis announced the establishment of Singularity University, whose stated mission is "to educate, inspire and empower leaders to apply exponential technologies to address humanity's grand challenges."[92] Funded by Google, Autodesk, ePlanet Ventures, and a group of technology industry leaders, Singularity University is based at NASA's Ames Research Center in Mountain View, California. The not-for-profit organization runs an annual ten-week graduate program during the northern-hemisphere summer that covers ten different technology and allied tracks, and a series of executive programs throughout the year.

In 2010, Aubrey de Grey applied the term "Methuselarity"[93] to the point at which medical technology improves so fast that expected human lifespan increases by more than one year per year. In "Apocalyptic AI – Visions of Heaven in Robotics, Artificial Intelligence, and Virtual Reality"[94] (2010), Robert Geraci offers an account of the developing "cyber-theology" inspired by Singularity studies. The 1996 novel *Holy Fire* by Bruce Sterling explores some of those themes and postulates that a Methuselarity will become a gerontocracy.

In 2011, Kurzweil noted existing trends and concluded that it appeared increasingly likely that the singularity would occur around 2045. He told *Time* magazine: "We will successfully reverse-engineer the human brain by the mid-2020s. By the end of that decade, computers will be capable of human-level intelligence."[95]

7 In popular culture

See also: List of fictional computers

James P. Hogan's 1979 novel *The Two Faces of Tomorrow* is an explicit description of what is now called the Singularity. An artificial intelligence system solves an excavation problem on the moon in a brilliant and novel way, but nearly kills a work crew in the process. Realizing that systems are becoming too sophisticated and complex to predict or manage, a scientific team sets out to teach a sophisticated computer network how to think more hu-

manly. The story documents the rise of self-awareness in the computer system, the humans' loss of control and failed attempts to shut down the experiment as the computer desperately defends itself, and the computer intelligence reaching maturity.

While discussing the singularity's growing recognition, Vernor Vinge wrote in 1993 that "it was the science-fiction writers who felt the first concrete impact." In addition to his own short story "Bookworm, Run!", whose protagonist is a chimpanzee with intelligence augmented by a government experiment, he cites Greg Bear's novel *Blood Music* (1983) as an example of the singularity in fiction. Vinge described surviving the singularity in his 1986 novel *Marooned in Realtime*. Vinge later expanded the notion of the singularity to a galactic scale in *A Fire Upon the Deep* (1992), a novel populated by transcendent beings, each the product of a different race and possessed of distinct agendas and overwhelming power.

In William Gibson's 1984 novel *Neuromancer*, artificial intelligences capable of improving their own programs are strictly regulated by special "Turing police" to ensure they never exceed a certain level of intelligence, and the plot centers on the efforts of one such AI to circumvent their control.

A malevolent AI achieves omnipotence in Harlan Ellison's short story *I Have No Mouth, and I Must Scream* (1967).

The web comic Questionable Content takes place in a "Friendly AI" post-singularity world.[96]

Popular movies in which computers become intelligent and try to overpower the human race include *Colossus: The Forbin Project*; the *Terminator* series; *The Matrix* series; *Transformers*; the very loose film adaptation of Isaac Asimov's *I, Robot*; and finally Stanley Kubrick and Arthur C. Clarke's *2001: A Space Odyssey*. The television series *Doctor Who*, *Battlestar Galactica*, and *Star Trek: The Next Generation* (which also delves into virtual reality, cybernetics, alternative forms of life, and Mankind's possible evolutionary path) also explore these themes. Out of all these, only *Colossus* features a true superintelligence. "The Machine" by writer-director Caradog James follows two scientists as they create the world's first self-aware artificial intelligence during a cold war. The entire plot of Wally Pfister's *Transcendence* centers on an unfolding singularity scenario. The 2013 science fiction film *Her* follows a man's romantic relationship with a highly intelligent AI, who eventually learns how to improve herself and creates an intelligence explosion. The adaptation of Philip K. Dick's *Do Androids Dream of Electric Sheep?* into the film *Blade Runner*, *Ex Machina*, and *Tron* explore the concept of the genesis of thinking machines and their relation to and impact on humanity.

Accelerating progress features in some science fiction works, and is a central theme in Charles Stross's *Accelerando*. Other notable authors that address singularity-related issues include Robert Heinlein, Karl Schroeder, Greg Egan, Ken MacLeod, Rudy Rucker, David Brin, Iain M. Banks, Neal Stephenson, Tony Ballantyne, Bruce Sterling, Dan Simmons, Damien Broderick, Fredric Brown, Jacek Dukaj, Stanislaw Lem, Nagaru Tanigawa, Douglas Adams, Michael Crichton, and Ian McDonald.

The documentary *Transcendent Man*, based on *The Singularity Is Near*, covers Kurzweil's quest to reveal what he believes to be mankind's destiny. Another documentary, *Plug & Pray*, focuses on the promise, problems and ethics of artificial intelligence and robotics, with Joseph Weizenbaum and Kurzweil as the main subjects of the film.[97] A 2012 documentary titled simply *The Singularity* covers both futurist and counter-futurist perspectives.[98]

In music, album The Singularity (Phase I: Neohumanity) by the Swedish band Scar Symmetry is part one of the three part concept album based on the events of the singularity.

In the second episode of the fourth season of The Big Bang Theory, the fictional character and scientist Sheldon Cooper tries to prolong his life expectancy through exercising and radically changing his diet to live forever as a cyborg, right through the singularity.

The popular comic strip, Dilbert, authored by Scott Adams, ran a series of strips covering the concept of singularity in late November and early December, 2015. In the series, a robot that is built by Dilbert's company becomes increasingly smarter, even to the point of having a soul and learning how to program.[99]

8 See also

- Eschatology
- Exocortex
- Fermi paradox
- Futures studies
- Global brain
- Mind uploading
- Outline of transhumanism
- Singularitarianism
- Strong AI, hypothetical artificial intelligence that matches or exceeds human intelligence.
- Technological determinism
- Technological revolution

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11.1 Text

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Sbrantner asst, Widr, Bass at Central College, Jorgenev, Helpful Pixie Bot, VanishedUser hjgjktyjhddgf, Marcoslee, Bibcode Bot, Nashhinton, Carlodellora, BG19bot, Buddha Manchester, Theomegapoint, Odx3, Brian Tomasik, Alexanderxerxes, PhnomPencil, Frze, Kirananils, Cadiomals, Jjorr24, Toccata quarta, Cleeder, InfoCmplx, Harizotoh9, MrBill3, Drkjcaserta, Star A Star, BigDocOK, Alexvreidy, BattyBot, DigitalDev, Favre1fan93, Cyberbot II, Postmodernista, Khazar2, EagerToddler39, Dexbot, Kyleshack2, Cwobeel, Erkleton, Cerabot~enwiki, 93, Jared.h.wood, BrighterTomorrow, Joeinwiki, BreakfastJr, Silas Ropac, Scott1234567, Madreterra, Tango303, Rolf h nelson, Legin1234567890, Transphasic, Comp.arch, Cevanert3, AmbivalentLife, Inflight Allright, Fixuture, Monyprice, Man of Steel 85, ColRad85, Andre Baerfuss, Bilorv, Monkbot, HiYahhFriend, TDurr1, Aristarchus310, Maurice'spieces, Filmfan24, Phacemelter, Junbibi, Izkala, ComicsAreJustAllRight, The Fat Rat of Chepstow, Abierma3, Ryanfleshman, Jerodlycett, Kaulo27, Zamaster4536, Jorgelpt, Sofcap, Spectra239, Jakeman123, Ronsams, Bancron, GreenC bot, QuinnLopi and Anonymous: 873

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