Ulrich A. K. Betz

Science and Religion United

The Salvation Machine

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Revelation 12:9
New International Version
The great dragon was hurled down—that ancient serpent called the devil, or Satan, who leads the whole world astray. He was hurled to the Earth, and his angels with him.

Cogite non cogitum cogitandum

Preface

I remember when I was a young boy at the age of 10 or so, I started to heavily think about the mysteries of the world. What was beyond the stars that shone at night? I remember my grandfather saying there were more stars ever and ever with no end. I found this thought fascinatingly interesting and intrinsically impossible at the same time. I remember passing by a cross with the crucified Jesus that was on my daily route to school and looking at it in contemplation. I thought about, as they told us in religion classes and in the church, if God was omnipotent and loving us, then why was there disease and suffering in the world? I heard about people getting sick with horrible cancer pain and people saying, “This is the punishment of God. They must have done something very bad in their life to deserve it.” I was told to treat the cross on the wall with respect because otherwise I would get sick immediately. I wondered if that was true or not. I saw the barn of our neighbor go up in flames one day. Where did that come from and why him and not the farmer next door? I heard about the Sermon on the Mount and that we should also turn the other cheek if attacked. I wondered what that meant for someone being attacked by a murderer.

I thought about what I had learned in biology, the evolution of species by means of natural selection, the fight for survival over the hundreds of millions of years. Next to our house I had found fossils from the Jurassic period of animals that were now extinct. I wondered how this correlated with what was readable in the Bible on creation. Our religion teacher said evolution cannot be true because for something as complicated as an eye to emerge randomly is as impossible as if he would disassemble his clock, throw the pieces on the table, and they by chance randomly form a clock again. The biology teacher, however, said that the Bible should not be interpreted in a worldly manner and that it could not be proven that God exists. It would probably just be an invention of the human mind. Nothing like a soul had ever been found when dissecting humans: they would just look like all the other mammals. My grandfather often went with me to the Rosenstein Museum in Stuttgart; I must have been there a hundred times and I loved it each time. I saw the various taxidermized species, ordered by their degree of relation to each other. I saw bones of extinct species, heard about dinosaurs and mammoths, and saw ancestry trees of species. He went with me to the Deutsche Museum in Munich; I will never forget that day, seeing sophisticated engineering machines and chemical reactions performed by automatic bots right in front of me. There was a reproduction of a huge blue whale hanging on the ceiling in the zoology room and the world’s first planetarium. My grandfather told me about a scientist called Gregor Mendel who had discovered how traits are inherited by looking at peas and experimenting with them in his garden. I thought about Charles Darwin and about how a good God could set up and create such a world where all inhabitants are in a constant fight for survival against each other and I was just lost. My grandfather said if I have doubts about God I should pray and it will go away—it did not.

I remember some people saying they would not believe in God; they would only believe what they see with their own eyes. I remember one day my father saying that scientists had found out that everything is made up of particles and waves at the same time, like radio waves. How could that be? When I was a young child, I imagined when listening to the radio that a small band of mini-humans were in the radio box playing the music for us. Then I learned the information is transmitted to the radio via radio waves over long distances and then transformed by a loudspeaker into sound. But how could something solid like a stone be a wave at the same time?

I remember my grandfather constantly reading many journals. Whenever there was an interesting article about a new discovery or invention, he cut it out and collected the pieces like treasure. Soon I started my own collection of interesting stuff and have continued to grow the collection until today.

Then I remember one day we went to the funeral of my uncle who had suddenly died from a heart attack, and I thought what happens to a person when the body is decomposed in the grave? The biology teacher said nothing would remain. The priest and the religion teacher said people go to either heaven or hell and live there forever in eternal pleasure or eternal pain. When my great aunt was dying, I remember my father said she was constantly hallucinating fire all over the place. My mother said that probably she already was half in purgatory.

Already in primary school, it was entirely clear to me that I wanted to become a scientist. A few years later at school then I decided I wanted to be a molecular biologist. I was so impressed with DNA and RNA, genetics and inheritance, transcription and translation and I found it utterly impressive to be able to say a word as complicated as desoxyribonucleic acid. I grew up in a combination of science and religion, mysteries over mysteries piling up in my mind and triggering so many thoughts—often diverging views, hard to reconcile. Almost two worlds entirely separate from each other.

As a child I remember one day, passing again by that cross on my way to school, I prayed "God if for my life I can ask you for one thing then I ask you for insight. Let me please understand the inner workings of this strange mysterious world you put me in." Fifty years later after studying biochemistry, acquiring a PhD in genetics and immunology, working for 30 years in R&D and innovation management, after 50 years of intense reading and thinking about these questions, after having been blessed with some personal experiences that changed my worldview forever, and after going through the fiery ring of trials that I did not all pass, I started to write this book. I dedicate it to my grandfather Karl Eschinger, without whom I would not be who I am today.

The book tries to develop a holistic worldview blending insights from science and religion. I personally think, but of course cannot prove, that the presented worldview is correct. Certainly, as I am a scientist and not a theologist, I might have missed some important points on the theological questions covered. Nevertheless, two points are essential, that science does not negate the existence of God and that even if we do not understand all secrets of the univese and our place within it, we can do a lot and should join forces to create a bright and peaceful future together.

I dedicate this book to my grandfather Karl Eschinger, without whom I would not be who I am today

Reinheim, Germany Ulrich A. K. Betz

Acknowledgments

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Contents

A Universe Full of Secrets

1

We are born into a world full of secrets that we only partially understand. We grow up and learn, age, and finally die. There are incredible pleasures to be found but also incredible pain ready to strike at us each day. We cannot predict the future, not even for the next second. We don't know where we are coming from, we don't know why we live, and we don't know where we will finally go. We don't know how everything started; we even don't know what "everything" really is and what part of "everything" we know or don't know. We don't entirely know what we don't know but could know, and we don't really know what we will never know.

The world we are living in is inherently beautiful and horrible, deeply rewarding and utterly dangerous at the same time and each day terrible and wonderful things can happen to us. It is just a fact, however the thought about it all too often and understandably we tend to suppress. But it is true. We could have wonderfully enriching experiences and meet amazingly inspiring humans, but also face disaster from natural sources, accidents, disease, cancer, and infection; we could suffer from endless pain for years to come due to an incident. Pain can also come from human sources such as crime and war in the extreme case, but also from smaller injuries such as treason, abandonment, and deception. At the same time, the world can be extremely beautiful with wonderful scenes of nature, with warming human relationships, love and friendship, amazing discoveries, wisdom, insights, kissing, laughing, and fun. Looking in the eyes of your newborn child can feel like heaven on Earth. We can have amazing achievements, deep spiritual experiences, learning, contemplation, and happiness. But whatever we do, the dark side is always there and does not go away.

There are several ways humans can react to this overall unpleasant situation. Option number one is "childish neglect" or "willful blindness." We pretend the dark side does not exist; we live into the day and suppress the thoughts about the dark side. This works as long as all goes sufficiently smooth. If bad things happen, people try to skip over them as quickly as possible and go back to "let's pretend all is good" mode. For an adult, rationally thinking person, it is not a noble way to live to

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castrate your thoughts by eliminating a part of the reality. The second option to deal with the situation is "endless pleasure seeking." Fully aware that life can be horrible, we try to get as much from the good side as possible as long as it works. We have fun, drown in pleasure, travels, parties, sex, and drugs; I think we all know where that leads to…. Option three is "final escape"; basically meaning suicide, afraid of potential pain, and suffering, we end our existence, the worst solution. But there is another option: to react to the reality of life, to fully embrace the situation as it is, and to strive to understand its secrets and do whatever is possible to make the world a better place and reduce suffering. Where this is not possible, suffering must be embraced and transformed to something larger. But the goal is to understand the world, its inner workings and do whatever is possible to improve it, beginning with ourselves.

And change and a new thinking is urgently required, as we see our planet in danger and us living at the brink of nuclear destruction, pandemics, pollution, and climate collapse. Oceans are drowning in plastic waste; microplastic has entered the food chains, potentially triggering an increase in autoimmune diseases and allergies. The world is heating up. There was enormous technological progress but at the cost of our environment. While people were admiring in front of their TV screens the technological wonder of the moon landing, humanity failed to see the full picture, as more or less exactly at the time when the first landing on the moon took place, the ecological footprint of humanity exceeded the biocapacity of the world's ecosystems. And now, the children alive today could experience in their lifetime a planet that is hotter than any *Homo sapiens* has ever experienced.

And then this mysterious world around us is not even stable, but constantly changing. It seems we are currently living in a time of utter disruption, unprecedented technological speed of progress particularly in the field of computers, and artificial intelligence, combined with a perception that old wisdom as transferred to us by religion seems out of date. Traditional institutions that had worth and power over many centuries are losing their appeal. A materialistic worldview with a naive understanding of what being rational means is spreading. Science over the centuries has had incredible successes. However, science remains forever silent on the most important question in life—why do we live and what should we do. Then, there is a growing wave of depression, mental health issues, and drug abuse, particularly amplified after the COVID-19 pandemic. Surveys have highlighted a horrible rise in issues like anxiety, depression, and suicidal ideation, especially among young people. The WHO has reported that depression is now a leading cause of disability worldwide. At the same time, affiliation with traditional religion has been on the decline in most Western countries. This can be attributed to a number of reasons. The influence of skepticism, agnosticism, and atheism, fueled by critiques of religious institutions and a growing belief in rationality, has contributed to this trend. At the same time, an amazingly unethical behavior from the side of Church officials has further strongly deepened the crisis. Nevertheless, a profound thirst for spirituality and deeper meaning in life has remained. There has been a notable rise in people identifying as "spiritual but not religious." This longing for spiritual connection is there even in people without a religious affiliation. People are seeking ways to transcend the mundane and connect to something larger than themselves. The Canadian philosopher Charles Taylor has intriguingly put it in his book *A Secular Age*: “Modern individuals have been denied a master narrative in which they may find their place, and without which their sense of loss can perhaps never be stilled, ... people today who inhabit a secular world and lack faith are missing out on something important, vital - perhaps the most important something there is ... there is in the modern world a massive blindness to the fact that there is some purpose in life beyond the utilitarian.” At the same time, there is the conviction that modern science and the laws of nature should not be ignored, but several accomplished scientists, for example, the leader of the Human Genome Project, Francis S. Collins in his book *The Language of God*, have gone on a journey from atheism to Christianity. There is a strong overwhelming desire to unite science and religion. People feel a gap. It seems that a new holistic way of seeing the world is eagerly awaited, giving context and guidance to our lives and societies. This book is making a contribution to create such a coherent inclusive worldview that satisfies our brains and our hearts. This book is written for open-minded people that have a thirst for knowledge. This book is written for people that are ready to widen their horizon and see a big picture. This book will make an attempt to unite into a holistic worldview three domains that are often perceived to be at war with each other since centuries if not millennia: science, religion, and magic-science, the incredibly successful endeavor that catapulted humanity from the stone age toward the age of computers and space travel; religion, the extremely powerful force that gives humans meaning and a home since millennia and provides a bigger picture and an answer to the question “why”; and finally magic, the highly debated experience of supranatural phenomena, parapsychological effects, so far impossible to convincingly prove and reproduce in the laboratory, but documented with numerous historic records from mystics and shamans all over the world over the millennia. Religion was fighting magic, religion was fighting science, science was fighting religion, science was fighting magic, and magic was always obscure and hiding. This book is written for people that are ready to fully embrace all dimensions of existence.

Further Reading

Collins FS (2007) The language of God. Free Press

Science: An Amazing Success Story

2

2.1 Examples of Triumphs of Science

Science is probably the most impactful endeavor in the history of humanity; the progress from stone wielding apelike creatures to the age of mRNA vaccines, space travel, and artificial intelligence is mind-blowing. Why are humans in that regard so very different from all other life forms on the planet?

The story of humanity begins in Africa around 6–7 million years ago with the emergence of a group of primates known as hominins, a subgroup of the great apes distinct from chimpanzees, our closest living relatives. Early hominins, like the Australopithecines, began to walk upright on two legs, a critical divergence from other primate behavior. About 2.0–1.5 million years ago, *Homo habilis* emerged, known for their creation of stone tools. The next major step in human evolution was *Homo erectus*, which lived from around 1.8 million to as close as 100,000 years ago. This species is known for more sophisticated tools and the earliest evidence of controlled fire. It migrated out of Africa and developed into *Homo denisova* in Asia and *Homo neanderthalensis* in Europe and parts of Western Asia from about 400,000–40,000 years ago and overlapped with modern humans for thousands of years, leading to instances of interbreeding. On average, people of European descent have between 1% and 2% Neanderthal DNA. The interbreeding events between Neanderthals and the ancestors of modern Europeans are believed to have occurred after the out-of-Africa migration but before the split of European and Asian lineages. Asian populations generally have a similar percentage of Neanderthal DNA as Europeans, roughly around 1–2%. Denisovan DNA is generally rare or almost nonexistent in most European populations. While the Denisovan contribution is lower than the Neanderthal contribution, certain populations in Asia, especially those in the Southeast Asian regions and Oceania, have detectable levels of Denisovan DNA. For instance, the Melanesian populations, which include indigenous groups from Papua New Guinea and the surrounding islands, have been found to have up to 3–6% Denisovan DNA. Similar to Neanderthal DNA, the presence of Denisovan DNA in

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African populations is minimal or non-existent. *Homo sapiens*, our own species, first appeared in Africa about 300,000 years ago, characterized by a significant increase in brain size and complexity, as well as the development of language, art, and complex social structures. Around 70,000–60,000 years ago, a small group of *Homo sapiens* migrated out of Africa, marking the beginning of a global dispersion that would lead to the colonization of every continent. Recent results published by Wang Jie Hu and colleagues have shown that human ancestors went through a severe population bottleneck with about 1300 breeding individuals between around 930,000 and 810,000 years ago. The bottleneck lasted for about 120,000 years and brought human ancestors close to extinction. This bottleneck is congruent with a substantial chronological gap in the available African and Eurasian fossil record and likely led to the evolution of a new human species ancestral to Homo sapiens, defined as Homo heidelbergensis. Later, around 70,000 years ago, the supereruption of the Toba volcano in present-day Indonesia is believed to have caused a significant global climate change leading to another severe bottleneck in human populations reducing them to as few as 1000 to 10,000 breeding pairs. So we would almost have gone extinct, and today's humans are all very closely related. The progress that *Homo sapiens* has made since it originated around 300,000 years ago in east Africa is outstanding. Already our ancestors used stone tools as long as 3.3 million years ago, and by 1.75 million years ago, they'd adopted hand axes and other cutting implements that remained in vogue for nearly 1.5 million years. Visualize the increased sophistication from the earliest primitive stone tools to the complexity of a semiconductor computer microchip. The Neolithic revolution, beginning around 10,000 years ago, saw the invention of farming tools due to the shift from hunter-gatherer societies to agricultural societies. The Bronze Age, starting around 3300 BC, and the subsequent Iron Age, starting around 1200 BC, brought significant advancements in toolmaking, with the smelting and working of metals allowing for a much wider range of more durable tools. The industrial revolution of the eighteenth and nineteenth centuries marked another major milestone in tool evolution, with the development of machines that could produce goods on a mass scale, like the steam engine. The twentieth and twenty-first centuries finally have witnessed the digital revolution, with the creation of computational tools. The development and proliferation of personal computers, the Internet, and smartphones represent the most recent significant evolution in the tools made and used by humans. Today we can talk instantly to each other person on the planet with our mobile phones, we have the entire knowledge of humanity available at our fingertips, we can fly from continent to continent even to the moon, we can build thinking machines, we can build machines that build stuff we need, we can build machines that build other machines, and we can synthesize molecules to cure diseases, image into the deepest secrets of our bodies, and generate new materials and molecules that never existed before on our planet with amazing properties. We shaped plants and animals to serve us and make the nutrition and living of billions of people on the planet possible; world population has reached 8 billion people on November 15, 2022, according to the United Nations. We have explored the deep secrets of matter and energy, even quantum mechanics, and can generate huge amounts of energy from splitting and fusing atoms; we learned about the 3.7 billion year history of life on Earth and can explore deep into the universe, stars, and black 13.8 holes, and even reach back to the big bang when the universe started its existence 4.5 billion years ago. We can turn night into day, for example, from the eighteenth-century candles to the LED; the output of light per input of energy has risen roughly a hundred millionfold.

Science, the understanding of the world, leads to technology, the tools to change the world. The word technology comes from the Greek *tekne τέχνη* (skilled craft) and *logia λόγια* (telling), implying systematic study of a technique. As Daron Acemoglu and Simon Johnson write in their book *Power and Progress*, "Technology is not simply the application of new methods to the production of material goods. Much more broadly, it concerns everything we do to shape our surroundings and organize production. Technology is the way that collective human knowledge is used to improve nutrition, comfort, and health, but often for other purposes, too, such as surveillance, war, or even genocide." We will return to this nature of science and technology as a double-edged sword that can be used for the good and the bad alike later in the book.

The greatest inventions of humanity and the progress in science and technology over the millennia have been summarized in numerous books, articles, and websites, for example, from AAAS/Science, Britannica, Wikipedia, John Becker, Interesting Engineering, CadCrowd, Leo Dean Jansen, and many others.

Looking back at past achievements, however, it is important to be aware of a principle called presentism. Presentism in the history of science refers to the tendency to interpret and evaluate scientific discoveries, theories, and practices based on current understanding and values, rather than in the context of the time when they were developed. Scientists and their work might be unfairly judged by today's standards. For instance, some historical scientific theories might seem incorrect or naive by modern knowledge, but were progressive or revolutionary in their own time. Presentism can lead to underappreciating the challenges and limitations faced by historical scientists. The significance of overcoming the technical, conceptual, and societal barriers of their time can be overlooked. There's a risk of assuming that current scientific theories are closer to the "ultimate truth." This can lead to discounting past theories that, while incorrect or incomplete by today's standards, contributed significantly to the advancement of science. Presentism might also cause misinterpretation of why certain scientific paths were followed or abandoned, ignoring the historical context, such as technological limitations, religious and cultural influences, or prevailing scientific paradigms. Finally, presentism can lead to a simplified narrative of science as a linear progression toward truth, ignoring the complex, nonlinear, and often contingent nature of scientific discovery and development. On the other hand, it is also opportune to ask, if a prominent historical figure would know what we know today, what would the person have said?

A compilation of the greatest discoveries and inventions is listed here. We will come back later to the topic of what made them possible, the role of human intellect, and the changes in views and paradigms that were required to make them see the light of day.

3.3mio BC	First stone tools.
1mio BC	Control of fire.
6000 BC	Development of agriculture.
3500 BC	Invention of the wheel.

3000 BC	Development of writing systems.
2400 BC	Discovery of the decimal system.
2670 BC	First pyramid built in Egypt during reign of Pharaoh Djoser by his architect Imhotep.
600 BC	Thales of Miletus—basic principles of electricity and magnetism.
550 BC	Greek philosophers begin constructing rational explanations for natural phenomena.
530 BC	Pythagoras—mathematical theorems, recognition of a connection between mathematics and nature.
500 BC	Development of iron smelting.
400 BC	Leucippus and Democritus articulate the earliest known version of atomism.
427–347 BC	Plato emphasizes the value of theory.
384–322 BC	Aristotle promotes logic in the observation and classification of natural phenomena; his writings become the cornerstone of Western thinking for nearly 2000 years.
300 BC	Euclid's "Elements"—foundational work of geometry.
300 BC	Aristarchus—heliocentric model of the solar system.
240 BC	Eratosthenes estimates the Earth's circumference with remarkable accuracy.
200 BC–150 BC	The Antikythera mechanism, an ancient Greek analog computer used to predict astronomical positions and eclipses, is created.
60	Hero of Alexandria, a Greek inventor, develops primitive steam engines and experiments with optics.
130–200	Galen's work in anatomy and medicine sets the standard for centuries.
250–300	Widespread use of the waterwheel for grinding grain, sawing wood, and pumping water.
499	Aryabhata's astronomical and mathematical treatise covers arithmetic, algebra, plane trigonometry, spherical trigonometry, and more.
820	Al-Khwarizmi's work develops algebra and what would come to be known as algorithms.
900	The Chinese invention of gunpowder, which would drastically change warfare.
1025	Avicenna's (Ibn Sina) "The Canon of Medicine," an encyclopedia of medicine, becomes a standard medical text.
1100	Windmills become widespread in Europe.
Late thirteenth century	The earliest recorded use of corrective lenses in Italy.
1300	The mechanical clock, a pivotal invention in timekeeping is introduced.
1300	The compass begins to be used in Europe, revolutionizing navigation.
1440	Gutenberg's printing press is invented in Mainz, Germany.

1543	Nicolaus Copernicus recognizes the sun to be in the center of the solar system.
1543	Andreas Vesalius publishes *On the fabric of the human body*, a groundbreaking work in the field of anatomy.
1572	Tycho Brahe observes a new star in the constellation Cassiopeia, challenging the notion of an unchanging celestial sphere.
1590	Zacharias Janssen builds the first microscope.
1600	William Gilbert publishes *De Magnete*, which describes the Earth's magnetic field and lays the groundwork for the modern science of geomagnetism.
1608	Hans Lippershey manufactures the first telescope.
1609	Johannes Kepler publishes his first two laws of planetary motion.
1610	Galileo Galilei—telescope observations of the moon, stars, and planets.
1628	William Harvey—circulation of blood.
1637	René Descartes—*Discourse on the Method*, which includes his philosophical statement *Cogito, ergo sum* ("I think, therefore I am").
1665	Robert Hooke—observes cells in cork.
1669	Phosphorus discovered by Hennig Brand.
1670	Gottfried Wilhelm Leibniz and Isaac Newton independently discover calculus mathematics.
1675	Antonie van Leeuwenhoek—discovery of microorganisms.
1687	Isaac Newton—laws of motion and universal gravitation, publishes *Philosophiæ Naturalis Principia Mathematica*, which lays the groundwork for classical mechanics.
1735	Carl Linnaeus—binomial nomenclature of species.
1751	Benjamin Franklin—experiments and observations on electricity.
1764	James Watt's steam engine.
1780	Luigi Galvani observes the connection between electricity and muscle action.
1796	Edward Jenner—smallpox vaccine.
1800	Alessandro Volta—invention of the battery.
1820	Hans Christian Oersted discovers the connection between electricity and magnetism.
1824	Sadi Carnot anticipates the second law of thermodynamics that disorder increases in the universe.
1826	Nicéphore Niépce's photography.
1827	Georg Ohm—Ohm's law.
1828	Friedrich Wöhler synthesizes an organic compound—urea in the laboratory thereby breaking down the categorical distinction between life and nonlife.

1828	First electric cars created.
1831	Michael Faraday—electromagnetic induction.
1833	Anselme Payen—discovery of enzymes.
1835	Charles Babbage designs the analytical engine programmable with punch cards (precursor to computer).
1837	Samuel Morse invents first electric telegraph.
1838	Matthias Schleiden and Theodor Schwann develop cell theory.
1840	Justus von Liebig invents the nitrogen fertilizer.
1845	Alexander von Humboldt reports on his explorations.
1855	Bessemer steel process.
1859	Charles Darwin—theory of evolution.
1859	Louis Pasteur demonstrates the presence of microorganisms in the air.
1865	Gregor Mendel publishes laws of hereditary.
1866	Alfred Nobel patents dynamite.
1869	Dmitri Mendeleev—periodic table of elements.
1869	Friedrich Miescher isolates DNA for the first time in Tübingen, Germany.
1873	James Clerk Maxwell—electromagnetic field equations.
1876	Alexander Graham Bell—invention of the telephone.
1879	Thomas Edison's electric light bulb.
1882	Robert Koch—disease-causing bacteria, Koch's postulates.
1885	Louis Pasteur—rabies vaccine.
1886	Carl Benz invents first modern gasoline-powered car that goes in series production.
1887	Nikola Tesla develops first induction motor running on alternative current.
1895	Wilhelm Conrad Roentgen—discovery of X-rays.
1896	Henri Becquerel—discovery of radioactivity.
1897	Marie Curie and Pierre Curie clarify the concept of radioactivity.
1897	Joseph J. Thomson discovers the electron.
1897	Rudolf Diesel builds the first diesel engine.
1898	Dmitri Ivanovsky and Martinus Beijerinck discover the first virus (tobacco mosaic virus).
1900	Max Planck—quantum theory.
1902	Theodor Fritsch's air conditioning.
1903	Wright Brothers—first powered flight.
1905	Albert Einstein—theory of special relativity.
1905	Albert Einstein publishes a paper on the photoelectric effect.
1908	Paul Ehrlich invents chemotherapy.
1909	Fritz Haber—nitrogen fixation.
1912	Alfred Wegener—continental drift theory.

1913	First genetic map developed by Alfred Sturtevant and Thomas Morgan.
1915	Albert Einstein—theory of general relativity.
1924	Edwin Hubble—discovery of galaxies outside the Milky Way.
1924	de Broglie introduces the wave-particle duality
1926	Erwin Schrödinger develops wave mechanics and the famous Schrödinger equation.
1927	Georges Lemaitre—big bang theory.
1927	Heisenberg formulates the uncertainty principle.
1928	Alexander Fleming—discovery of penicillin.
1929	Edwin Hubble—expansion of the universe.
1931	Reinhold Rüdenberg, Ernst Ruska, and Max Knoll develop the electron microscope.
1932	James Chadwick—discovery of the neutron.
1931–1933	Discovery of the influenza virus by Richard Shope, Wilson Smith, Christopher Andrewes, and Patrick Laidlaw.
1934	Wallace Carothers invents Nylon.
1934	Kurt Gödel reveals that some mathematical ideas cannot be proved true or false.
1938	Nuclear fission discovered by Otto Hahn and Fritz Strassmann.
1941	Konrad Zuse invents the first programmable fully automated digital computer Z3.
1942	Conrad Waddington coins term epigenetics, heritable mutations that do not change the DNA sequence.
1942	Enrico Fermi—first controlled nuclear chain reaction.
1946	ENIAC, the first general-purpose electronic computer.
1947	William Shockley, John Bardeen, and Walter Brattain—invention of the transistor.
1953	James Watson, Francis Crick and Rosalind Franklin—structure of DNA.
1954	First solar cell capable of converting sunlight into electrical power.
1955	Jonas Salk—polio vaccine.
1957	Launch of Sputnik 1—first artificial satellite.
1958	Jack Kilby and Robert Noyce—invention of the integrated circuit.
1961	Marshall Nirenberg and Johann Matthaei unravel the genetic code showing that a series of three RNA nucleotides, a codon, can code for a single amino acid.
1961	Yuri Gagarin—first human in space.

1961	Claus Jönsson performs the world's first double-slit experiments with electrons, directly demonstrating the particle-wave duality.
1964	Arno Penzias and Robert Wilson discover radiation from big bang.
1967	Jocelyn Bell Burnell and Antony Hewish—discovery of pulsars.
1969	Apollo 11—first humans on the moon.
1969	Creation of ARPANET, the precursor to the Internet.
1970	Hamilton Smith and Daniel Nathans develop recombinant DNA techniques.
1971	Invention of the microprocessor by Intel.
1973	The Global Positioning System (GPS) by the US Department of Defense.
1973	Martin Cooper (Motorola)—first mobile phone call.
1975	Stanley Cohen and Herbert Boyer—recombinant DNA.
1977	Voyager 1 and 2—detailed images and data of the outer solar system.
1980	Smallpox eradicated.
1980	First knockout mouse generated by Mario R. Capecchi, Martin J. Evans, and Oliver Smithies.
1981	First flight of the space shuttle.
1983	Kary Mullis—invention of polymerase chain reaction (PCR).
1983	Discovery of the human immunodeficiency virus (HIV) by Luc Antoine Montagnier and Robert Charles Gallo.
1984	Alec Jeffreys—development of DNA fingerprinting.
1985	Ozone hole over the Antarctic discovered as dramatic statement about the effect of human activities on the environment.
1987	Yoshizumi Ishino publishes on what later becomes CRISP gene editing.
1989	Tim Berners-Lee—invention of the World Wide Web.
1990	Launch of the Hubble space telescope.
1990	Start of the human genome project.
1990	First gene therapy conducted in a patient by W. French Anderson.
1993	Victor Ambros and Bruce Wightman discover microRNA.
1995	First Bose-Einstein condensate produced.
1996	Dolly the Sheep—first cloned mammal.
1996	James Allison lies foundation for immunotherapy to fight cancer.
1997	Mars Pathfinder rover lands on Mars.
1997	Deep Blue IBM supercomputer beats world chess champion in match.

1998	Andrew Fire and Craig C. Mello describe RNA interference.
2001	Human Genome Project and Celera both publish a first draft of the human genome.
2003	First detection of extrasolar planets, exoplanets.
2003	Wilkinson Microwave Anisotropy probe captures an image of the oldest light in the universe revealing that the universe is 13.7 billion years old.
2004	Discovery that transplantation of gut bacteria can increase obesity, a milestone in microbiome research.
2006	Shinya Yamanaka introduction of induced pluripotent stem cells.
2008	Superconductivity discovered in iron-based material.
2010	Creation of synthetic organism at J. Craig Venter Institute.
2011	IBM Watson supercomputer defeats two human champions on the television show Jeopardy!.
2012	Discovery of the Higgs boson.
2012	The Voyager 1 spacecraft enters interstellar space.
2012	CRISPR-Cas9—Genome editing technique invented by Emmanuelle Charpentier and Jennifer Doudna.
2016	Detection of gravitational waves.
2016	Demonstration that killing of senescent cells in animals can extend their life and reduce disease.
2018	First image of a black hole.
2019	Google together with NASA and Oak Ridge National Laboratory claim quantum supremacy, a milestone in quantum computing.
2019	Discovery of SARS-CoV2.
2020	Development of mRNA COVID-19 vaccines by BioNTech, Pfizer, and Moderna based on the scientific work of Drew Weissman and Katalin Karikó
2020	First zero-emission hydrogen fuel cell-powered flight of a commercial-size aircraft completed by ZeroAvia.
2021	Googles DeepMind AI predicts the molecular structure of hundreds of thousands of proteins.
2022	Lab-grown brain cells learn to play the game pong.
2022	Milestone in nuclear fusion reached delivering more energy than used.
2022	Release of large language model-based chatbot ChatGPT by OpenAI reaches 1 million users after 5 days.
2023	Unfreezing and transplanting rat organs.
2023	Scientists at the University of Cambridge and the California Institute of Technology created synthetic human embryos using stem cells.

2023	A new law of evolution is proposed, extending the established Darwinian ones, and described as the "law of increasing functional information."
2024	2023 confirmed as the hottest year on record by several science agencies.

As published in my article *Is the force awakening?*, the progress that was achieved can be visualized by comparing some key statistical parameters and how they changed over time. Let's have a look at what humanity achieved so far in the various technology areas in boosting its natural capabilities.

Population

Growth in human population size can be used as a baseline of our advancement and has certainly seen a tremendous increase. Starting from a bottleneck of only 2000–20,000 humans, we have now expanded to 8 billion. This would result in a population advancement factor of 4×10^6.

Transport Speed

The fastest human footspeed on record is 45.7 km/h seen during a 100-m sprint, the average speed between the 60th and the 80th meter by Usain Bolt. The fastest transportation speed achieved up to date is 39,897 km/h reached by Apollo 10 command and service module (CSM) upon reentry into Earth orbit. On regular transportation, the Shanghai Maglev, also known as the Shanghai Transrapid, tops the list with its maximum operating speed of 460 km/h. This results in a transport advancement factor or 1×10^3 or 10 only, respectively.

Calculation Speed

In general, the speed of supercomputers is measured and benchmarked in FLOPS (floating-point operations per second); currently the Frontier—HPE Cray EX235a—is the fastest machine with 1679 Petaflops per second; the human brain can only make about two conscious calculations per second. This results in an advancement factor of almost 10^{18}.

Communication

Naturally humans are able to communicate with ~300 other humans as determined via analysis of hunter-gatherer social networks. With the mobile communication technologies today, one person is basically able to reach every other human on the planet. This results in an advancement factor of 3×10^7.

Life Expectancy

What is commonly known as average life expectancy is technically life expectancy at birth; in other words, it is the average number of years that a newborn baby can expect to live in a given society at a given time. A major determinant of life expectancy at birth is the child mortality rate which, in our ancient past, was extremely high skewing the life expectancy rate dramatically downward. The life expectancy at birth of hunter-gatherers is around 30 years; in Japan currently it is about 84 years. The combination of high infant mortality and deaths in young adulthood from accidents, epidemics, plagues, wars, and childbirth, particularly before modern medicine was widely available, has significantly lowered life expectancy at birth in the past, but for those who survived early hazards, a life expectancy of 60 or 70 would not be uncommon even in ancient times! Taking life expectancy at birth as a measure, we calculate an advancement factor of only 3; if we would look at life expectancy of adults, it is almost zero! Human lifespans have remained more or less constant for almost 2000 years; when Socrates died at the age of 70 around 399 BC, he did not die of old age but instead by execution. It is ironic that ancient Greeks lived into their 70s and older, while more than 2000 years later, modern humans aren't living much longer, and today in developed countries, the average life expectancy of a 50 year old is around 84. Contrary to common notions, 70-year-olds weren't considered rare freaks of nature in previous centuries. Galileo Galilei died at 77, Isaac Newton at 84 and Michelangelo at 88. The war against death is likely to be one of the flagship projects in the coming centuries.

Energy Generation

Historically humans were mainly generating energy from burning wood. A typical wood fire generates 16.2 MJ/kg, while a modern nuclear power plant is able to generate 80,620,000 MJ/kg from U-238/Pu-239. This results in an advancement factor of 5×10^6.

Information Storage Density

Areal density is a measure of the quantity of information bits that can be stored on a given length of track, area of surface, or in a given volume of a computer storage medium. In 2016 Sony has announced a new tape that holds 148 gigabits (Gb) per square inch beating a record set in 2010 more than five times over. Interestingly, the data storage capacity, speed, and duration of DNA go far beyond. Naturally it can be calculated that on stone or paper, 10 bits per square inch can be engraved. This results in an advancement factor of 10^{10}.

Food Production/Acres Needed to Feed a Single Person

The 25 top calorie staple crops worldwide according to 2008 FAOSTAT data required 10^9 hectares to grow. In terms of calories, one hectare can feed about ten persons these days. In contrast it takes one to ten square miles of land per person to support a hunter-gatherer lifestyle. With 1 square mile = 259 hectare, this results in an advancement factor of 3×10^4.

Construction: Building Height

Göbekli Tepe is an archaeological site of a temple in southeastern Turkey and has been dated back to 9500–8000 BC. The building is in fact the oldest structure on Earth that we have found to date. It has a height of ~15 m.

Jeddah Tower (Arabic: برج جدة) is a skyscraper construction project in Jeddah, Saudi Arabia. It is planned to be the first >1 km-tall building and would be the world's tallest building or structure upon completion, standing 180 m taller than the

Burj Khalifa. The development however is currently on hold. Today the world's tallest self-supported human-made structure is the 828-m-tall Burj Khalifa in Dubai, United Arab Emirates, which opened on January 9, 2010. This results in an advancement factor of around 70.

In summary, it can be concluded that the fields where humanity has made the greatest progress are the fields of computing and communication, while interestingly in life time extension after childhood, the progress was almost zero!

At this point in time, it is important to emphasize that progress during human history has not been consistently advancing and there were even times where things were going backward. A commonly cited example of scientific stagnation or regression is the European Dark Ages (approximately between the fifth and the tenth century). After the fall of the Roman Empire, Europe saw a decline in many aspects of culture and learning, including science. The infrastructure that had supported learning and science in the Roman era, such as libraries, academies, and the patronage system, crumbled. Many texts and scientific works were lost or destroyed during this period, leading to a significant loss of knowledge accumulated during antiquity. Restoring the level of scientific understanding and advancement to where it had been during the height of the Roman Empire was gradual, with significant progress occurring only during the Renaissance and the Scientific Revolution. For example, European mathematics only began to reach the sophistication of ancient Greek mathematics by the sixteenth century. Roman engineering and architectural achievements, such as the construction of aqueducts, bridges, and large domed structures like the Pantheon, were not matched in Europe until the late Middle Ages and Renaissance. Techniques for building large-scale structures, particularly domes, were redeveloped and then finally surpassed, as seen in the construction of Brunelleschi's Dome in Florence only in the fifteenth century. Also authoritarian regimes or dogmatic belief systems can suppress scientific inquiry, as seen in various historical instances such as the suppression of heliocentric ideas in the early modern period. Economic downturns or lack of funding can also slow scientific progress. Events like plagues, famines, and natural disasters can also impact scientific progress by diverting resources and attention or causing societal upheaval. Conversely, prosperous times or significant funding (like during the Space Race) can accelerate scientific advancements. During the course of history, there have been instances where knowledge has been lost or destroyed, such as the burning of the Library of Alexandria, which can represent considerable setbacks for scientific progress. While the burning of a library is no threat to the knowledge of humanity today, it is still not clear what a global catastrophe would do to the assembled knowledge and in an extended global power shutdown, for example, large parts of human knowledge might not be accessible anymore. This serves as a warning for us that the achievements are not guaranteed and that it requires constant work to keep the fire of the enlightenment burning and the scientific mindset alive.

Interestingly, there have been multiple reports that the speed of scientific progress is slowing down since the mid of the twentieth century. Michael Park and colleagues, for example, via analyzing data on 45 million papers and 3.9 million patents, have shown that progress is slowing in several major fields and that papers and patents are increasingly less likely to break with the past in ways that push science and technology in new directions suggesting that slowing rates of disruption may reflect a fundamental shift in the nature of science and technology.

In the following paragraphs, some of humanity's greatest discoveries and inventions are described in more detail. I have also recently published the article *Game changers in science and technology—now and beyond* which gives an overview on more recent developments and an outlook into the future.

Composition of Matter

At its core, matter comprises atoms, which are themselves composed of subatomic particles: protons, neutrons, and electrons. Atoms, the building blocks of matter, are central to the concept of elements. Each element, from hydrogen to uranium, has a unique number of protons in its atomic nucleus, defining its atomic number and chemical properties. Electrons, which possess a negative charge, orbit this nucleus and play a vital role in chemical bonding, determining how atoms interact and combine to form molecules. Neutrons and protons, located within the nucleus, are more massive than electrons and are termed nucleons. These nucleons are composed of even smaller particles known as quarks, held together by gluons, carriers of the strong nuclear force. The electromagnetic force is conveyed by the photon, the strong force by the gluon and the weak force by particles called W and Z boson. The Higgs boson completes the theory by giving the other particles mass. Beyond atoms and molecules, matter can be organized into different states based on its physical properties. These states include solids, liquids, gases, and plasmas, each representing different arrangements and movements of atoms or molecules. At the macroscopic level, matter's composition gives rise to the vast diversity of materials we observe, from gases in our atmosphere to metals and polymers. At the microscopic and subatomic levels, understanding matter's composition is crucial for advances in fields ranging from chemistry to particle physics. Chemistry delves into the study of matter and its properties, particularly focusing on how different atoms combine to form molecules through various reactions. At the heart of this discipline lies the understanding of how these atoms, governed by their electrons, bond together to create a myriad of molecular compounds with distinct characteristics as investigated by chemistry. The periodic table of elements is a tabular arrangement of chemical elements that categorizes them based on their atomic number, electron configurations, and recurring chemical properties. Elements are ordered in rows, called periods, and columns, known as groups or families. Dmitri Mendeleev is credited with its creation in the late nineteenth century; several additional scientists contributed to its development. The periodic table not only organizes known elements, from hydrogen to the heavy actinides and lanthanides, but also predicts properties of undiscovered ones. Its design offers a comprehensive view of element relationships and atomic structure. In the realm of organic chemistry, the primary building blocks consist of the elements carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), and phosphorus (P), often abbreviated as CHONSP. These elements are foundational to life on Earth. Carbon is unparalleled in its ability to form stable covalent bonds with other carbon atoms, leading to vast chains and ring structures. This forms the backbone of organic molecules, from simple hydrocarbons to complex polymers. Hydrogen atoms often complement these carbon frameworks, while oxygen, usually in the form of hydroxyl or carbonyl groups, imparts reactivity and polarity to organic molecules. Nitrogen is a key component of amino acids, nucleic acids, and numerous other bio-relevant molecules. Sulfur, found in some amino acids and vitamins, can form strong covalent bonds. Phosphorus plays a pivotal role in energy storage and transfer, particularly in molecules like ATP (adenosine triphosphate). Reactions in chemistry, guided by these building blocks, create the diverse molecular landscape essential for life and the advanced materials of modern civilization. Antoine-Laurent de Lavoisier (1743–1794) is often hailed as the "Father of Modern Chemistry" for his remarkable contributions to the field. Lavoisier played a crucial role in developing a systematic chemical nomenclature, which provided a consistent way to name chemical compounds. This was instrumental in moving chemistry toward a more scientific and less alchemical practice. He also formulated the law of conservation of mass, which states that matter cannot be created or destroyed in a chemical reaction. This fundamental principle became a cornerstone of modern chemistry. To get an overall understanding of dimensions it is intriguing to note that the number of atoms in the universe is estimated to be 10E82, on earth 10E50 and in the human body 7 x 10E27.

Agriculture

The term "Malthusian trap" refers to a situation where, as population increases, any advancements in food production and other resources are outstripped by the growing population, leading to stagnation in living standards, increased mortality, and sustained population pressure on resources. This concept is based on the ideas of Thomas Robert Malthus (1766–1834), an English cleric, and scholar, who theorized that, while population grows geometrically (1, 2, 4, 8, 16, etc.), food production only grows arithmetically (1, 2, 3, 4, 5, etc.), inevitably leading to resource shortages. However, since Malthus's time, advancements in agricultural technology, genetics, resource management, and global trade have allowed food production to increase far more rapidly than Malthus had predicted, enabling the global population to grow to levels he would have considered impossible. The first country to break out of the Malthusian trap was England during the Industrial Revolution. Nitrogen is a critical element for plant growth, but atmospheric nitrogen (N_2) is not directly usable by most plants. Nitrogen fixation is the process by which atmospheric nitrogen is converted into ammonia (NH_3), a form that can be assimilated by plants. This process can occur either biologically or industrially. Justus von Liebig (1803–1873), a German chemist born in Darmstadt, is considered one of the founders of agricultural chemistry. Liebig's Law of the Minimum states that plant growth is not determined by the total amount of resources available but by the scarcest resource, the limiting factor. In other words, the availability of the most limiting nutrient will control the growth rate and yield of a plant, regardless of the availability of other essential nutrients. The Haber-Bosch process is the industrial method to synthesize ammonia from nitrogen gas and hydrogen gas. This ammonia is then used to manufacture nitrogen-based fertilizers, such as urea, ammonium nitrate, and ammonium sulfate. The development of this process in the early twentieth century greatly increased the availability of nitrogen fertilizers, revolutionizing agriculture and significantly boosting crop yields globally. When nitrogen-based fertilizers are applied to crops, they enhance plant growth by supplying essential nitrogen, which plants use to synthesize amino acids, proteins, and other vital compounds. Humans, and animals in general, obtain nitrogen primarily by consuming plants or by consuming other animals that have fed on plants. Therefore, the nitrogen atoms in the proteins and other molecules in our bodies can, in many cases, be traced back to synthetic fertilizers produced via the Haber-Bosch process, especially in regions where the consumption of industrially produced food is high. It is estimated that approximately half of the nitrogen in the human body comes from the Haber-Bosch process, reflecting its massive impact on global food production and the nitrogen cycle.

The domestication of plants marked the beginning of agriculture around 10,000 years ago. This domestication process involved the selection and cultivation of wild plants with desirable traits, ultimately leading to increased yields and the development of modern agricultural crops. The progression of agriculture has witnessed numerous instances of improved breeding methods, ranging from classical breeding to advanced genetic techniques. These improvements have been crucial for enhancing crop yield, resilience, and nutritional value. Traditional maize varieties, derived from teosinte, for example, yielded roughly 20–30 bushels per acre in the early 1900s. Current high-yielding maize hybrids can produce upward of 200 bushels per acre under optimal conditions. The advent of genetically modified maize with traits such as herbicide tolerance and insect resistance has further contributed to yield stability and increase. Traditional rice varieties, before the advent of the high-yielding varieties of the Green Revolution, generally produced around 1–2 tons per hectare. High-yielding varieties developed during the Green Revolution can produce up to 10 tons per hectare under optimal conditions. The world average yield for rice was around 4.5 tons per hectare in 2019. Golden rice was primarily developed for its beta-carotene content making it much more valuable than classic rice which lacks this precursor of vitamin A.

Wheat is another essential crop where various breeding techniques have significantly impacted yield, disease resistance, and nutritional value. Traditional varieties of wheat, prior to modern breeding advancements, generally had yields of around 0.5–1 ton per acre. Modern high-yielding wheat varieties can produce around 3–4 tons per acre under optimal conditions, with the world average being around 3.5 tons per hectare as of 2019. Semidwarf varieties developed during the Green Revolution, like Norin 10 wheat, have substantially improved wheat yields globally due to their enhanced responsiveness to fertilizers and reduced lodging risk. Breeding programs have developed wheat varieties with resistance to devastating diseases like stem rust, leaf rust, and stripe rust, significantly reducing yield losses. Breeding programs have also created wheat varieties with improved water-use efficiency and drought tolerance, allowing cultivation in arid and semiarid regions

and to the development of wheat varieties that can be cultivated in saline soils, expanding the potential cultivation area for wheat.

Computers

The history of the computer begins with the Antikythera mechanism, an ancient Greek analog computer used to predict astronomical positions and eclipses for calendrical and astrological purposes, dating back to the second century BC. This artifact was among wreckage retrieved from a shipwreck off the coast of the Greek island Antikythera in 1901. In 2008, a team from Cardiff University used computer X-ray tomography and high-resolution scanning to image inside fragments of the crust-encased mechanism and read the faintest inscriptions that once covered the outer casing. This suggests it had 37 meshing bronze gears enabling it to follow the movements of the Moon and the Sun through the zodiac, to predict eclipses, and to model the irregular orbit of the Moon. Also robotics potentially was already present in Ancient Greece, in Homer's Iliad for example the god Hephaestus is described in book 18 as having golden servant-robots (tripods). Over centuries, computation evolved, with devices such as the abacus and the slide rule offering simple mathematical operations. Interestingly there is the legend that two renowned medieval scientists had constructed automata too, that is, the legendary talking column or statue of Albertus Magnus (1200–1280) and the legendary talking brazen head of Roger Bacon (1219–1292). In 1623 Wilhelm Schickard (1592–1635) in Tübingen, Germany, invented a mechanical computing device which was capable of adding and subtracting numbers. The only model ever completed was lost in the upheaval of the Thirty-Year War. A second version for calculating the complex movements of the planets, which Schickard commissioned for his friend Johannes Kepler (1571–1630), was destroyed in a fire. Based on drawings and descriptions left by Schickard and Kepler, the Tübingen Professor B. V. Freytag Löringhoff reconstructed Schickard's "calculator clock" between 1957 and 1960, proving that it actually worked. In the nineteenth century, Charles Babbage (1791–1871) conceptualized and designed an automatic mechanical calculator, his "Difference Engine". He also conceived a more advanced machine, the "Analytical Engine", which was programmable using punched cards, a method later used in early digital computers. The twentieth century brought significant advancements. In the late 1930s and early 1940s, German engineer Konrad Zuse (1910–1995) developed the Z3, considered the world's first programmable, fully automatic digital computer.

Post World War II, the development of electromechanical devices and then fully electronic computers, such as the Atanasoff-Berry computer and the ENIAC, took place. These machines were massive and expensive.

The invention of the transistor in the 1950s and the integrated circuit in the 1960s led to smaller, cheaper, and more powerful and efficient computers. The 1980s saw the rise of personal computers, like the IBM PC and Apple Macintosh. The title of "first personal computer" is claimed by several machines:

Kenbak-1 (1971): Often cited as the first commercially available personal computer. It was a simple machine designed and built by John V. Blankenbaker that lacked a microprocessor, and only 40 units were reportedly sold.

Micral N (1973): Built by André Truong Trong Thi and François Gernelle, the Micral N is considered the first personal computer to be powered by a microprocessor (the Intel 8008).

Xerox Alto (1973): While not commercially available to general consumers, the Xerox Alto was groundbreaking. Developed at Xerox's Palo Alto Research Center (PARC), it introduced many of the elements of the modern personal computer, including a graphical user interface (GUI).