THE MICROSCOPE
Vol. 71:1, pp 30–42, 2024
https://doi.org/10.59082/LIOA1075

CRITICAL FOCUS

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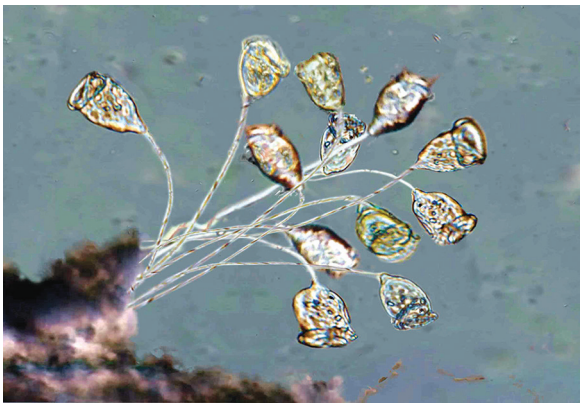
My, How Things Change

We are deluged with claims that AI is a revolution, but greater upheavals have created our modern world. We should cherish past acccomplishments — and kick that bucket list.

To celebrate the 50th article of Critical Focus, here is my latest idea: the negative birthday. Take your age and deduct that from the year when you were born, then you can see just how much science (and society) have changed in a lifetime. The average reader of *The Microscope* is about 38, born in 1986. Deduct their age from that date and we go back to 1948. The Second World War had recently ended, telephones had operators, hardly anybody had a television (there were only 300,000 in the entire U.S.) and there was no McDonald's. And 38 is young.



Perhaps the most important discovery in biology was Antony van Leeuwenhoek's observation of microbes in 1676, including *Vorticella*, imaged (as in this photo) through a single lens. Modern society tends to downplay the remarkable progress made by forgotten pioneers, though the move towards automation through robotics and AI had its roots with experimenters in previous centuries. We should recognize them with respect.

The future is more distant than the past. A change due by 2030 seems way off in the future, but that is only 6 years to go — yet 6 years in the past was 2018 and a film made then you would regard as a current movie. My negative birthday? I have to take a deep breath to consider the fact — that takes us back to 1854, to the era of President Abraham Lincoln and the height of the Civil War. No cars, no radio, no telephone, Queen Victoria was just 35, Thomas Edison was 8 years old. The Republican Party was founded, the first elevator was demonstrated in New York, runaway slaves were sent back to slavery, and Nebraska was founded only for the First Sioux War to break out.

We have been living through eras of upheaval for centuries. These days the broad sweep of history has been forgotten, and everybody dwells on personal experience. Who could imagine Gen Z eagerly signing up to fight a war? Today, it's about personal indulgence — the claim to fame is their aim. Perhaps this is an aftereffect of the absurd belief that youngsters can achieve anything they want.

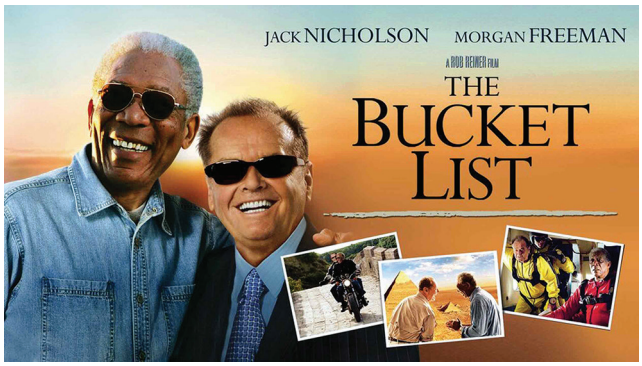
Everybody is meant to have a bucket list. Ditch it.

It's an appalling idea. People are encouraged to note amazing things to do, exotic places to go, fabulous experiences to fulfill, before they die. That's not what you want. The need is to embrace all the extraordinary phenomena that surround us as we live, not have a destination labeled "death."

The term "bucket list" was born on June 29, 2006, when the UPI news agency announced the 2007 film "The Bucket List": "Jack Nicholson and Morgan Freeman are set to star in a film.... The two men make a wish list of things they want to do before they kick the bucket — called the Bucket List." The film came out, everybody started talking about it, and now everyone is encouraged to have one. The drawback with a bucket list is that people resent what they didn't get to see and do. Everyone should take what opportunities arise, create new avenues where nobody thought one might exist, and give as much benefit to others as you can. If you do that, you will look back on a life filled with richness and bursting with memories. The bucketeers, meanwhile, will pass seething with resentment.

My first round-the-world lecture tour in 1978 embraced 38 stopovers in two months and the press reported that my air ticket was 6 ft long. I headed east, crossing the International Date Line as I flew between Samoa and Hawaii, so I returned married for one day longer than my wife. I saw all the interesting sights on the way, from the Taj Mahal in India, perched like a vast meringue overlooking the Yamuna River, and the Penis Shrine of the Goddess Tubtim in Bangkok, where you are surrounded by phalluses of every size (the tallest being as big as me), on to the soaring, lofty Sydney Opera House in Australia and the lost memorial to Queen Salote of Tonga, hidden in the rainforest of the beautiful coral island of Tongatapu. Alcohol was banned for the inhabitants, and I had to apply for a government license before I could buy a beer. Then, straddling the States from balmy San Francisco via my first major lecture in Chicago and on to New York, where it was way below zero, before the transatlantic flight home. No overhead lockers in the planes those days; just coats and scarves lying on an open shelf.

During the previous decade, my foreign travels had extended from Spain right across Europe to communist East Germany, and from Scotland down to North Africa. But on this global tour I realized a lifelong lesson: traveling somewhere just to view something is pointless. It is life's experiences that we need to treasure, and those are available everywhere. I've been told by more people than I can recall how looking over the Grand Canyon was anticlimactic, and that, after traveling 7,000 miles, they couldn't experience the



The 2007 movie "The Bucket List" launched the craze for a set of destinations everybody must see during their lifetimes. It is an idea doomed from the start: many sights turn out to be anticlimactic, and if any are missed, they become objects of long-term regret. It's more realistic to seize the opportunities that come your way, reveling in the experiences we encounter by chance.

surreal sunset on Santorini because of the trampling hordes of exuberant tourists. Or because it was cloudy.

We are all curious about the world and like to investigate how things happen. Writing a list of targets is not the way to plan a life. The most popular bucket list items are said to be these: see the Taj Mahal, visit the Grand Canyon, fly in a seaplane, get a tattoo, explore the Great Barrier Reef, enjoy an epic American road trip, scuba dive in the Gulf of Mexico, gaze at the aurora borealis, admire the Great Pyramid of Giza, trek to the stone city of Petra, go on an Alaskan cruise, observe Komodo Dragons in the jungle, and walk on the Great Wall of China. No, I don't have a tattoo, and I never went to the Grand Canyon. Flew over it once. The rest have happened, in the course of work, and each taught me something about the way the world works. Bucket lists are best written retrospectively.

If you complied a bucket list, you will spend your final hours bemoaning anything that you didn't achieve. You once rescued a bird, comforted a child, saved a major project on the point of collapse, identified an elusive microscopic particle, created something wonderful, solved an intractable problem, cut a superb section, made your parents laugh with happiness, held the hand of someone in distress … and here you are, bewailing the fact that you never got to see Stonehenge (I used to explore it with the kids, but casual tourists can't walk to the stones now) or climbed up that Mayan pyramid in Chichén Itzá (yes, I did, though nobody's allowed to ascend it any more). Adding to the burden of tourism helps nobody. After a century of seeking to promote tourism, tourist hotspots from the Canary Islands and Mallorca to

The Pontiac Ghost was promoted as the world's first invisible car. It was launched at New York World's Fair in 1939, the year I was born. Ever since Henry Ford launched the legendary Model T, car ownership heralded a global revolution in personal transportation. Transparent cars have occasionally been produced since, though nobody admits it was first done 85 years ago.

Barcelona and Venice are protesting against tourism. The curse of Instagram has put travel to shame. Microscopists have a uniquely penetrating view of the world, so our list would include watching meiosis, following ciliates, rotating the polarizers with a preparation of birefringent crystals on the stage, observing capillary blood flow, or seeing sperm swim. Spreading the word about our microscopical insights is eternally satisfying, and there is no sense of anticlimax in that.

But I have seen people look at London's Tower Bridge, and the Eiffel Tower in Paris, and say, "Well, that's something else off my bucket list," as they turn their backs to walk away, since the job was done. The endless fascination of simply being alive is what we should all celebrate, every moment of the day; and the chance to put back some of what we learn is the whole purpose of living. Teenagers often moan about the pointlessness of existence, but only if they're after what they can get. Once they're aware of what they can give, life suddenly reaches beyond the horizon.

My curiosity began as far back as I can remember. When I heard that a neighbor's dog was run over on the highway, all I wanted to do was go and see its squished remains spread out for all to see. It didn't enter my head that they had reverentially retrieved the poor creature's corpse and took it to the veterinarian. I thought it would be flattened out and drying in the sun.

The hidden structure of things was always a preoccupation. When I was seven, my engineer grandfather gave me a magnifying glass. To this day I remember the first object that came in for scrutiny: the half-tone screen of a printed magazine picture. Then it was a nettle. I kept caterpillars and watched them pupate, and then emerge, pumping up their wet, limp wings until they dried in the sun and became beautiful butterflies that could fly to the flowers. What went on inside? There were hidden forces at work in the world, and I wanted to know what they were.

Each of the articles in this column has delved into the lessons I've learned from life, by looking at the world through my eyes as a microscopist. It is hard to believe that this is the 50th column in the Critical Focus series. So let's broaden the scope, just once. Microscopy is a core science, right? This has been an era of scientific revolution, and the one thing people say to me more than anything else is how fast science is changing our world. Nobody will argue with that — though we must not forget how much change people have experienced from science and technology in the past. As I explained last time ("Microscopy's Ingenious Legacy," *The Microscope*, 70:4, pp 171–184, 2023), microscopists owe much to history. We are marinaded in it. Everywhere we look, science and technology have altered our world. Yet, do people really understand what's going on?

A pinnacle of scientific achievement is the automobile. My favorite is the world's first invisible car. Well, not invisible exactly, but transparent. With its plexiglass superstructure, chrome-plated internal mechanicals and crisp white tires, it deserves its name, the Pontiac Ghost. This space-age miracle was premiered by General Motors in the Highways and Horizons pavilion at the New York World's Fair 85 years ago in 1939, exactly when I was born. Artificial-fiber garments were on display, Westinghouse exhibited a 7 ft (2 m) autonomous robot that could hold cogent conversations, while Nycon 1 (the first science fiction convention) had a guest appearance from Superman. The first computer game was on display, alongside a keyboard-operated speech synthesizer, while AT&T unveiled Voder, an electronic voice generator that addressed the visitors. So not everything novel is new.

Microscopy was set for a major revolution when August Köhler and W. Loos perfected the phase contrast microscope. You may imagine how proud I am to hold the medal commemorating Köhler's name, awarded by the State Microscopical Society of Illinois. The world's first electron microscope was just in production by Siemens-Schuckertwerke in Germany. Manfred von Ardenne had already developed the first scanning electron microscope. He insisted on living and working on the same premises, a vast luxurious house with laboratories and even an observatory. Some 500 staff worked on a range of topics, from plasma beam

technology to treating cancer patients. This was an age when the communist party claimed to control every aspect of life, but von Ardenne declined to join the party and maintained his independence and his bourgeois lifestyle. He was considered unassailable and the authorities allowed him his freedom because they were convinced he was a national asset. After reunification, von Ardenne continued his research, and to this day, his son Alexander is director of the Von Ardenne Institute for Applied Medical Research. If there isn't a television documentary on his life, there should be.

WORLD WAR TECHNOLOGY

Computers were already in use when I was born. In Berlin, an aircraft technician named Konrad Zuse had designed his Z3 electromechanical computer in 1938 and got it running in 1941. This was a digital computer with a clock speed of 1 Hz — but it wasn't electronic, though it was programmable. In December 1939, John Atanasoff and Clifford Berry designed a truly electronic computer at Iowa State University, which first ran in 1942 and was the first binary digital machine. Although it was electronic, it was not programmable and could be used only for linear equations.

The computers that helped win World War II decoded German military messages at Bletchley Park, 50 miles northwest of London. They have been restored and are there to this day, clicking and whizzing away as their dials spin and the letters clock up. These computers had a curious nickname — Bombe. Everyone admires the genius of Alan Turing, who worked throughout WWII on decoding the German transmissions. His story was told in "The Imitation Game" film of 2014. He spearheaded the campaign to decode messages sent using the Germans' Enigma machines, and he is always credited as being the person who finally cracked the code. Except that he didn't.

Enigma machines were pioneered during World War I, and in the following years, the machines became globally distributed by mail order to every government, organization, or company wanting to send confidential information as an unbreakable code. When the German military started using them, a Polish codebreaker, Marian Rejewski, devised a device to decode the messages in the fall of 1938. Within a year, there were six of his ingenious machines working simultaneously in Warsaw, each carrying out the work of 100 top cryptographers. This is how the Poles knew they were about to be invaded by the Germans in 1939, which is why Rejewski's Bombes were brought safely to Britain and ended up in Bletchey Park. Turing's genius was in extending the idea and building ever bigger computers to decode the German messages throughout the war. But it was the Poles who started it and first cracked the code. And the Bombe? It was cryptically named so that nobody would guess what they were planning. The Bombe was the cryptologists' favorite treat: a hemispherical ice cream that was the specialty of their local coffee shop. Check out Google for Bombe recipes.

Also in 1939, a revolutionary low-frequency oscillator was manufactured in California for the Disney movie "Fantasia," which was filmed that year. The designers subsequently moved on to computers and ancillary hardware — they were Bill Hewlett and David Packard, who set up their company in a garage when I was a newborn baby. It's still there, at 367 Addison Avenue, Palo Alto. At around the same time, New Yorker Katherine Blodgett was announcing her invention of non-reflective glass.

In January 1939, Niels Bohr calculated that splitting a single atom of U-235 would release the equivalent of 200 million EV electrical power. Lise Meitner and her nephew Otto Hahn, with Fritz Straßmann, announced the splitting of the uranium atom. The atomic bomb that was dropped from the Enola Gay onto Hiroshima at the war's end was packed with 64 kg of U-235. The destruction was immense — yet the amount of uranium that was consumed in creating the detonation was about 0.5 g, the mass of a monarch butterfly. People like to say how incredibly efficient a nuclear weapon would be but, in fact, it's the most inefficient bomb ever devised.

Among the preoccupations of the people in 1939 were the new movies, like "Gone with the Wind" and "The Wizard of Oz," the first appearance of Batman in a Detective Comics magazine, and the first public transatlantic aircraft in history, a flying boat operated by Pan Am; while Germany saw the first flight of a jet airplane, the Heinkel HE 178. The French were still executing murderers on the guillotine in public, Eugen Weidmann being the last to undergo this medieval ritual in June 1939.

Marian Anderson, a black singer, was prevented from performing at Constitution Hall in Washington, D.C. and banned from a public school theater (a decision causing Senator Eleanor Roosevelt to resign from the Daughters of the American Revolution, who sanctioned the ban). Instead, Anderson performed at the Lincoln Memorial and attracted an audience of 75,000 fans. Siam changed its name to Thailand that year then, when Germany invaded Poland, Britain declared war and weeks later, the U.S. announced its

short-lived neutrality. Indeed, the major topic of discussion all that year was German expansionism, and by Sept. 1 the rumor became reality when Britain finally declared war on Germany. It was a turbulent time, when the future of Western civilization seemed to be hanging in the balance.

Today, our current preoccupation is with artificial intelligence, AI. As I've said before, AI isn't remotely intelligent. It is digital automation, and it is increasingly heuristic, but that's it ("AI: Artificial, Yes. Intelligent, Not," *The Microscope*, 66:2, pp 71–83, 2018). The term AI was dreamed up by practitioners to impress the public. Modern software makes it easier to fake videos, compose copy, produce pictures, forge documents, analyze a sequence, or create a list. But people could always do that anyway. Besides, AI is not the threat we think it is, even though everybody says it is a major revolution. In the U.K., Sir Patrick Vallance (the government's outgoing chief scientific adviser) insists it's as big as the Industrial Revolution; UNESCO heralds AI as the "fourth industrial revolution" (including the internet and mobile phones as the previous two), while *Time* magazine proclaims "AI is different from previous waves of technology because of how it unleashes new powers after the discovery of fire, the invention of the wheel, the harnessing of electricity." Google CEO Sundar Pichai insists: "AI is more profound than, I dunno, electricity or fire."

I can think of plenty of revolutions that had far greater impact. Indeed, our sketchy understanding of scientific history means that the names of many of the greatest innovators are missing, dates are wrong, motives misunderstood. Most of the great revolutions in the history of humankind were brought about by people few have ever heard of, yet they transformed society in ways that put AI in the shade.

One of the greatest was brought about by printing, which was to trigger a global revolution. Printing presses date from the 9th century, when Chinese scholars carved pages into woodblocks. Pages with characters you could re-arrange was the brainchild of a Chinese alchemist called Pi Sheng in 1045.

Moveable type in Europe emerged in 1470, when a Medieval work on theology was printed in the Netherlands. It was an illustrated book entitled *Speculum Humanae Salvationis* (the Mirror of Human Salvation), which had previously existed only as hand-copied manuscripts. We do not know who printed it, though the earliest Dutch printer of whom records exist was Laurens Janszoon Coster, who died around 1440. The pioneer we know, Johannes Gensfleisch zur Laden zum Gutenberg (to spell his name in full) did not have a press until a decade later. But imagine: during Gutenberg's lifetime his workers were determined to keep their methods secret, lest others cash in on the idea. But within 50 years from the first Gutenberg Bible, there were over 1,000 printing establishments in more than 200 cities scattered across Europe, turning out millions of affordable books in dozens of languages. That was an astonishing revolution in European society, and all in the space of a half century.

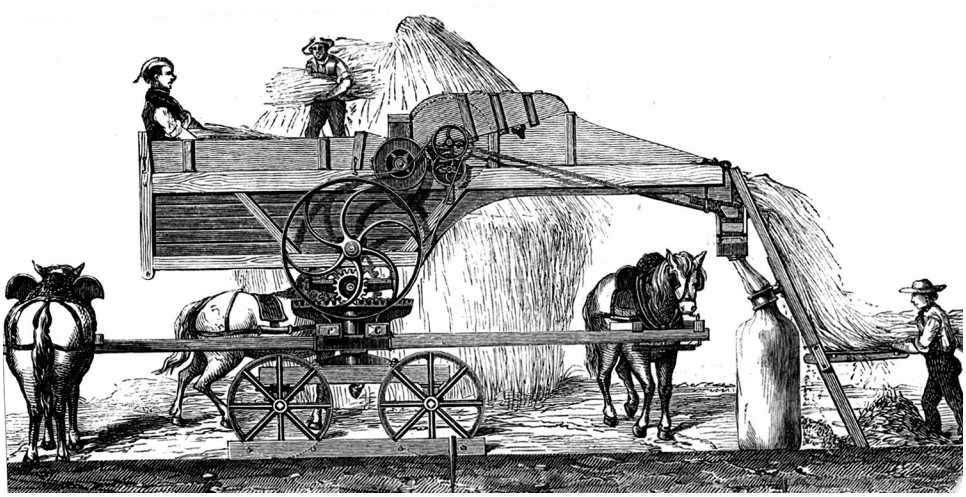
WORKFORCE UPHEAVALS

If you want a real upheaval that puts AI in its place, think back to 1769, when a single scientific machine, pioneered in the North of England, could automatically spin cotton thread, doing away with spinning wheels. Within a few years, machinery could produce more textiles than a team of manual weavers. That really was a revolution. Workers rebelled. It is said that a young weaver named Ned Ludd* wrecked one of the new machines in 1779, and a rebellion spread across the North of England, where tens of thousands of artisans were about to lose their jobs. Twelve thousand soldiers were sent to put down the rebellious objectors, and many of the ringleaders were publicly hanged. The government passed a law to make it a serious offense to interfere with the new machines. They did not seek to safeguard employees; their aim was to ensure that the advance of science and technology was unhindered in serving the interests of the wealthy entrepreneurs.

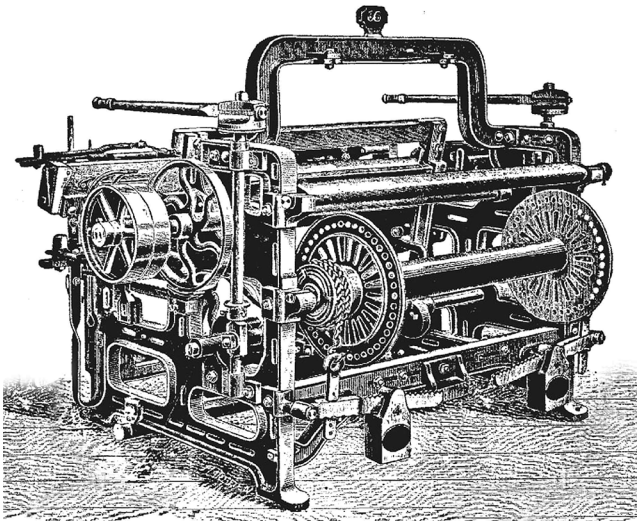
Agriculture was revolutionized when threshing machines were invented. The threshing of wheat, to separate the kernels of grain from the stems, had always been done by flailing the harvested crop by hand. There was a thrust to do it through the newly emerging technologies, and the answer emerged in Scotland in 1786, when Andrew Meikle, a millwright, devised the first mechanical thresher. It was powered by horses walking in a circle, the first three horsepower machine. James Watt, the steam engine pioneer, was saying that his steam engines could replace 200 horses, saving the costs of housing, feeding, and grooming with one single investment.

So the threshing machines were soon adapted to run on steam power and — as well as the horses — the agricultural workers were suddenly superfluous

*There is no evidence that a real Ned Ludd existed. He was said to have lived in Sherwood Forest (like Robin Hood), and seems to have been an invented character in stories told at the time. No matter; to this day, we refer to those who resent modern technology as Luddites, and Sherwood Forest still exists.



The origin of horsepower: mechanical threshing machines were invented in Scotland by Andrew Meikle in 1786. There were riots to prevent them from taking the place of manual labor. When improved threshing machines were developed in America, the response was different. In the spirit of enterprise, mechanical threshers were welcomed to handle crops from newly cultivated areas.



The first successful powered loom was created in 1784 by Edmund Cartwright, a graduate from Oxford University, who became well known as an inventor. It was a revolutionary machine largely made from cast iron; nothing like it had been seen before. New machines could now weave thread and create textiles, while inevitably putting tens of thousands of artisans out of work.

to requirements. The growing sense of resentment burst out into rioting in August 1830, when a threshing machine was wrecked by rioters in the Kent countryside, southeast of London. The Luddites had long celebrated their mythical commander as Captain Ludd, and the legendary leader of these thresher riots was popularly known as Captain Swing (a name conjured up to embody the swinging motion of workers threshing wheat).

Letters of protest were delivered to employers, setting out demands and deadlines; but they remained obdurate. Science and technology were accepted as heralding an exciting and profitable new era that nothing should halt. As the rioting spread, police and troops were sent to arrest the ringleaders. Some 2,000 were eventually apprehended, 19 were publicly hanged, and some 500 were transported to Australia for life (the authorities soon relented, and they were allowed back after a few years).

It was different in the spirit of enterprise across America, where twin blacksmiths Hiram and John Pitts of Winthrop, ME, announced their new Ground Hog Thresher in 1837. They took the British invention and improved it, so the crop was carried on a conveyor. The mechanical threshers were greeted with enthusiasm. Only by using machinery could vast new acres of colonized land be harvested. The new threshers were greeted as the way to the future, rather than as a means of subverting the past.

Roadways brought another change to society. After the last Ice Age, north America was woodland and prairie. Farming by the indigenous communities was facilitated by burning great swathes of the land. Across Britain there were only tracks, for the inland wastelands left as the last Ice Age retreated were forested, and largely impenetrable. Only when the Romans invaded did road building commence. They created specifications for their roads, with stones of a set size being laid in layers until polygonal paving slabs were laid to finish the roadway. They constructed networks of stone-slab highways across Britain and Western Europe some 2,000 years ago, and many have been in use ever since. In Britain there are highways from Dover, via London, to North Wales, yet few realize they lie on an ancient trackway (dating back thousands of years, and established by the Ancient Britons), which

the Romans paved with stones. Similarly, the road the Romans constructed between London and York is a major highway today, even though nobody gives the Romans a thought.

This is not just ancient history. General George S. Patton used the Roman roads when planning his strategy for WWII. Military historians think of Patton as aggressive, driven, and uncompromising, but he was able to philosophize about deeper aspects of warfare. During the liberation of France, the Wehrmacht defended the main roads, where they thought Patton would bring his tanks. Patton knew better and had maps drawn up, showing the roads that had been built by the Romans some 2,000 years earlier, and chose those instead. Patton calculated that the construction would bear the weight of his military advance. Here were few defenses, so Patton could outflank the German troops by harnessing the technology of Ancient Rome.

Canals brought about a revolution of their own. There was nothing new about canals; the first were constructed in Iraq 6,000 years ago. The earliest canals in the U.S. date back 3,500 years, and by the time the ancestors of the Hohokam people started constructing canals in Arizona 1,000 years later, they were already experienced hydrological engineers. They constructed 1,000 miles of canals around the area of Phoenix, more than all those in Amsterdam and Venice combined. When the city's founding farther Jack Swilling arrived on the scene, he set up a company to restore and expand many of the prehistoric canals. One of those became part of the Salt River Project, and still brings water to the city of Phoenix. This is the oldest canal in the world that is still in use today. The Mother Brook canal that still connects Dedham and Hyde Park in Boston was opened in 1639 by English settlers to feed watermills to grind wheat, and that's far older than the great majority of the famous European canals.

Canal projects in Europe included the Royal Canal in southwest France, allowing boats to travel between the Atlantic and Mediterranean without having to sail around Spain. It was opened in 1681 and was renamed the Canal du Midi after French revolutionaries had disposed of the monarchy. Once the industrial revolution had come to pass, canal building in Britain became the largest construction project in the world and involved detailed and meticulous surveying to ensure that canals followed the most propitious route. A unique network of some 4,000 miles of canals was constructed in a single lifetime, between 1757 and 1810. If you want a revolution in society, there you have an astonishing example. The industrial canals meant that thousands of tons of materials could be delivered across country instead of a few sacks being carried by horse-drawn carts. In a single barge, 100 tons could be towed by just one horse.

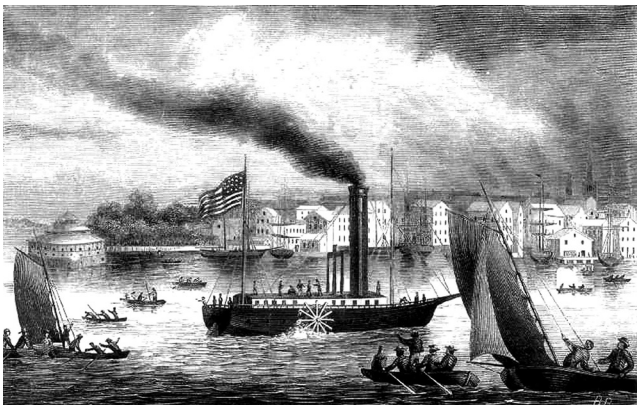
STEAMING AHEAD

The most far-reaching revolution was the harnessing of steam power, for this gave birth to our age of industry. The first harnessing of steam power was by Thomas Savery, a British military engineer in 1698, who devised a means to exploit condensing steam to raise water. The first practical steam engine was built in England by Thomas Newcomen in 1705, and it was superseded by James Watt's patent for a beam engine in 1769. Many engines of this design still operate, including the massive pumping engines at London's Kew Bridge. The largest has a cylinder 90 in. in diameter (2.28 m) and stands over 40 ft tall (12 m). It is the biggest in the world, and the whole building trembles as its massive beam tilts when steam roars into the cylinder. At Smethwick, near Birmingham in the English midlands, the oldest beam engine can still be seen in operation. It dates from 1779, so it's almost as old as the U.S.

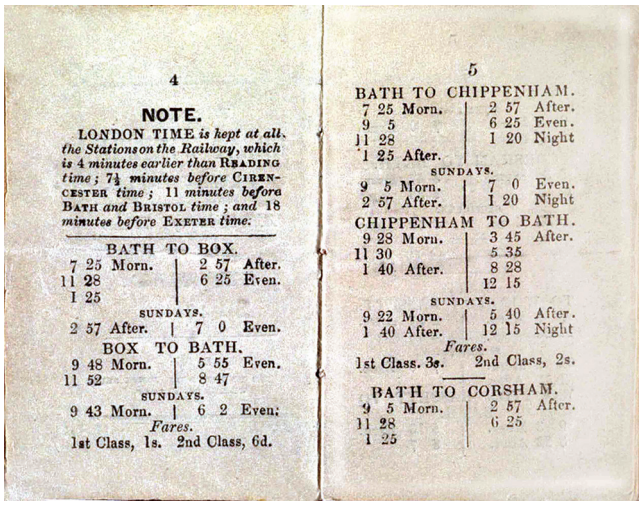
Steam engines provided industrial power based on science ("Coming Up for Air," *The Microscope*, 69:3, pp 123–134, 2022) in an era when trudging horses, falling water or laboring men and windmills had been the only sources of energy. Within the space of a few decades, they were replaced by huge hissing machines. Tens of thousands lost their jobs. Industry was born in the late 1700s and was to sweep from Britain and across the world.

The first steam-powered boat was built by an American, William Henry, a gunsmith in Lancaster, PA. He was a member of the American Philosophical Society and was friends with Benjamin Franklin, David Rittenhouse, and Thomas Jefferson. Henry was fascinated by the new steam engines powering the emergent industries in Britain, and in 1760, he sailed to England and was courteously entertained by James Watt, who gave him every detail he wished to know. Back in the U.S., Henry set about adapting his own design for a machine that could power a boat, something the British had not attempted. In 1763, he launched his experimental stern-wheeled paddle steamer on the Conestoga River. The shaking of the heavy steam engine was more than the vessel could endure; it began to break apart then capsized and sank. This was the first time steam power had ever been seen in the U.S., and it was the first powered vessel that ever existed, anywhere in the world.

Not for 20 years did anyone come close. Then, the



Robert Fulton launched his pioneering passenger steamboat the Clermont on the Hudson River in 1807. Within a few decades, steam-powered ocean-going vessels had made international travel — in comfort and safety — into a reality. Traditional sailing ships were replaced with luxurious, well-appointed liners that ran to regular schedules and provided home comforts for passengers.



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NOTE.

LONDON TIME *is kept at all the Stations on the Railway, which is 4 minutes earlier than* READING *time; 7½ minutes before* CIRENCESTER *time; 11 minutes before* BATH *and* BRISTOL *time; and 18 minutes before* EXETER *time.*

BATH TO BOX.

7 25 Morn.	2 57 After.
11 28	6 25 Even.
1 25	

SUNDAYS.

2 57 After.	7 0 Even.

BOX TO BATH.

9 48 Morn.	5 55 Even.
11 52	8 47

SUNDAYS.

9 43 Morn.	6 2 Even.

Fares.

1st Class, 1s. 2nd Class, 6d.

5

BATH TO CHIPPENHAM.

7 25 Morn.	2 57 After.
9 5	6 25 Even.
11 28	1 20 Night
1 25 After.	

SUNDAYS.

9 5 Morn.	7 0 Even.
2 57 After.	1 20 Night

CHIPPENHAM TO BATH.

9 28 Morn.	3 45 After.
11 30	5 35
1 40 After.	8 28
	12 15

SUNDAYS.

9 22 Morn.	5 40 After.
1 40 After.	12 15 Night

Fares.

1st Class. 3s. 2nd Class, 2s.

BATH TO CORSHAM.

9 5 Morn.	2 57 After.
11 28	6 25
1 25	

Local time had traditionally been used around the world, but the birth of the railroad in England meant that timetables would benefit if there was a nationwide standard. A legal case in 1858 was prematurely determined, because an appellant was running on London time. Great Tom, a huge bell in Oxford, is the only one that still chimes at local Oxford time each evening: 9:05 p.m.

Marquis Claude de Jouffroy d'Abbans in France built a boat using a British steam engine made by Newcomen. Called the Pyroscaphe, it made its first trip on the Saône river in July 1783. In America, John Fitch constructed a successful steamboat named the Perseverance, which made its first trip on the Delaware River in August 1787, and in 1807, Robert Fulton built the first seagoing steamship, the Clermont. It established a regular service steaming between New York City and Albany, NY in 30 hours.

By 1837, the SS Great Western built in Britain by Isambard Kingdom Brunel was running a regular service between Liverpool and New York. The ship is now restored and on display in Bristol, U.K. Science and technology had revolutionized international travel, and once more, it was all in the space of a lifetime.

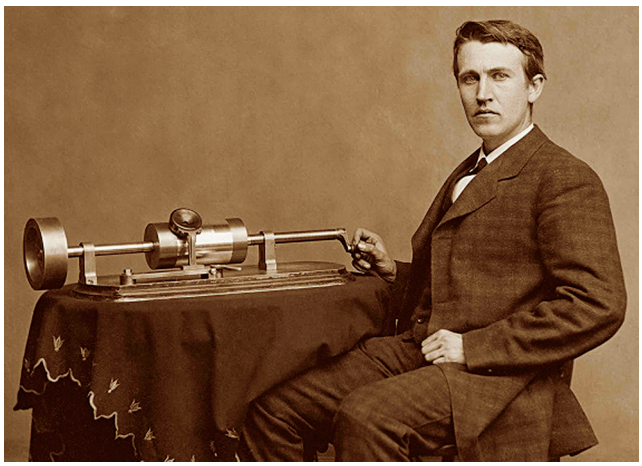
Then think of one of the greatest upheavals in human history — the dawn of mass public transportation. We joke "Beam me up, Scotty,"* but it actually happened in the 19th century.

People who had rarely traveled further than the next town could now buy a ticket, take a seat, and end up hundreds of miles away without effort. The first public railway opened between Stockton and Darlington in northern England in 1825, and within 90 years some 23,000 miles of railway had been established crisscrossing the British landscape in an orgy of construction. In a single lifetime, people extended their ability to travel comfortably and at speed from a few miles to cover the whole country. The bridges, cuttings, and vast viaducts built in the 1800s now carry modern express trains, and the magnificent original infrastructure has stood the test of time.

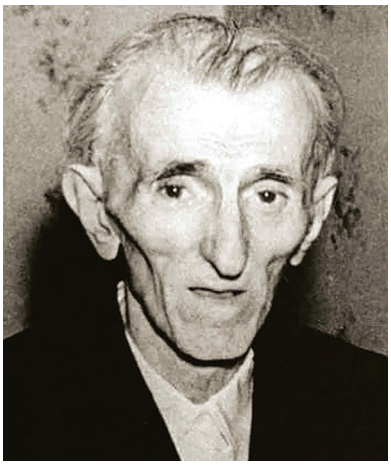
Trains gave birth to the notion of a time zone. The world had used local time ever since timekeeping began, so noon in London was 11 minutes earlier than local time in Bristol, about 100 miles west. So national time was introduced in 1855, based on the zero meridian at Greenwich. In October 1884, an International Meridian Conference was held in Washington, D.C., where it was agreed to divide the world into 24 1-hour time zones. The American delegate, Lewis M. Rutherford, proposed: "the adoption as a standard meridian that of Greenwich passing through the center of the transit instrument at the Observatory of Greenwich." And so Greenwich Mean Time (GMT) was born. It meant that the contiguous U.S. would straddle four time zones, nine when dependency territories are included. The biggest country of all, Russia, extended over 11 time zones.

The French refused to adopt GMT until 1911, even then redefining it as "Paris Mean Time retarded by nine minutes and 21 seconds." But they did have their revenge in 1967, when the French proposed that GMT should be succeeded by a system based, not on the clock at Greenwich, but on pooled readings from

*This command is associated with Captain James T. Kirk in the TV series "Star Trek," first broadcast in 1966. However, those words were never said. Kirk once announced: "Mr. Scott, beam us up," and on another occasion, "Beam me up." Like "Play it again, Sam," from the 1942 movie "Casablanca," the words we quote were never said in their original context.



Thomas Alva Edison was America's greatest inventor and one of the most prolific of all time. Although his work is widely misinterpreted (he did not invent the incandescent light bulb), some of his innovations — like playing back recorded sounds with this phonograph from 1877 — triggered a worldwide revolution that gave rise to the streaming of audio.



For all his fame and the importance of his contributions to modern society, Nikola Tesla died in poverty at the age of 86, friendless and alone, in the New Yorker hotel in Manhattan.

hundreds of atomic clocks from institutes around the world. This gave rise to Universal Coordinated Time. People are puzzled that the agreed abbreviation is not the obvious UCT, but UTC. It's because the French for Universal Coordinated Time is Universel Temps Coordonneé (UTC) so, in the end, the French had their way.

A WORLD EMPOWERED

Think of the scientific miracle of electricity, exhaustively investigated by Michael Faraday in London in the early 1800s. His research gave us the first dynamo and electric motor, and our essential understanding of the laws of electromagnetics. Faraday had little education (he learned to read and write at Sunday school) yet became one of the greatest scientists of his century. He was an enthusiast for the microscope, and the Whipple Museum at Cambridge University still has some of his original slides.

In February 1879, Newcastle, England, became the first city to have a street illuminated by incandescent electric lamps, designed by Sir Joseph Swan, and in April that year, Cleveland turned on 12 conventional arc lamps to illuminate their public square. In 1882, Thomas Edison's team lit up a square mile of Manhattan.

The early electrical power systems were based on Edison's favorite, direct current (DC) at 110 volts, but a Serbian electrical engineer, Nikola Tesla, preferred alternating current (AC) at 220/240V, since only AC can be distributed over distances of more than a mile. The practical problem was that no AC motor was known. In his thirties, Tesla emigrated to the U.S. and briefly joined the Edison Machine Works in New York City. Then, as a lone inventor, he developed the world's first AC motor, and unwisely sold all his patents and designs to the Westinghouse Company.

In 1893, Edison proposed to power the Chicago World's Fair, but the organizers knew that the Tesla AC system was more reliable, more controllable, and far cheaper, so the Westinghouse Company won the contract. Tesla's AC system soon swept across the world, leaving him impoverished; but his 220/240V became the global standard. Only North America and Colombia, along with a few island nations, stayed with Edison's 110V. After the Chicago exhibition, everyone wanted electricity, and by 1925, roughly half of all homes in the U.S. were connected to the electrical mains. It was another spectacular revolution within a single lifetime.

Thomas Edison had an extraordinary list of inventions with 2,233 patents. I find the Thomas Edison Center at Menlo Park, CA utterly absorbing, and I know Edison would be so pleased to think that, in his home country, 110V still holds sway. And imagine how Tesla would feel, with his name personifying the electric car. Experimental electric vehicles (EVs) had been investigated in Europe during the 1880s, but the first successful electric car emerged in the U.S. in 1890 from Des Moines. In 1900, the world speed record for a car was held by an EV, and the first battery powered car to exceed 200 miles (320 km) on a single charge was the Tesla, which is today the best-selling EV in the world.

It was in New York that Joseph Henry had invented the electromagnet and first experimented with electromagnetic induction. He conjured up the con-

cept of an electrical generator in 1832 but discovered that Faraday had already introduced the idea in London. Joseph Henry's greatest innovation was the electrical telegraph, which he pioneered in 1831. It wasn't the first; that had been set up in Geneva, Switzerland in 1774 by physicist Georges-Louis Le Sage. It ran on static electricity and had one cable for each of the letters of the alphabet; however, it never extended beyond his home. By 1816 in London, there was a similar telegraph extending for 8 miles, though these were only experimental and weren't destined to change the world. Several forms of telegraph were devised in which magnetized needles would point to discrete letters — until the ingenuity of Henry Morse in America gave us a practical way to send information rapidly. Morse code meant that a single signal could replace the complexity of identifying discrete letters in an alphabet, and it was an instant success. It took 10 days for news to cross America by the Pony Express, but information could be telegraphed long distances without a delay. Within 18 months, telegraph wires spanned the continent, and the Pony Express shut down. Wireless was to follow, then television, and each of these steps produced a revolution in society. Yet we think we exist in an era uniquely given to change?

And what of personal transportation? There were early cars powered by steam. The first we know was a toy, a diversion for the longest serving emperor in Chinese history, Shengzu of Qing. It was constructed by a Flemish Jesuit, Ferdinand Verbiest, in 1679. But the first usable steam-powered vehicle carrying passengers was built in France by Nicolas-Joseph Cugnot in 1769. The Americans were quick to follow, and the world's center of steam car production came to be centered in New England. In Lanark, IL, a self-taught engineer, Charles Cotta, started making steam vehicles by hand, and in 1900, he patented the idea of a four-wheel drive car. How many of us realize that the idea behind today's 4×4 had its origins in a small garage in Illinois? By 1900 there were twice as many steam-powered cars in the U.S. as those driven by the newfangled internal combustion engines. Virtually all were domestically produced, and Americans remained the only manufacturers of steam-powered cars until the last Endurance Steam Car was completed in Dayton, OH in 1925.

Internal combustion was an idea that took time to emerge. The Dutch experimenter Christian Huygens is best known for his work on microscopes and clocks, but in 1672, he created the first internal combustion engine, using gunpowder as fuel. In 1508, Leonardo da Vinci in Italy had mentioned a device using gunpowder to lift weights with fire, and a remarkable English inventor named Samuel Morland had proposed an engine using gunpowder to raise water from mines.

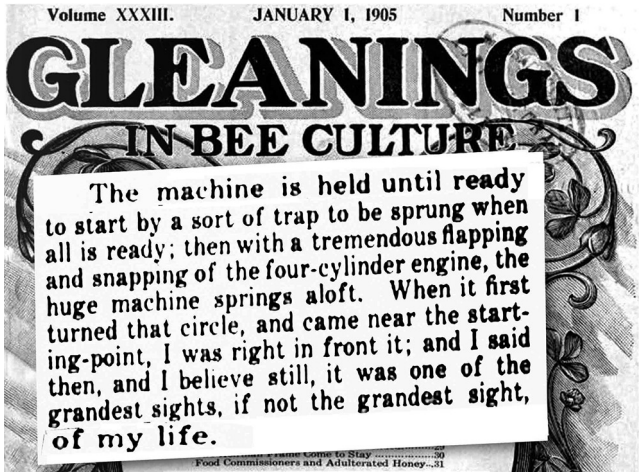
The first kerosene-fueled engine was created by Siegfried Marcos in Austria in 1864, and a gasoline engine was successfully demonstrated in 1876 by German engineer Nicolaus August Otto. Karl Benz demonstrated in 1886 a three-wheeled dogcart, powered by a four-stroke engine, then Wilhelm Maybach (with Gottlieb Daimler) designed an inexpensive gasoline engine. My great grandfather had a small automobile called a Voiturette in 1895, and the growing public interest in cars led to the first popular automobile produced in the U.S. This was the Curved Dash Oldsmobile, designed by Ransome Eli Olds in 1901. It was Olds who introduced the revolutionary idea of an assembly line, which Henry Ford harnessed to mass-produce the Model T in 1908. It was manufactured (in a range of colors including green, gray, red and blue, not just black) until 1927. By then, owning a car was popular; so once more we had a revolution taking place within a generation.

And planes? The Wrights first flew in 1903. Nobody was interested. The following year they asked an acquaintance, Amos Ives Root, to write an account of their experiments for *Scientific American*. That distinguished journal summarily rejected it, so Root published his account … in a beekeepers' magazine called *Gleanings in Bee Culture*. Thus was born the aircraft era. Just 44 years later, in 1949, my father took me to see the inaugural flight of the de Havilland Comet in London, the first jet airliner in the world. A scant 20 years after that day, I took my own children to see the Concorde taking off from Filton, in the West of England. In a scant 54 years we went from the Wright Flyer to supersonic flight.

I flew on the Concorde twice, and once had a chance to join the pilots on the flight deck. Flying to New York from London in the stratosphere you could see the earth's curvature, and frictional heating meant that the windows were too hot to touch. And now, jet travel around the globe is abundantly available for anyone buying a ticket. That's a revolution, if ever there was.

TODAY'S REVOLUTIONS

We imagine that we live in an age of scientific awareness, but in previous centuries, science was far more familiar to the public than it is today, and great revolutions were expected. A Victorian home was hardly complete without a microscope, and in my library is a set of *Cassell's Household Guide*, published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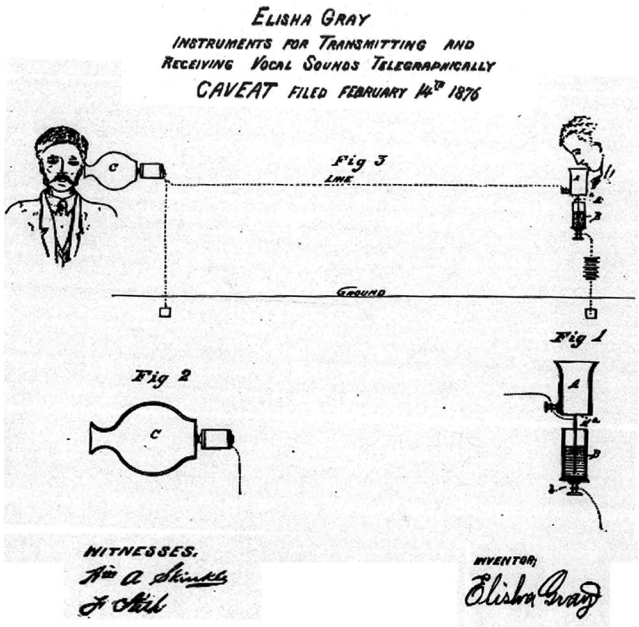
GLEANINGS IN BEE CULTURE

The machine is held until ready to start by a sort of trap to be sprung when all is ready; then with a tremendous flapping and snapping of the four-cylinder engine, the huge machine springs aloft. When it first turned that circle, and came near the starting-point, I was right in front it; and I said then, and I believe still, it was one of the grandest sights, if not the grandest sight, of my life.

The Wrights invited a contributor to *Scientific American*, Amos Root, to submit a report of their pioneering flights. The magazine rejected it, so Root published an account in an obscure beekeeper's journal that he edited. A copy recently sold for $5,000 (twice the estimate). Although the journal no longer exists, his company does. Root Candles still sells beeswax products.



Alexander Graham Bell is known as the inventor of the telephone, but Elisha Gray from Chicago submitted his patent proposal on Valentine's Day, 1876, the same day as Bell. Gray's document, placed earlier, lay further down the in-tray, and so Bell's proposal was registered first. The two were acquainted, and Gray often insisted Bell had plagiarized aspects of his design.

for housewives in 1869. It enjoins the reader to note the "spread of education and the consequent growth of intelligence and competition" in which the "woman finds her chief sphere of duty" and offers to help train this new generation "for the duties of life." And what were the principal preoccupations of the young housewives for whom the book was intended? The start was devoted to finance, and the economics of running a home, and there was much on specialist cookery. That may have been regarded as important in 1869, but I don't see it taught in schools today. Turn the pages, and here's a topic every young housewife should know: chemistry. Chemistry is at work all day long in the household, "from the moment the housemaid strikes the first match in the morning, till the final candle is extinguished at night." The chemistry of food is the next topic, and later the young housewife is introduced to a range of procedures — ranging from chemical tests to relative density — with which to detect adulterated flour. Later sections offer advice on distinguishing genuine gemstones from imitations, using hardness, electrical conductivity, and the presence of microscopic inclusions. This is the science that housewives needed to know 155 years ago. How many people know that now?

The public's knowledge of science and technology today is rooted in the movies and posts on their mobile phones. We are taught that the cinema began in 1896 with the Lumière brothers and their short movie of the train arriving at La Ciotat, France, which had the audience screaming in terror as the locomotive approached. But America was earlier. Thomas Edison had perfected his Kinetoscope movie camera by 1891 and planned to show his first movie, a glimpse of blacksmiths hammering on an anvil, at the Chicago World's Fair of 1893. The plans fell through, and the first public viewing of a movie was at the Institute of Arts and Sciences in Brooklyn, NY, on May 9, 1893.

Movies were traditionally viewed during their season at the cinema, and if you missed them, you missed them. Today's streaming services are themselves a revolution.

Another was the cellphone. Although some countries had introduced some experimental analogue mobiles, the first commercially available handheld cellphone was demonstrated in the car park at Soldier Field, Chicago, on Oct. 13, 1983. Their growth since has been phenomenal. Since 2016, there have been more cellphones in the world than people. They are rarely used as phones; people write posts, watch movies, play games, check data, book tickets, run bank accounts, and take micrographs through their microscopes — and, just occasionally, actually telephone people.

Cellphones are computers. The first computer I used was an Elliott 803 in 1962, a machine the size of a

kitchen designed by Iann Barron. Its CPU was as big as a wardrobe. I used to be championed for coding software (I showed that red blood cells circulate around the body faster than the plasma in which they are suspended), and it was all input on five-channel punched paper tape. Barron and I later became good friends, and I discovered he was only 3 years older than me. He was a computer genius, who had built the thing! All I could do was use it. It took a 1,000 ft (305 m) spool of punched paper tape to hold 1.3 MB data on his 803 computer; within 20 years you could store that on a 3.5-in. floppy disk no bigger than a beer mat, and 20 years after that the same data could be stored in something the size of bacteria. And now? We know there is more computing power in your cellphone than put a man on the moon, and today's smartphone is more powerful than your desktop computer.

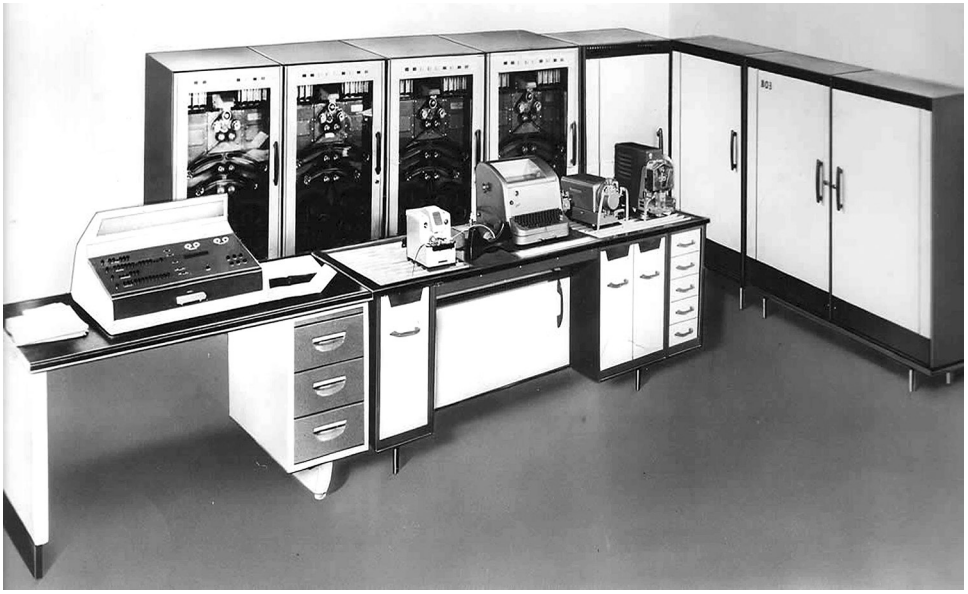
And that's what keeps kids glued to the screen. This is the real revolution that has changed everything: social media — rather than authenticated facts — now rule young people's lives. Generations of children went to school for a thousand years because that's where learning would be found. Schools had the books you required. Teachers were wise folk who could instill the knowledge you needed. Now that awareness is available to all; every activity you want to master is on YouTube, every fact you could ever need is available online. Cookery and climbing, construction and the creative arts — all are available to any user, along with hard pornography, bloody executions, torture, and abuse. Once seen, these things cannot be unseen, and this is what haunts young people's lives. One-third of internet users are minors, with 86% of 3–4 year-olds having access to a tablet, and almost 90% of 15-year-olds owning a smartphone. Children post an average 26 times per day, totaling some 70,000 posts by the time they leave school. They watch TikTok and YouTube, ignore television, and they don't read newspapers.

The algorithms operating the Chinese app TikTok capture our youngsters into engagement by creating obsessive discord, aggression, and the fear of exclusion, until it dominates their lives. They inevitably feel anxious, and modern medicine has designated this "generalized anxiety disorder," so it now becomes a disease necessitating costly treatment. It's not the first time a rival nation has tried to dumb down their opponents. In the 1830s, the British were covertly importing vast amounts of opium, grown in India, through their Chinese trading posts, as settlement for the Chinese tea that the English coveted. The result was a docile and compliant Chinese community — and it gave rise to the Opium Wars, starting in 1839, when the Chinese decided to fight back. Now it's their turn, and the Chinese are using it to full advantage.

The original cellphone was a Motorola DynaTAC, weighing 1.75 lb and costing $9,000. The first call was made to Alexander Graham Bell's grandson by Ameritech Mobile Communications president Bob Barnett on Oct. 13, 1983 in the parking lot of Chicago's Soldier Field. Within 40 years, there were more cellphones in the world than people. Their proliferation has dramatically changed society.

In China, intent on global advancement, their very different algorithms take browsers to educational pages, uplifting sites, with morale-boosting links that bring self-advancement and comfortable contentment. The world of our cyberkids is regulated by algorithms that we cannot influence, coded to order by private individuals serving their own interests and without external mediation. Those people have more power than governments. The stress, detachment from reality, and self-centered obsessiveness of the young is being exacerbated by forces society cannot control.

The greatest mistake made when the internet was young was allowing users to keep their identity secret. That's the cause of the abuse, threats, and unpleasantness online that nobody would post if we all knew who they were. In consequence, Western youngsters are being habituated into anxiety, anger, and regret, as Chinese youths are being uplifted, encouraged, and reaffirmed. Fictions and fake news about gender, vaccines, climate change, and dieting are now our norm. Free speech is dead. Social media sites can banish subscribers if they post something their algorithms don't want, so people are deterred from advancing an unacceptable idea, meaning that freedom of thought is banished too. There are no folk more asleep to reality than those who are woke, nobody more driven to use hate speech than those promoting inclusiveness, and no one more narrow-minded than those embroiled in political correctness. Even microscopical reality has



The first computer I programmed was this Elliott 803 at the Cardiff Institute of Science and Technology in 1962. It occupied an entire room to itself, and a 1,000 ft (305 m) spool of punched tape stored just 1.3 MB of data. Only one of the original computers is still fully operational, at the museum of Bletchley Park, U.K., where the World War II codebreaking computers have also been restored.

been subverted by this overwhelming tide of misinformation ("Farewell Reality, Hello Jellybeans," *The Microscope*, 70:1, pp 35–47, 2023). That's the revolution we are experiencing, and it has Western society on a downward slide to terminal decline. We need a radical revolution to adapt to this new world of uncontrollable disinformation that everyone has in their pocket.

The influence of digital automation, AI if you must, is slight by comparison. It is the continuing trend we have been experiencing since that first powered loom was patented by the English inventor Edmund Cartwright in 1785. Artificial intelligence? It is stupid. Recently I wanted to know how many cells there are in a Thysanopteran thrip, a tiny little insect no bigger than *Paramecium*. The size of their cells is known, and so are the dimensions of the thrip; so an intelligent mind that was better at math than me would work out the volume, and divide that by the size of an average cell. I thought I'd consult ChatGPT. You should always prime the system by inputting the essentials, so I posted the details of the thrips and then added the essential facts about the cells. When I asked it how many cells there were, ChatGPT described thrips, and then outlined cells. The intelligent part relating the two was missing. One user asked about the History of Midwifery in Trinidad and Tobago and was given an analysis titled, "The Impact of Attention-Deficit Hyperactivity Disorder on Modern Society." A woman promoting her home for vacation rental used a site "powered by AI," only to find its algorithms chose a photograph of a dilapidated outhouse, rather than the beautiful holiday home. There are so many articles online where users bemoan the sheer idiocy of these large language models. ChatGPT can sometimes seem smart, though. Another user, exasperated at the end of a tiring day, was asked if there was something else they wished to know, and input: "Tell me a word starting with F and ending with UCK." Without a pause, ChatGPT responded: "The answer you need is FIRETRUCK."

Remember that artificial intelligence acquired its name because its proponents wished to dignify their progress with a term everybody would find exciting. It is, though, just digital automation. Nothing more. And it won't take over the world. We automated farming, navigation, washing our clothes and dishes, manufacture, calculations, weather forecasting … and generative software is just another small step along the way.

A single cell exhibits intelligence; no AI program comes close. The truth is, intelligence is innate. It doesn't rely on language. People who cannot speak, and never have, are as intelligent as any of us — yet AI programs simply interpret the syntax of the English language. That might be ingenious, and it can be astonishing, but it has nothing whatever to do with intelligence. If only everybody understood how we came to be where we are, then it would slot more easily into context. You could start by reading this article in class. Read aloud, it lasts for 48 minutes. That's not too long, out of the 1 million minutes children spend going to school — and it might benefit them far more than the mind-numbing dross they find on social media. ■