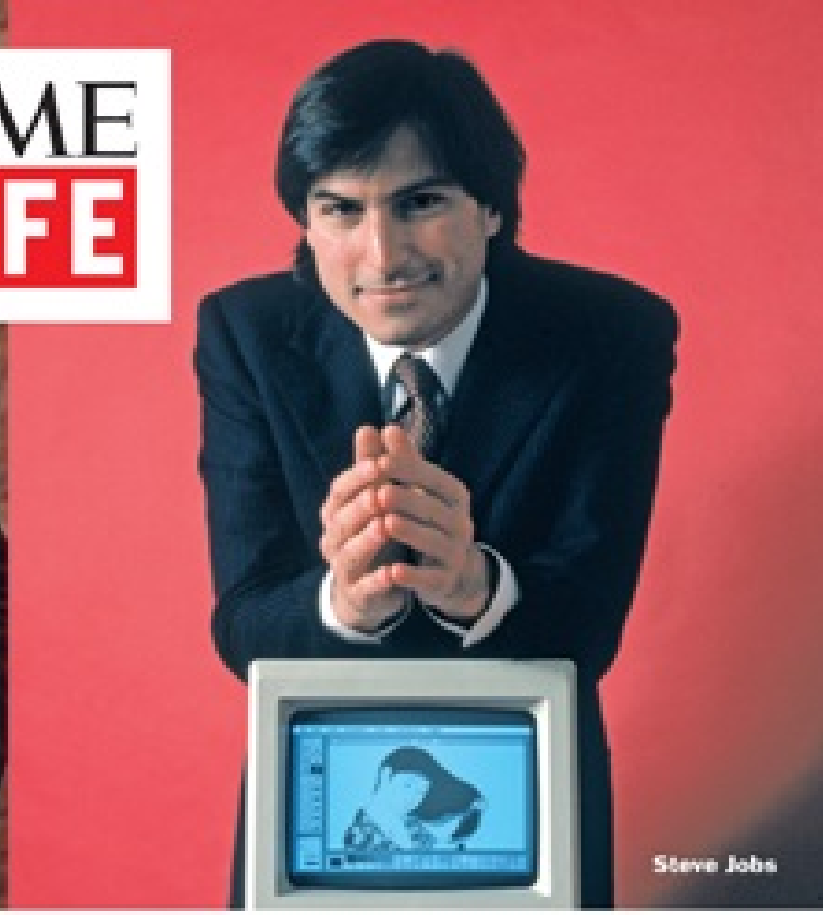


TIME LIFE

American Inventors

A HISTORY OF GENIUS


TIME
LIFE
Thomas Edison
Steve Jobs
American Inventors
A HISTORY OF GENIUS
Jonas Salk

AMERICAN INVENTORS

A History of Genius

Benjamin Franklin's 1752 experiment identified lightning as electricity and provided a basis for lightning rods.

Elon Musk is a serial inventor and entrepreneur: he has helped launch not only the space-launch service SpaceX, but also PayPal and Tesla Motors.

Contents

AMERICAN INVENTORS

Born That Way

There is a cultural mystique to the American inventor, something akin to the cowboy or patriot in popular imagination. Before America reinvented democracy for the modern era, the American inventor personality had already emerged: many of the founders were inventors, and the country's early success and growth was fueled by innovation of all kinds, from navigation to military tactics. Throughout the hamlets and growing cities, the industrious and restless found new ways of building, organizing, and farming, too. Invention, it seemed, was in the nation's lifeblood.

Even the term "American inventor" is evocative, conjuring images of plowing prairies and harvesting crops, of illuminating the Great White Way, eradicating disease, and harnessing the physical universe. For some, such accomplishments have meant financial gain. But being an inventor is not just about seeking wealth, it's about having an impact: to invent and commercially succeed in shaping the world's first mass society is, as Steve Jobs put it, to "put a ding in the universe."

One reason the inventor personality has thrived here is because of America's diversity. As one of the most open societies in the world, the United States draws people from all corners. The exchange of ideas percolates synergistically. What is developed by one inventor is taken up by another and pushed further, improved, perfected.

Individualism comes into play. American inventors are as diverse as their origins and run the gamut of personality types. There are the sole tinkerers and the business-minded, the blithe and the morose. Some come from money; others died in debt but with patents to enrich their descendants.

In America, application rapidly follows theory, the French political thinker Alexis de Tocqueville noted two centuries ago. Inventions and innovations spur productivity and inspire derivative ideas. Citizens may first be wary of change, but they soon embrace and rapidly adopt new technologies. They understand that essentially American viewpoint put across by automotive inventor and businessman Charles Kettering: "The world hates change, yet it is the only thing that has brought progress."

INDUSTRY

American innovation has always delivered first, better, and faster.

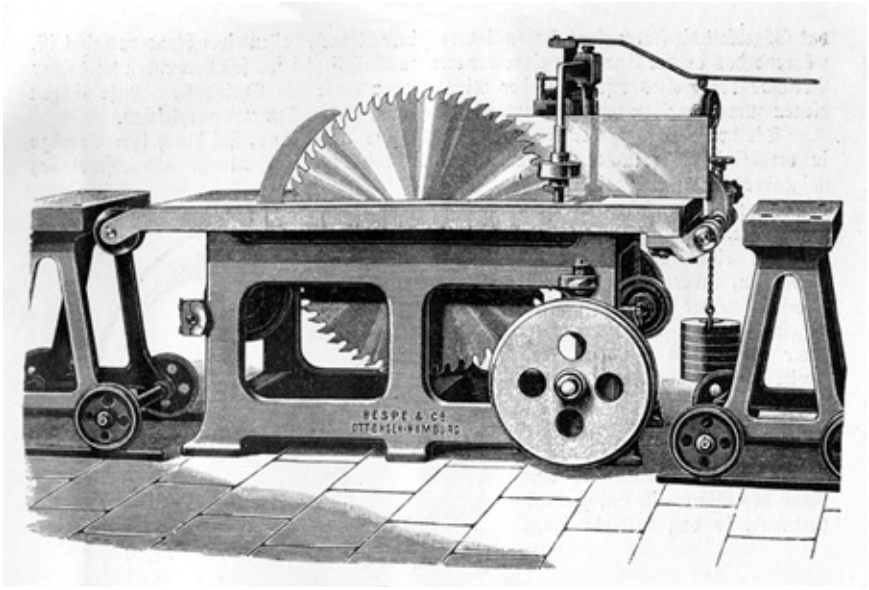
About one-third of industrial robots, invented by an American, are used for welding.

Blade Runner

TABITHA BABBITT

(1779–1853)

Circular saw, mass-produced nails



An illustration from a 19th-century book on inventions shows a large circular saw.

In 1793, nine-year-old Tabitha Babbitt and her family joined a settlement founded by the Harvard Shakers, a group of idealistic pacifists who had split from the Protestant Church. The community, the first of its kind in Massachusetts, was self-sustaining in many ways, with a thriving forestry trade that included logging, milling, and woodworking. The Shakers' commitment to gender equality opened a door for Babbitt, who took up weaving, furniture making, and eventually inventing.

As she worked, Babbitt observed fellow Shakers using a whipsaw to cut wood for furniture. It was an inefficient process that required two people pulling back and forth on a dual-handled saw blade to slice through a log. Babbitt realized that a round saw blade on an axle, with a continuous spinning and cutting motion, would reduce the manpower required. She created a circular saw, powered by water, that sped up the log-cutting process and soon was adopted by New England sawmills.

Mass-Producing Nails

Babbitt introduced a number of other manufacturing techniques. One of these was cut nails, which at the time were individually hand-forged.

Babbitt was interested in the idea of mass production and how it could improve productivity. Instead of making nails one by one, she wanted to produce them in

batches. She took a large, single sheet of iron and, using a template, stamped out multiples.

Despite such labor-saving advances, Babbitt never earned much money—or recognition—for her accomplishments beyond her Shaker community. Why? One reason is that it contradicts Shaker beliefs to patent work. Yet Babbitt continued to invent until the end of her life. When she died in 1853, she was working on a new idea: false teeth.

Electric-powered circular saws use the same principle pioneered by Babbitt.

Point Man

ELIAS HOWE

(1819–1867)

Lockstitch sewing machine

Howe's sewing machine, which used an eye-pointed needle and a shuttle to form a lockstitch, marked the beginning of the sewing-machine industry.

By the early 1800s, more than 40 inventors had tried unsuccessfully to automate sewing. Among them was a Massachusetts machinist named Elias Howe, who stumbled upon the answer in a nightmare. Howe dreamed that he had been captured by a primitive tribe that was trying to stab him with unusual-looking spears. Instead of the standard solid pole, theirs had holes in the end, right below the pointy tips. The image inspired Howe to move the thread hole for his machine from the middle to the tip of the needle.

Weaving Together a Plan

Howe's interest in sewing machines sprang from his experience in the textile industry. At 14 he became an apprentice at a textile factory in Lowell, Massachusetts, not far from his home, then entered another mechanical apprenticeship at a Cambridge textile mill in 1838. It was at the mill, where Howe learned to repair precision instruments,

that he began to conceive and develop an automatic sewing machine.

By 1846 Howe had received a patent for his invention, which featured a number of novelties, including a shuttle beneath the cloth to form a lockstitch and an automatic feed. Unable to convince American tailors of the value of the machine, Howe moved to England to try his luck. But the British were only slightly more interested buyers, and Howe returned to the United States, discouraged and destitute, in 1849. Tragically, his beloved wife died of consumption almost immediately upon his arrival, and he was left struggling to support and raise three children alone.

Sewing Up a Lawsuit

Things got worse when Howe discovered that inventors Isaac Singer and Walter Hunt had begun selling a pirated version of his automatic sewing machine while he was away in England. He sued Singer and Hunt and other manufacturers for patent infringement, a battle he ultimately won. But once the lawsuits were resolved, Howe and Singer entered into a business agreement in which Howe allowed Singer to sell the machines under the "Singer" name, provided they were designed and manufactured by Howe. The Singer sewing machine revolutionized the garment-making industry, and Isaac Singer and Elias Howe became millionaires.

Howe finally achieved financial success when he licensed his invention to Isaac Singer.

The Wizard of Menlo Park

THOMAS EDISON

(1847–1931)

Light bulb, phonograph, and more

A carbon filament lamp, similar to the type invented by Edison

It was not immediately clear that Thomas Alva Edison would amount to much. When he started school at age seven, in Port Huron, Michigan, Edison was derided by a teacher as "addled." The comment prompted his mother to withdraw her son, who was hard of hearing, from class and homeschool him. The experience changed Edison's life. It instilled him with a love of learning, self-reliance, and incredible drive.

The Early Years

After a brief period selling newspapers in his early teens, Edison set out on his own at age 16. He worked throughout the Midwest as a traveling telegraph operator but eventually relocated to Boston to take a job with the Western Union Telegraph Company as a telegrapher. In his free time, Edison tinkered with his first major invention, an electronic voting machine. However, it failed to generate interest.

Within a year Edison was off to New York to seek better opportunities. He continued his work as a telegrapher but also tackled his next invention, an improved electronic stock ticker. Success came quickly when he developed a mechanism that allowed different stock transactions to be synchronized and printed. The Gold and Stock Telegraph Company acquired rights to the invention in 1870, earning Edison $40,000 (more than $830,000 in today's dollars). Lore has it that Edison was so stunned by the

offer that he nearly fainted.

Menlo Park

With his windfall, Edison was able to quit his telegraphy job and focus on inventing. He set up a laboratory and factory in Newark, New Jersey, and began developing products. One of these was a powerful telegraph, which quadrupled signal station capacity and was designed for Western Union. But before the deal was signed, railroad magnate Jay Gould intervened, offering Edison more than $100,000, which the inventor accepted.

Now wealthy, Edison shut down his workshops in Newark, and in 1876 relocated to the New Jersey countryside to build a research facility in Menlo Park. Dubbed the "invention factory," Edison's lab created a model for the pursuit of innovation. Instead of working alone, often at home or else in a small workshop with one or two assistants, inventors at Menlo Park collaborated with teams of scientists and craftsmen. The sprawling complex included a physics lab, a machine shop, a blacksmith shed, a glassworks, a carpentry shop, an office, and a library. It was also accessible for workers, since it was near a railway; it was close to the financial centers of New York and Philadelphia, giving Edison a pipeline to bankers.

In a letter to the president of Western Union, Edison boasted that his Menlo Park laboratory would produce "a minor invention every ten days and a big thing every six months or so."

Enter the Phonograph

Two of the biggest of these "big things" were the phonograph and the light bulb. Edison began developing the idea for the phonograph in 1877 while trying to find a way to record the dictation of letters so that they could be played back and transcribed. One inspiration was the work of a French printer named Édouard-Léon Scott de Martinville, who in 1856 had graphed sounds by mounting a vibrating stylus to a diaphragm on a megaphone. In that process, Scott de Martinville dragged a stylus over a rotating glass cylinder coated with carbon, etching the "sound" into the carbon in the form of a wavy line. Edison replaced the cylinder with one sheathed in tinfoil and succeeded in recording sound and playing it back. He demonstrated his invention for members of the U.S. Congress and President Rutherford B. Hayes. The public was astounded when they heard of the phonograph, and the *Daily Graphic*, an illustrated New York newspaper, dubbed Edison "The Wizard of Menlo Park."

A Light Goes On

Technically, Edison did not invent the light bulb, but he made it burn better than anyone had before. The first step was selecting the right filament—a material that would give ample light and be durable enough not to burn out. Edison and his workers experimented with over a thousand materials, including paper, thread, wire, and human

experimented with over a thousand materials, including paper, thread, wire, and human hair. In 1879 they hit on their best option: carbonized thread. The next year Edison improved the bulb by substituting carbonized bamboo for the thread and upgrading a vacuum pump he used to remove air from the glass globe. The improvements meant the filament could burn for almost 1,200 hours.

An Inventor's Legacy

The light bulb and the phonograph gave Edison worldwide fame, and he became as much an industrialist and business manager as an inventor. Edison's "rags-to-riches" story made him an American icon, and he received a Medal of Honor from the U.S. Congress in 1928. During his lifetime, he registered 1,093 U.S. patents, the most by an American until astrophysicist Lowell Wood, who has worked on everything from anticoncussion helmets to vaccination technologies to nuclear reactors, passed him in 2015.

A colorized photo of Edison in his laboratory in 1904

EDISON WAS A SAVVY BUSINESSMAN. TO GET CONSUMERS INTERESTED IN HIS NEW LIGHT BULB, HE PUBLICIZED HIS SEARCH FOR THE PERFECT FILAMENT.

Stop It

ELISHA OTIS

(1811–1861)

Safe elevators

This illustration shows Elisha Otis's dramatic demonstration of his elevator safety brake at New York's Crystal Palace in 1854.

Today, Elisha Otis's name might be synonymous with elevators, but the New Yorker (by way of Vermont) did not invent the vertical transport machine. Instead, he created the elevator safety brake, a device that rendered elevators safer, more efficient, and popular.

Lockdown

Otis left home at age 20 to try his luck as a wagon driver in Troy, New York. He married and returned to Vermont, where he started a family and opened a gristmill and then a sawmill, both of which failed. Otis turned to carriage-and wagon-making but was sidelined, first by a near fatal case of pneumonia and then by the death of his wife. He moved to Albany with his two young children to work at a bed-making factory. It was here that Otis's inventing career took off. Trying to improve the factory's output, he

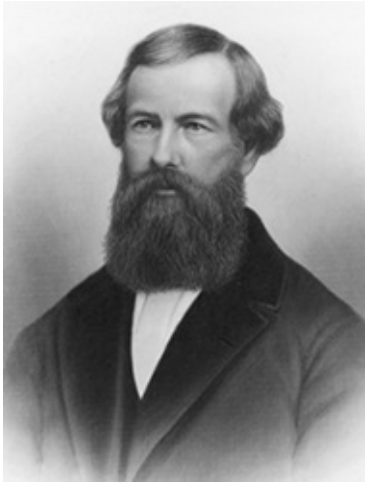
here that Otis's inventing career took off. Trying to improve the factory's output, he began developing a device that could turn bedposts at a much faster rate.

With a bonus from his boss, Otis struck out on the side, producing a variety of inventions, but he lost his factory space and relocated first to Bergen City, New Jersey, and then to Yonkers, New York. While working as a mechanic at Maize & Burns, a bed manufacturer in Yonkers, he designed a hoisting device to move heavy equipment around the factory's two floors. Worried that the ropes used to operate the platform-style elevator might break under the weight of heavy lumber or beds, Otis added wooden notches to the inside of the elevator shaft and a strong steel spring to the top of the elevator. If the elevator cables broke, the spring mechanism snapped into the notches and prevented the platform from falling. Otis had invented the elevator safety brake.

Going into Business

Otis left Maize & Burns to market his brake full time. At a demonstration at New York's Crystal Palace in 1854, he stood on a hoist like the one in his factory and rose up high above the crowd. Then, to the shock of the audience, he asked an assistant to cut one of the ropes with an ax. The crowd gasped when his assistant dramatically cut the cord suspending the platform, but the brakes worked, and the plank dropped just a few inches and came to a stop. Otis sold seven "safe elevators" that year and 15 the next.

In 1857, the five-story Haughwout and Co. building on Broadway, in New York City, installed the first passenger elevator with Otis's locks, as well as other safety devices. After Otis died at age 50, from diphtheria, his sons, Charles and Norton, carried on the business, which became the leader in elevator manufacturing as the country entered the skyscraper age. Today, Otis Elevators are produced by United Technologies Corporation.



Otis, in a painting from 1855, helped make skyscrapers possible.

A Big Gun

SAMUEL COLT

(1814–1862)

Revolver

Using interchangeable parts, Colt was one of the first to capitalize on assembly line manufacturing.

Born in 1814 in Hartford, Connecticut, young Samuel Colt liked to take machines apart and put them back together to learn how they worked. While studying to be a navigator at Amherst Academy in Massachusetts at age 16, that curiosity got him expelled: he was tinkering with some explosives and accidentally blew up a classroom.

Getting the Gears Turning

Colt's father gave him the choice of coming to work in his textile mill or putting his education to use. Colt chose the latter, sailing as an apprentice aboard the *Corvo*, bound for India. He cared little about ropes and sails, but he was keenly interested in the rotating gears that drew and released the *Corvo*'s anchor.

After the ship arrived in India, Colt got a chance to handle a repeating pistol made by inventor Elisha Collier. The gun didn't work, but it inspired Colt, and he soon began

work on a pistol with a rotating cylinder that mimicked the movement of the anchor gears he had observed during his long voyage. He created a working model with a bullet-loaded chamber that revolved around a shaft and dubbed it a "revolver." When the gun fired, it activated the cylinder, which rotated and placed another bullet in the chamber automatically. The gun was ready to fire again in less than a second. That beat the usual pistol-reloading time of 20 seconds.

Booming Business

Colt patented the invention in 1835, and with the help of some investors, he formed the Patent Arms Manufacturing Company, in Paterson, New Jersey. Business was slow, so Colt traveled to Washington, D.C., to try to secure a government contract. That effort failed, and in 1842, Patent Arms closed its doors.

Colt's luck was about to change, however, with the advent of the Mexican-American War, a fight for the disputed territory of Texas. The conflict created a demand for a steady supply of arms from the U.S. government. Samuel Walker, captain of the Texas Rangers, was familiar with Colt's revolvers, having used them during the Seminole Wars. He paid Colt a visit in New York City and collaborated with the entrepreneur to improve the pistol. Walker's superior at the time, American general Zachary Taylor, ordered a thousand Colts for troops under his command, and the Texas Rangers adopted the weapon as their official gun.

With his reputation launched, Colt in 1855 began work on a factory in Hartford, Connecticut, that eventually became the world's largest privately owned arms-manufacturing plant, employing over a thousand people. By the end of that year, Colt was one of America's richest men. He purchased an estate in Connecticut called Armsmear and had a net worth of $15 million. Colt died in January 1862, at the onset of the Civil War, a conflict in which Union forces would prevail using more than 300,000 revolvers manufactured by Colt's company.

A mid—19th-century Colt Navy percussion revolver.

COLT WAS A MARKETER AHEAD OF HIS TIME. HE NOT ONLY COMMISSIONED WELL-KNOWN ARTISTS TO CREATE ADS, HE SOLICITED CELEBRITY ENDORSEMENTS AND PURSUED PRODUCT PLACEMENT DEALS.

Power House

GEORGE WESTINGHOUSE

(1846–1914)

AC distribution, railway air brake

Westinghouse reading a newspaper in the early 1900s

George Westinghouse first got interested in power and engines as a boy during the 1850s, when he helped out in his father's New York machine shop. But it was the Civil War that helped spark the idea that would make him wealthy and famous. Convinced that an expanded railway network would help the broken nation heal, Westinghouse looked for solutions to improve rail shipping. His first invention, compressed air railroad brakes, made it easier and safer for locomotives to suddenly stop. His Westinghouse Air Brake Company became a success, and he expanded into Europe and Canada.

A Debate in Current Events

In the 1880s, Westinghouse watched as inventors Thomas Edison and Nikola Tesla competed to establish a standard method to deliver electricity to American homes and businesses. The stakes were huge, with both men angling for lucrative contracts to wire cities. Edison argued in favor of direct current (DC), where electrons flow steadily in a single direction, creating a small amount of electricity that can travel only a mile or so from its source. Tesla, by contrast, promoted alternating current (AC), where electrons

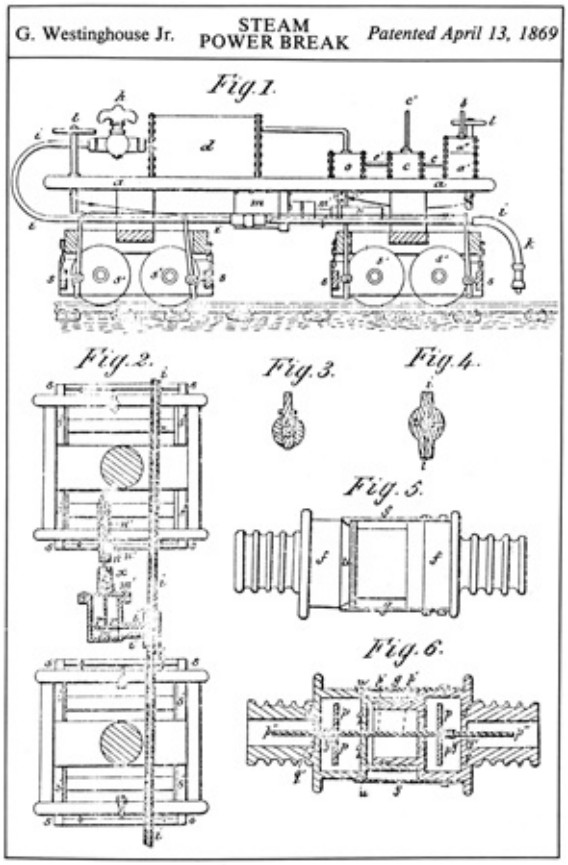
repeatedly switch directions, creating more and highervoltage electricity, which can travel long distances.

Westinghouse saw a business opportunity in the developing electrical industry, and in 1884 he formed the Westinghouse Electric Company to produce and distribute the new form of power. After considering and rejecting Edison's DC method, Westinghouse bought Tesla's AC patents with the goal of establishing a system to power a major city. He also hired Tesla, who had briefly worked in Edison's lab, to lead the project.

The "War of the Currents"

The battle lines were drawn. With Westinghouse and Tesla a team, Edison worked to discredit them. Among other stunts, Edison publicized the fact that the state of New York used a Westinghouse-built AC generator for its electric chair and arranged to have an elephant electrocuted at Coney Island with AC current to dramatize its dangers. (The elephant, Topsy, had killed a circus spectator.) This "War of the Currents" between AC and DC waged on for seven years, with the winner declared in 1893. That's when Westinghouse and Tesla won the contract to light the World's Columbian Exposition in Chicago. At the time, Chicago boasted more electric lights than any other city, and the installation at the world's fair demonstrated the safety and efficiency of AC current. Soon after, Westinghouse built an AC power plant at Niagara Falls, which provided New York City with its electricity.

Today, AC remains the electrical standard, while DC is used for batteries, fuel cells, and solar cells. It is also used to power some electric railways.



The patent drawing for Westinghouse's steam power brake, 1869

WESTINGHOUSE WAS A DOWN-TO-EARTH EMPLOYER KNOWN FOR FAIRNESS, PROVIDING SOCIAL SERVICES AND CUTTING HALF A DAY FROM THE WORK WEEK.

Shock and Awe

NIKOLA TESLA

(1856–1943)

Second industrial revolution

Tesla sits calmly reading, demonstrating the safety of the arcing electricity created by his resonant transformer.

The everyday miracle of electricity would not have been possible without the experimentation of scientist Nikola Tesla. Born in what is today Croatia, Tesla emigrated to the United States in 1884 to work for Thomas Edison, but the two men were polar opposites in temperament and methods: Edison was self-taught and methodical, while Tesla, who had been trained as an engineer, was freewheeling and quirky. After a financial dispute, the men parted ways.

Inductive Reasoning

One of Tesla's first contributions after setting out on his own was his transformation of the electric motor. At the time, most motors used direct current and required mechanical connections between the rotor (the part that turns) and stator (the magnets encasing the rotor) in order to work. Tesla removed the need for any mechanical connection between the stator and the rotor by supplying alternating current to the stator, which created a rotating magnetic field and caused the rotor to spin.

Tesla patented the so-called induction motor in 1888. Inventor and industrialist George Westinghouse licensed the patent and worked with Tesla to standardize

George Westinghouse licensed the patent and worked with Tesla to standardize transmission of the alternating current essential to power these motors. With widespread electrification in the early 20th century, the induction motor brought power to the masses. It made possible the proliferation of small machines, from woodworking tools to blenders, that so transformed American life in the early decades of the 20th century that it earned the name the second industrial revolution.

Coming Uncoiled

In 1891, Tesla created the resonant transformer, or Tesla coil, which turned a relatively low-voltage current into a wide-ranging electrical field. Anything within the reach of the field could be powered by it, without wires. The inventor theorized that a few massive Tesla coils placed strategically across the globe could provide wireless electricity to the entire world.

Posthumous Power

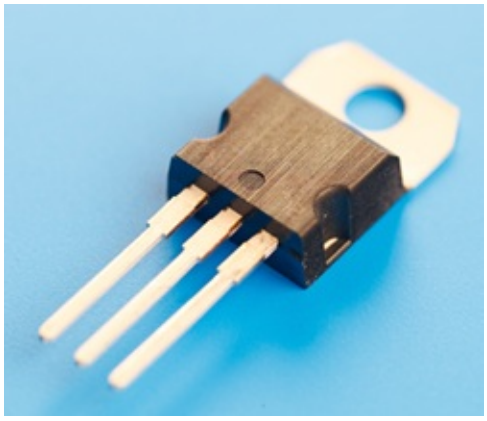
When Tesla died in a humble room in the New Yorker Hotel in January 1943, he was penniless and unrecognized for many of his innovations. Today he is considered an iconoclast folk hero among engineers and inventors. Martin Eberhard and Marc Tarpenning, the founders of Tesla Motors, named their electric car company in Tesla's honor, and entrepreneur Elon Musk, another founder (he is also behind the aerospace manufacturer SpaceX and PayPal), has named Tesla, as well as Thomas Edison and Winston Churchill, as his idols.

Pioneer of Silicon Valley

WILLIAM SHOCKLEY

(1910–1989)

Transistor



An early transistor

Controversial transistor co-inventor William Shockley had such a difficult personality that when he died, in 1989, he was estranged from his three children and virtually friendless. Nevertheless, by helping to create the transistor, a device that amplifies electric currents, Shockley laid the groundwork for the electronic age.

Nuclear Reactionary

Born in 1910 in London to American parents, Shockley spent only a few years in England. When he was very young the family resettled in Palo Alto, California; he was homeschooled and kept apart from other children. Shockley was exceptionally bright and after a brilliant undergraduate career he went on to receive his PhD. His mentor, Philip Morse, a leading physicist, got him a job at the famous Bell Laboratories research facility in New Jersey.

With a colleague, James Fisk, Shockley began to explore ways of using nuclear fission (when an atom breaks into smaller parts) as an energy source in 1939. Shockley developed on the idea of separating uranium into chunks, which led directly to the design of the first nuclear reactor. Due to the highly dangerous nature of his findings, which could be used to develop an atomic bomb, the U.S. government seized the information and prevented Shockley from working further on the project. All of his findings were made classified, and even U.S. government scientists were prevented from accessing them. Shockley and Fisk were also barred from trying to patent their discovery.

When World War II broke out, Shockley's former mentor, Morse, called on him to

help improve tactics of American submarines, such as depth charges and convoy formations. Shockley took a leave from Bell and joined the Anti-Submarine Warfare Operations Group at Columbia University. In 1944 he began training bomber crews with the Army Air Corps, traveling all the world to teach radar skills to pilots.

Developing the Transistor

By the end of the war, the United States had been wired for phone service from coast to coast. However, the network had been built using vacuum tubes, which amplify electric charges. The 30-year-old technology had a number of challenges: the tubes broke easily, were expensive to produce, needed to be warmed up before they could be used, and even attracted moths.

Shockley returned to Bell Labs, which put together a team charged with developing a "solid state" alternative to vacuum tube–based transistors. A solid-state model meant that the electric current would be contained within solid material instead of the problematic glass tubes. Building on wartime research, Shockley, along with engineers John Bardeen and Walter Brattain, explored solutions using materials that didn't break but still conducted and amplified electrical signals.

In 1947, Bardeen and Brattain had a breakthrough when they created an early transistor using germanium, a chemical element similar to tin or silicon that is capable of carrying an electric current. Shockley was not directly involved in the work, and he decided to one-up his colleagues. He holed up in a hotel room for four weeks and, working mostly with pen and paper, came up with an improved version.

Bell Labs introduced the transistor in 1948; the company named it by combining *trans* and *resistance*. At a hundredth the size of a vacuum tube, the transistor's size and functionality would ultimately make microchips possible. Within a decade, transistors replaced vacuum tubes in radios and other electronics as the preferred means of conducting power.

From Nobel Prize to Persona Non Grata

Shockley and his colleagues won the Nobel Prize in Physics in 1956.

Shockley left Bell Labs and formed his own company, Shockley Semiconductor, in Palo Alto, California, in 1956—the unofficial beginning of Silicon Valley. His reputation, however, was tarnished by a series of offensive comments he made, such as advocating the sterilization of people with an IQ of less than 100, and he ultimately was shunned by the scientific community.

Shockley poses in his lab the day in 1956 it was announced that he had been awarded the Nobel Prize in Physics.

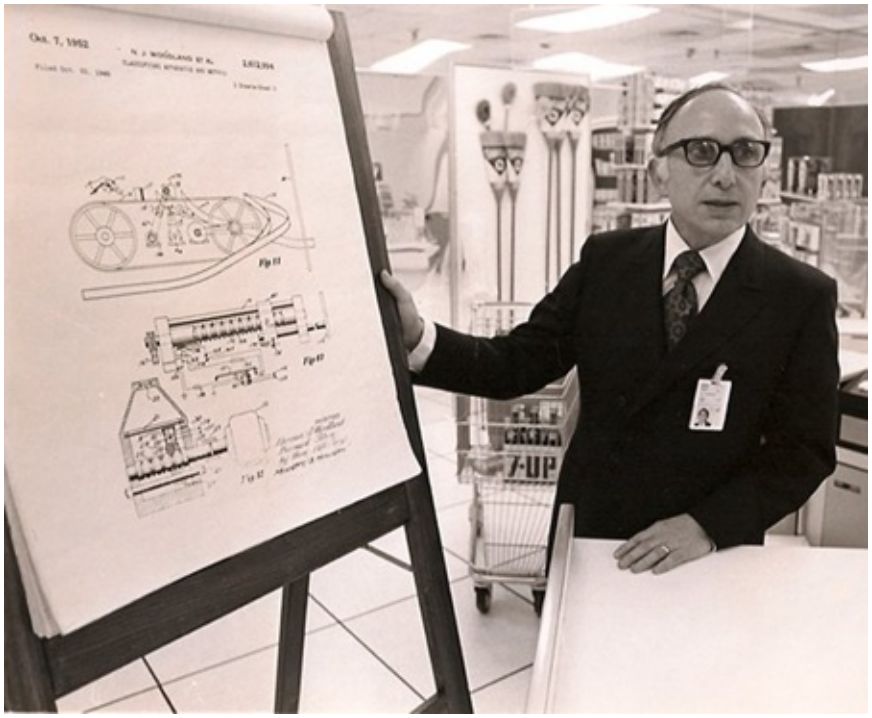
TIME MAGAZINE CALLED SHOCKLEY "ONE OF THE CENTURY'S MOST IMPORTANT SCIENTISTS."

Raising the Bar

NORMAN JOSEPH WOODLAND

(1921–2012)

Bar code



Woodland explains his prototype scanner for products with bar codes.

Two elements of Norman Joseph Woodland's young life figured into his invention of the bar code: his affinity for Morse code, learned as a Boy Scout, and his love of the beach, which traced back to his birthplace of Atlantic City, New Jersey.

Check It Out

In 1948, Woodland was earning his master's degree at Drexel University, when a Philadelphia grocery store executive visited the campus. The grocer asked one of the school's deans if there was a way to devise a computerized checkout and inventory tracking system. Another student named Bernard Silver overheard the conversation, and when the dean passed on the opportunity, Silver told Woodland about it. Woodland became so fascinated by the idea that he quit school to devote full time to a solution. While mulling the problem at a beach near his grandparents' house in Miami, Florida, he drew in the sand with his fingers. The lines gave Woodland a flash of inspiration.

Shrinking the Scanner

Woodland thought that a combination of wide and thin lines could be interpreted like the dots and dashes used in Morse code. An optical computer scanner could read the series of markings. Woodland and Silver filed a patent for the idea in 1949. The original design was circular so that the code could be read in any direction.

In 1951 Woodland landed a job with International Business Machines Corporation in Armonk, New York, and the following year he and Silver were granted their patent. At first, few retailers took an interest in the system, which was the size of a desk—not even the grocer who had asked the students to create it. Woodland and Silver sold their patent to Philco for $15,000. It would be all they ever earned from their invention. Philco later resold the patent to RCA.

When the patent expired in 1969, different companies moved to advance upon the idea. Woodland never gave up on his dream of seeing the scanning system reach its full potential. At IBM's facility in Raleigh, North Carolina, he worked with engineers to develop a handheld laser scanner and bar code scanning system.

Every Grain of Scan

Along with his bar codes, Woodland and IBM engineer George Lauer devised a numerical coding system (the universal product code, or UPC), which assigned every product a unique identifying number and bar pattern. Instead of Woodland's original circular design, the UPC was square, which made it easier to print. Supermarkets adopted the UPC code as an industry-wide standard in 1973.

Bar codes enable manufacturers and sellers to automatically track inventory and sales data. Today, bar codes in the United States and Canada have 12 digits, while international versions use 13.

WOODLAND ALSO WORKED ON THE TOP-SECRET MANHATTAN PROJECT DEVELOPING THE ATOMIC BOMB DURING WORLD WAR II.

Strong-Arm Man

GEORGE DEVOL

(1912–2011)

Industrial robot

Devol demonstrates his Unimate robotic arm.

What do you get when you introduce a self-taught electrical engineer to a science fiction fan at a cocktail party? In the case of George Devol and Joseph Engelberger, a path leading to the invention of the industrial robot.

The Unimate

When Devol and Engelberger met in 1957, both men were already fascinated by robots. Devol, who had begun work on a digitally operated programmable robotic arm, was convinced that one day machines would do work that humans could not or would not do. Engelberger, also an engineer, was an avid fan of science fiction writer Isaac Asimov's *I, Robot* collection of stories and a receptive audience. They teamed up and committed to making the industrial robot a reality. In 1961 Devol received a patent for the device, which he dubbed "Unimate"; the patent was so original, it cited no prior patents as reference.

The first functional Unimate robot, powered by a self-contained hydraulic system, debuted at a Chicago trade show later that year. In a demonstration, the arm picked up metal letters and spelled out words. The invention so impressed a Ford Motor

Company executive that the automaker submitted an order for thousands.

Automation Nation

Ford put the machines to work in its Detroit plant, where they were programmed to pick up and weld die castings onto auto bodies—a dangerous job for humans as the castings were molten hot and weighed 500 pounds. The Unimates took their orders from commands programmed into a magnetic drum containing magnetic tape. In 2005 *Popular Mechanics* magazine named Devol's Unimate one of the Top 50 Inventions of the Past 50 Years.

In his late career, Devol devoted his time to running a robot consulting business. He continued to develop new robotic technologies, including visual and tactile sensors. When he died in 2011 at age 99, he had over 40 patents to his name.

Extremely Focused

THEODORE MAIMAN

(1927–2007)

Laser

Laser is an acronym for "light amplification by the stimulated emission of radiation."

Engineer and physicist Theodore Maiman developed an interest in electronics and technology at an early age. As a teenager in Los Angeles, he made pocket money repairing radios, a skill that led to a job with the National Union Radio Company when he was just 17.

After college and earning his degree in engineering physics, Maiman pursued research in electrical engineering and experimental physics. As a doctoral candidate, he worked on calculating the measurements of split helium atoms, research that would later help him in his invention of the laser. In 1956, he took a job in the Atomic Physics Department at Hughes Aircraft Company (later called Hughes Research Industries) in Culver City, California, where he worked on a microwave amplification project for the U.S. Army Signal Corps.

The Development of the Laser

While many inventions are created to fulfill a need, the laser was developed for the pure science of it—to see whether light could, as luminaries like Einstein had proposed, be super-concentrated and directed. That quest led to a predecessor of the laser called the maser (an acronym for "microwave amplification by the stimulated emission of radiation").

Invented in 1953 at Bell Labs in New Jersey by engineers Charles Townes and Arthur Schawlow, the maser concentrated not light but radio waves into a single beam of energy.

Across the country, Maiman heard about Townes and Schawlow's discoveries and was intrigued. He wondered if he could create a device that would concentrate light in the same way the maser did radio waves. After convincing his supervisors at Hughes to give him a budget of $50,000, he embarked on a project to develop the device in 1959.

Crystallizing the Vision

Maiman's breakthrough came just months later, when he wrapped a ruby crystal in glass tubing. The tube flashed rapidly with the delivery of high-voltage energy and then stopped. Each flash pumped energy into the ruby crystal in the form of trillions of photons (light particles) on the same wavelength. This created a beam of pure red light. In May 1960, Maiman demonstrated the first working laser at the Hughes Research Laboratory.

Maiman spent the remainder of his career creating and developing laser technology, first at his own company, Konrad Corporation, and later at TRW Electronics. In 2000 in his adopted home of Vancouver, he completed a memoir, *The Laser Odyssey*, that shared personal stories with scientific insights. He died in 2007.

Today, lasers that Maiman helped develop can cut through metals, plastics, and human tissue; read data; and have thousands of civilian and military applications. The U.S. Navy has even used a 50,000-watt fiber-optic laser to shoot down an unmanned drone. Maiman himself always championed laser technology's nonviolent uses and specifically disliked the nickname "death ray."

Theodore Maiman, inventor of the laser, poses with one, circa 1980.

LASERS CUT CLEANLY THROUGH METAL, PLASTIC, AND HUMAN TISSUE. OF COURSE, THEY ALSO READ DATA. THEIR APPLICATIONS ADVANCE BASIC KNOWLEDGE AND THEORY.

Bulletproof Plan

STEPHANIE KWOLEK

(1923–2014)

Kevlar

Stephanie Kwolek models a pair of protective work gloves made with Kevlar.

Two of the key elements that led to the invention of Kevlar, the miracle material used to fortify bulletproof vests, buildings, and bridges: a Polish mom's love of sewing and textiles and a dad's interest in science.

The couple's daughter, Stephanie Kwolek, was born in 1923 in New Kensington, Pennsylvania. Kwolek had an early interest in science of the natural world and collected and categorized seeds and leaves. She also thought seriously about becoming a doctor. After earning a degree in chemistry, Kwolek was hired by the DuPont Company in Buffalo, New York. Her work there was so rewarding that she set aside her plans for medical school and chose to focus entirely on chemistry.

Creating Kevlar

In 1964, Kwolek was charged with creating a synthetic fabric that was stiff, tough, and heat resistant so that it could be used in car tires. It also had to be easily reproducible in a lab. DuPont's research into polymers, or large molecules of repeated units, led her to mix different polymer chains with different solvents. She hoped this would provoke the chemical reactions needed to make the polymers tough and heat resistant.

One experiment had an unexpected result: instead of turning clear and viscous, the polymer produced a milky and watery liquid. It weighed very little, a quality it retained

when it changed into a solid. It also solidified far stiffer and stronger than Kwolek had thought was possible. The material was unsuitable for the tire assignment, but Kwolek convinced her colleagues to turn her new polymer into a fiber. These fibers became the basis for Kevlar, which is now five times stronger than steel.

Stronger Than a Speeding Bullet

Besides bulletproof vests, Kevlar has been used to make firefighter gear, aircraft parts, and outdoor equipment like skis and kayaks. In 2008 DuPont released a tougher and lighter version of the bulletproof vest called Kevlar XP. A million XP vests were sold in just six years. A police officer once visited Kwolek to ask her to autograph a vest that had saved his life—one of the thousands of men and women who benefited from the invention.

Unfortunately for Kwolek, she signed over the patent rights for Kevlar to DuPont and never received direct compensation for her invention. In her retirement, she tutored high school students in chemistry and was held up as a role model for young women entering the sciences. She was even turned into the subject of an inspirational children's book in 2013, *The Woman Who Invented the Thread That Stops Bullets*. When Kwolek died in 2014, the chief executive of DuPont, Ellen Kullman, called her "a true pioneer for women in science."

FIVE TIMES STRONGER THAN STEEL, KEVLAR HAS BEEN USED TO MAKE BULLETPROOF VESTS, FIREFIGHTER GEAR, AIRCRAFT FRAMES, SKIS, AND KAYAKS.

Mr. Clean Energy

STANFORD OVSHINSKY

(1922–2012)

Amorphous materials, fuel cells

Stanford Ovshinsky as a student studied human and machine intelligence and neurobiology and as a science "outsider" was able to bring disparate fields together in ways not fostered in more conventional settings.

Stanford Ovshinsky, the son of an immigrant Lithuanian scrap dealer, never went to college and was outside the mainstream scientific community in the 1950s. Yet this self-taught physicist and engineer held more than 400 U.S. patents. He was critical to the development of so many inventions that the *Economist* magazine once ran a feature on him entitled "The Edison of Our Age?"

Amorphous Materials

Conventional wisdom in the 1950s held that only crystallized silicon was an effective enough conductor of electricity to be used to make transistors. The thirty-something Ovshinsky thought differently.

The heart of Ovshinsky's idea was that thin layers of atoms would be a more powerful

and less expensive method of creating and storing energy than crystallized silicon. These layers of "amorphous materials" were noncrystalline although they conducted electricity the same way. His hunch proved correct. When exposed to a charge, the amorphous materials reorganized their molecules into a semicrystalline form and carried a current. The design was modeled on the workings of the human nerve cell, which conducts an electrical impulse when the nerve is stimulated. He dubbed this new discovery "ovonics."

In 1960 Ovshinsky founded Energy Conservation Laboratories with his second wife, Iris, to create products incorporating ovonics. Over the next few decades, the company had a hand in developing such inventions as the solar-powered calculator and technologies that led to modern computer memory.

Environmental Champion

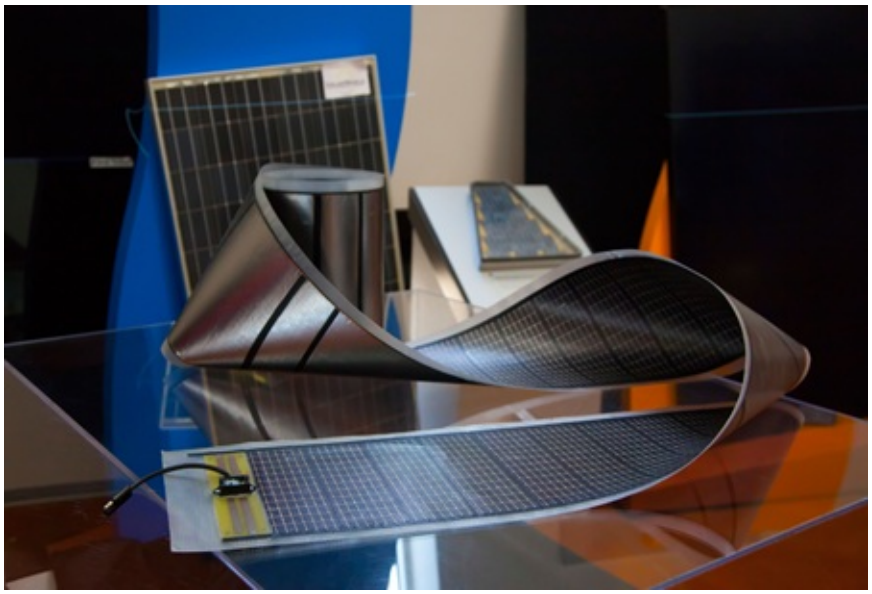
Instilled with a commitment to social justice issues by his progressive father from a young age, Ovshinsky became interested in environmental protection long before it was fashionable. As early as the 1950s he was warning of the dangers of oil dependence and the threat of climate change. This eventually led him to search for a clean energy source in the 1980s. Using the principles of amorphous materials, he created solar panels that could be "printed" in long sheets, instead of the tiny cells of the time. He renamed his company Energy Conversion Devices to reflect the success of his new product.

Ovshinsky turned his focus to developing a new type of nickel metal-hydride (NiMH) battery. Nontoxic and recyclable, these batteries use clean hydrogen to generate power. By 1992, Ovshinsky had developed an NiMH battery large enough to power a car. Most electric and hybrid vehicles today use Ovshinsky's rechargeable battery, and nearly every hybrid vehicle manufacturer in the world has licensed his patents for NiMH technology.

Not content with just advancing the battery, Ovshinsky began researching a way to use hydrogen gas as a car fuel. He developed a system for producing hydrogen with no harmful emissions. One of the challenges was to keep the gas from exploding. Ovshinsky overcame the problem by creating special containers that absorbed and released the hydrogen like a sponge. This made it safer to store and transport.

To put this new technology into practice, Ovshinsky invented a kind of hydrogen fuel cell that operated at lower temperatures and was inexpensive to produce. The fuel cell converted hydrogen and oxygen into electricity to power a vehicle's motor. Hydrogen and oxygen are raw materials far more abundant in nature and easier to obtain than petroleum. Another benefit of the hydrogen fuel cell is its lack of pollution: the waste steam is just water vapor. While hydrogen-powered cars have been eclipsed by electric

and hybrid vehicles, some auto executives believe that fuel cells are a promising technology.



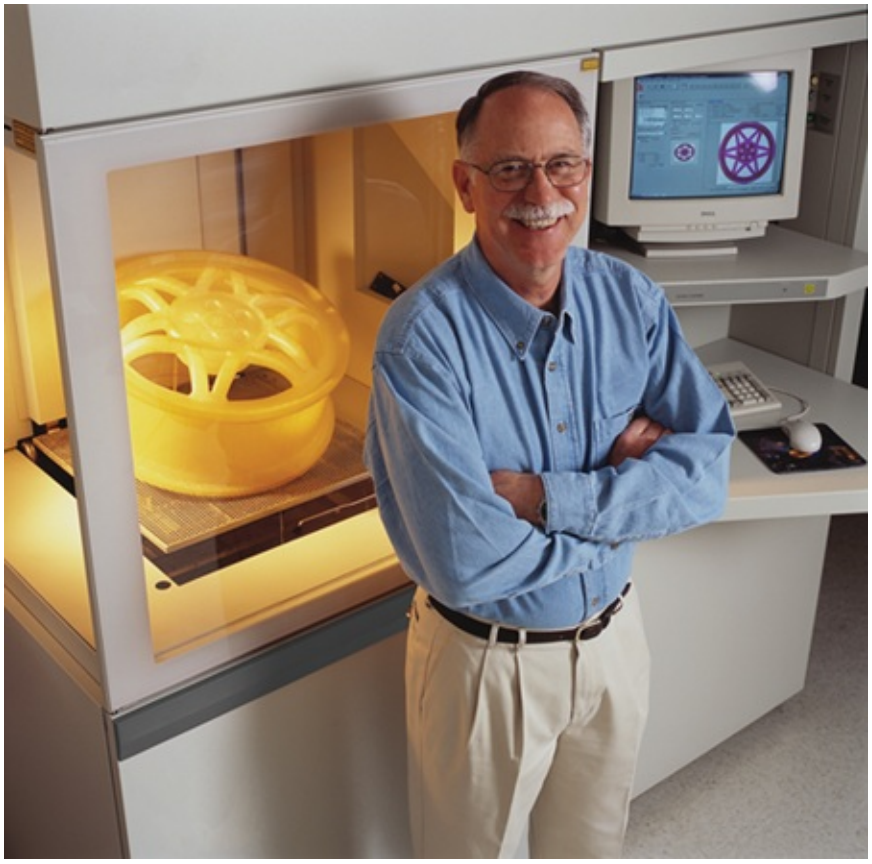
Thin film solar panel

Taking Shape

CHUCK HULL

(b. 1939)

3-D printing



Chuck Hull with a 3-D printed prototype at his company, 3D Systems

Even when companies like General Motors and Mercedes-Benz began to express interest in Chuck Hull's 3-D printer in the 1980s, he told his wife that it would probably be 30 years before his invention, created to solve a design challenge, would enter the mainstream. He wasn't far from wrong. Today 3-D printing is one of the most talked-about and versatile technologies.

New Dimensions in Printing

In his early 40s, Hull was an engineer for Ultraviolet Products, a company that used ultraviolet (UV) light to apply very thin layers of plastic veneer to furniture and other products. He began to wonder if this technology could be used to make prototype

plastic parts quickly, since fabricating in plastic was then a very time-consuming process. Hull's employer liked the idea of instant prototypes and let him experiment after hours in a back room.

Hull began working with the liquid materials known as photopolymers that he had used to coat furniture. When these materials were hit with a UV light, they hardened into solid plastic. Hull realized that he could stack the ultra-thin layers of plastic into three-dimensional shapes. He set up a vat of the liquid material and directed a beam of UV light over the surface. The liquid "cured," or hardened, into the desired shape. When he did this layer by layer, the stacked shapes assembled into a completed object. The steps reminded Hull of printing a document, but in more dimensions, so he called the method "three-dimensional printing."

Hull patented the idea in 1986 and left the furniture company to start 3D Systems, the world's first additive printing company, in Valencia, California. His earliest clients were GM and Mercedes, which planned to use 3-D printers to build car and car part prototypes.

3-D Printing Today

Today, Hull's technology is used to make prosthetics, rocket engines, and even entire cars. It has transformed the medical field, allowing doctors to make realistic models of patients and their internal systems to study before operating.

As 3-D printing technology advances, the only limitation will be the user's imagination.

WHEN HE FOUNDED 3D SYSTEMS IN 1986, HULL TOLD HIS WIFE THAT IT WOULD PROBABLY BE 30 YEARS BEFORE THE GENERAL PUBLIC WOULD BE INTERESTED. HE WAS RIGHT.

INFORMATION

From computer coding to email, American inventors have led the way into the digital world.

Communications satellites route everything from voice and data transmissions to the Global Positioning System (GPS).

Mr. Live Wire

SAMUEL MORSE

(1791–1872)

Telegraph

Translating Morse code into common language was a valuable skill until the introduction of radio voice transmission.

One of the most famous inventors in American history didn't even start his career in the sciences. Samuel Morse's first calling was actually as a portrait painter. He was good enough to get into the Royal Academy of Arts in England, and his self-portrait hangs in the National Portrait Gallery in Washington, D.C. But it's what Morse did after he switched careers that earned him that place in the Portrait Gallery—invent the telegraph. The device sent electrical pulses along wires at an incredibly fast speed, providing a means for instantaneous, long-distance communication.

Portrait of the Artist as a Young Man

The son of a Calvinist pastor, Morse was raised in Charlestown, Massachusetts. He began to dabble in the arts while in preparatory school and pursued them in college. He also attended lectures on electricity, which would come in handy later in life when he began to experiment with the telegraph.

Morse's father wanted him to become a bookseller, but he eventually gave in to his son's wishes and let him set sail for London and the Royal Academy. Morse returned to

son's wishes and let him set sail for London and the Royal Academy. Morse returned to the States in 1815 and established an art studio in Boston. He married, began a family, and supported his wife and three children as a portrait painter.

Over the next 10 years, Morse depicted many famous statesmen, including presidents John Adams and James Monroe. He also found time to tinker with engineering projects, such as a water pump for fire engines that he patented with his brother Sidney in 1817 and a marble-cutting machine in 1822.

A Change in Direction

After moving to New Haven, Connecticut, Morse received a special commission from the City of New York to paint a portrait of the French aristocrat and military officer Marquis de Lafayette, in 1825. It took Morse a full year to complete the portrait, due to Lafayette's busy travel schedule—he toured all 24 states during his extended American visit.

As Morse was working on the portrait one day in Washington, D.C., a messenger on horseback arrived with a letter informing him that his wife was ill. The painter rushed back to New Haven but arrived too late: his wife had died while he was en route. In his grief Morse wished for a way that he could have learned sooner of her failing health despite being several hundred miles away.

Morse mulled over ways to make such communication possible, but the responsibilities of family life as well as his new position as president of the National Academy of Design in New York made it difficult. But a chance encounter with Boston scientist Charles Thomas Jackson in 1832 rekindled Morse's imagination. Jackson, who had experimented extensively with electromagnets, told Morse that he had successfully transmitted electric pulses along conductive wire.

Pulsation Communication

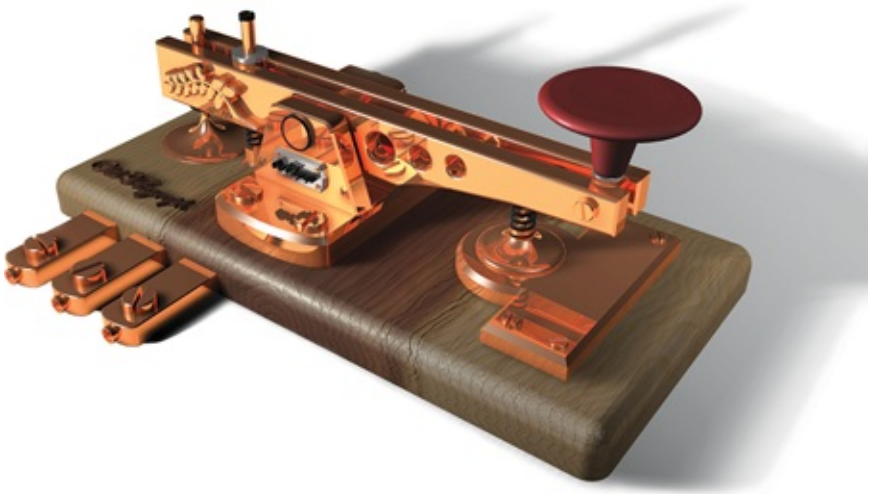
By 1838 Morse had teamed up with New York University chemistry professor Leonard Gale and young inventor Albert Vail to build a working model of the "recording telegraph." The design was quite simple: pressing down on a key sent an electrical signal over the wire to a receiver at the other end. The length of the electrical pulses would vary, short or long, leading Morse and another partner of his, Alfred Vail, to create a system in which combinations of long and short beeps could be interpreted as a kind of code. The two collaborators unveiled the invention in 1838 in Morristown, New Jersey, where they had done much of their research and development. The first transmission (via "Morse code") was, "A patient waiter is no loser."

The message proved a prophetic one, as Morse had to wait a few more years before he could find investors for the telegraph. Finally, in 1842, he set up a working telegraph between two committee rooms of the U.S. Capitol to demonstrate the invention's

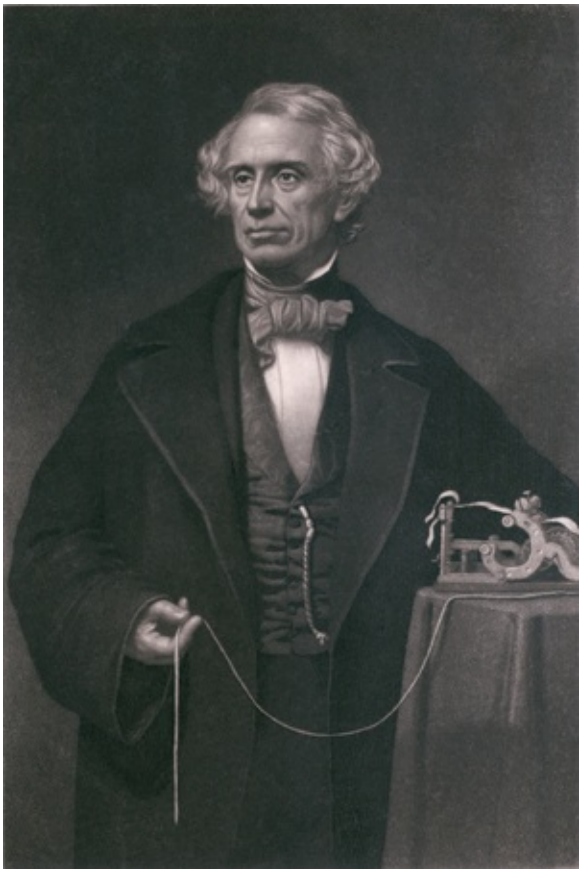
potential. Congress was impressed and earmarked $30,000 the following year to build a 38-mile telegraph line between Washington, D.C., and Baltimore. From the Capitol, Morse messaged to his assistant in Baltimore the first telegram over more than 10 miles: “What hath God wrought!” The simple electrical pulses transmitted over a wire changed long-distance communication.

Lauded Abroad and at Home

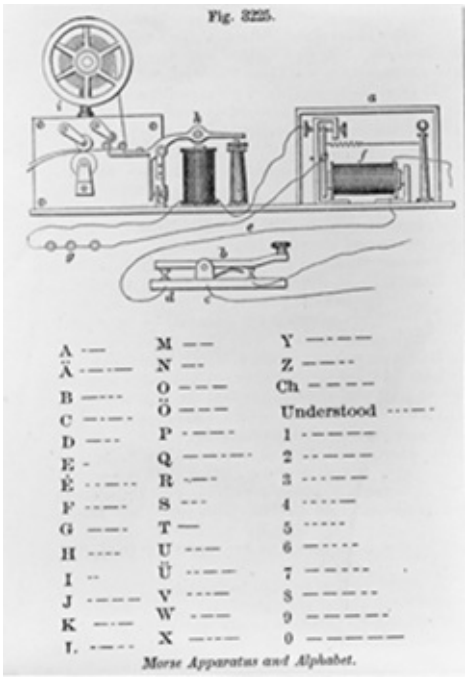
Despite the U.S. government’s key role in getting the invention off the ground, Morse had difficulty obtaining a patent in America due to bids for credit from other inventors and his partner Vail. He ended up securing his patent for the telegraph in Istanbul, in part because the sultan, Abdülmecid I, believed strongly in the invention. Morse’s final years were spent with his second wife and four new children. His status as the “inventor of the telegraph” secure, he retired into a quiet family life. He donated much of his newfound wealth to philanthropic causes, including colleges and temperance organizations, and supported many young artists until his death in 1872.



In a standard “straight key” transmitter such as this one, the signal is “on” when the handle is depressed and “off” when it is released.



Samuel Morse maintained his passion for art throughout his life, helping to found the National Academy of Design in New York City in 1825 and serving as president from 1826 to 1845 and from 1861 to 1862.



Morse Apparatus and Alphabet.

Morse code, the language of dots and dashes, has been called the Victorian Internet for its universal adoption.

SOS, THE UNIVERSAL DISTRESS SIGNAL, IS RECOGNIZED IN INTERNATIONAL TREATIES IN ITS MORSE CODE EQUIVALENT: THREE DOTS, THREE DASHES, AND THREE DOTS.

The Image Maker

GEORGE EASTMAN

(1854–1932)

Consumer photography

A 1906 Eastman Kodak advertisement promoting cameras for children

Inventor George Eastman brought photography to the masses and helped build Rochester, New York, into one of America's storied company towns, but his life was far from picture-perfect. By the time he was 16, Eastman had lost his father to a brain disorder and a sister to polio. To help his struggling mother, he worked as an errand boy and took accounting classes that ultimately helped him land a clerk job at Rochester Savings Bank. There, a colleague suggested Eastman buy a camera to photograph some land in which he was considering investing. The purchase would change the young man's life.

Simplifying the Process

The first camera Eastman bought in 1878 was the size of a small safe and came with equipment weighing 50 pounds. The photography process at that time was cumbersome. To take a single picture, the photographer had to coat a fragile glass plate with light-sensitive chemicals (a task performed in the dark), insert the stillwet plate

into the massive camera, shoot the photo, and develop it immediately. Eastman wondered: Why shouldn't there be a camera that was so simple and lightweight it could be carried and used by a child?

Eastman began reading scientific journals and experimenting with the developing process at home. In a breakthrough, he established a way to produce glass plates that remained light-sensitive when dry, allowing them to be used at a photographer's convenience. Before long, he created chemical-coated paper to replace the plates, then fabricated the first roll of film, made of a plastic called celluloid. In 1888, Eastman introduced the Kodak, a simple box camera loaded with 100 exposures of film that sold for $25. Once the pictures were taken, the photographer sent the camera back to the Eastman Kodak plant in Rochester, where the film was developed and the camera reloaded and returned.

Dominating the Industry

Eastman established the Eastman Kodak Company in 1892. Eight years later, the firm debuted the Brownie, a camera named after some popular children's book characters, which were featured on the box. Priced at just a dollar, the Brownie was small enough to hold in your hands. It transformed photography from a technically demanding process that was largely left to professionals to a highly versatile medium that allowed people everywhere to document their daily lives. "You press the button—we do the rest," promised the ad slogan.

Eastman Kodak went on to dominate the photography industry for a century. Eastman became extraordinarily wealthy. He funneled his earnings into philanthropy, giving to universities, dental and medical facilities, and arts institutions. But his story had a somber end. In 1932, suffering from a painful spinal condition, he shot himself in the heart. He was 77. Eastman is the only person to have two stars in a single category on the Hollywood Walk of Fame, both for his invention of roll film.

The Brownie camera with the box it came in

George Eastman demonstrates one of his cameras aboard the *Majestic* ocean liner in 1926.

EASTMAN NAMED THE BROWNIE AFTER POPULAR CHILDREN'S BOOK CHARACTERS, WHICH WERE FEATURED ON THE BOX.

License to Print

OTTMAR MERGENTHALER

(1854–1899)

Linotype

A wooden letter block tray stores a variety of typeset letters.

The man who revolutionized the printing industry around the world got into the business via a job in a modest machinist's shop in Washington, D.C.

Otto Mergenthaler emigrated to the United States from Germany in 1872. He took a job in a machinist's shop, and when the business moved to Baltimore, Mergenthaler followed, eventually becoming a co-owner. One day a customer asked him to help improve the design of a typewriter for newspapers. As he worked on a solution, Mergenthaler became fascinated with the printing process.

Slugging It Out

Starting in the 1870s, Mergenthaler dedicated himself to creating a machine that would make printing more efficient. At the time, the typesetting method invented by Johannes Gutenberg—in place since the 1500s—required each character to be set by hand. Inspired by the wooden molds used to make Christmas cookies in his native Germany, Mergenthaler hit on the idea of a machine that would cast *and* stamp letters. He created brass forms, much like the bakeware for cookies, that could be filled with

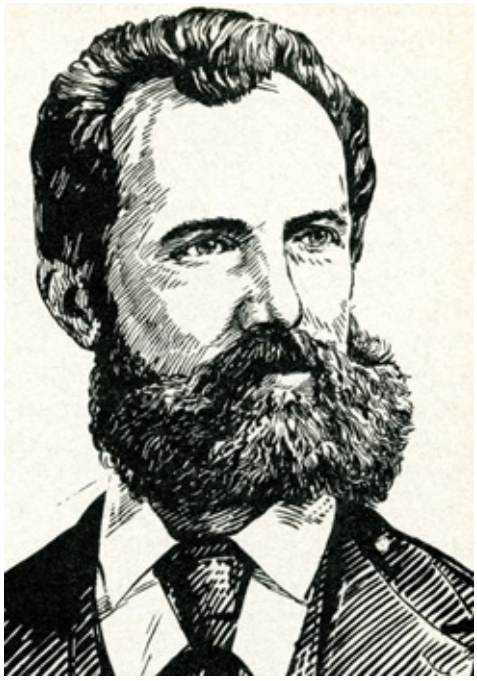
molten metal in the shape of a letter.

Mergenthaler's linotype machine allowed an operator to type letters into a special 90-character keyboard; the machine then assembled words from the molds, then cast them into lead. The lead lines of type, called "slugs," were used to print, then melted down (at a temperature of 550°F) and used again. After much hard labor and securing 50 patents, Mergenthaler's machine was finally ready in 1886. *The New York Tribune* became the first paper to use the linotype in July of that year. The debut book was *The Tribune Book of Open-Air Sports,* published in 1887.

"The Eighth Wonder of the World"

Linotype transformed the newspaper world. Publications that used linotype could print material much faster, allowing them to grow and reach larger readerships. The technology spread quickly, and by 1910 there were 25,000 professional linotypists. For some, Mergenthaler's invention qualified him as the second Gutenberg. Thomas Edison went so far as to label the linotype machine "the eighth wonder of the world."

Though Mergenthaler was able to enjoy some of the fruits of his success, he ultimately did not live long enough to see the impact of his invention. Soon after his return from a celebratory trip to his German hometown of Württemberg, he contracted tuberculosis. He died in 1899 at age 45. Linotype machines—loud, seven-foot-tall behemoths—powered the newspaper industry until the 1970s, when they were replaced by offset lithography printing and computer typesetting.



The end of Ottmar Mergenthaler's life was marked by difficulties, including a house fire that destroyed his recently completed autobiography.

MERGENTHALER'S INVENTION OF THE FIRST MACHINE TO EASILY AND QUICKLY COMPOSE ENTIRE LINES OF TYPE USHERED IN A REVOLUTION IN PRINTING. THOMAS EDISON CALLED IT "THE EIGHTH WONDER OF THE WORLD."

Keeping Tally

HERMAN HOLLERITH

(1860–1929)

Tabulating machine

Statistician and inventor Herman Hollerith in 1880

If inventor Herman Hollerith hadn't dated the daughter of statistician John Shaw Billings in the years following the Civil War, the tabulating machine might never have been created.

At the time, there were so many new immigrants to the United States that the Census Bureau didn't finish its 1880 population count until 1887. To prevent a similar lag for the 1890 census, the federal government hired Billings to oversee the process. Billings in turn realized that the massive project required automation. He turned to Hollerith, a professor of mechanical engineering at the Massachusetts Institute of Technology, who was wooing Billings's daughter Kate.

Instrumental Inspiration

Hollerith's invention would set the course for modern computing, but inspiration came from an old world fixture: the player piano. Popular in the late 19th century, these instruments used rolls of paper with holes punched into them to manipulate individual

keys. Similarly, Hollerith's device took its tabulating cues from cards with holes that corresponded to specific data points.

When the cards were manually fed into a machine, they were pressed by wires into small pools of mercury, each for a different punchcard hole. The holes or combinations of holes punched in sheets of electrically nonconducting material could record statistical items pertaining to each person surveyed. Mechanical counters operated by electromagnets could then count and tally the information.

Punch Card Programming

Using Hollerith's tabulating machines, the years-long job of conducting the 1890 census was cut to three months and saved taxpayers a reported $5 million. In 1896, Hollerith started the Tabulating Machine Company in Washington, D.C. After merging with other businesses, Tabulating Machine became Computing-Tabulating-Recording Company, and in 1924 it was rechristened the International Business Machines Corporation—familiar to the world today as IBM.

Punch cards entered every walk of life in the 20th century, improving data management across business and industry. Later in life, Hollerith withdrew from the fast-paced life he had helped create. He retired from his company in 1921 to raise Guernsey cattle on his farm in rural Maryland and died in 1929.

Government clerks use massive tabulating machines to manage Social Security records of millions of Americans in 1940.

He Found His Calling

ALEXANDER GRAHAM BELL

(1847–1922)
Telephone

An early Bell Telephone pay phone sign from 1899

For Alexander Graham Bell, the inventor of the telephone, the study of sound was both a professional and personal subject. His father and his grandfather taught speech and elocution, his mother was hearing-impaired, and Bell himself founded a school for the deaf. When he developed the basic technology for the telephone, he was trying to create an aid for the hearing-impaired. Later in life, Bell refused to have a telephone in his study because he thought it would distract him from his scientific work.

Waves of Sound

While living in Boston in the mid-1870s, Bell began experimenting with transmitting several telegraph messages simultaneously over a single wire and with devices to help the deaf learn to speak. In 1874 he completed a machine that vibrated visibly when spoken into. He intended this phonoautograph, as he called it, to help students visualize sound, but the idea of being able to see sound as a wave inspired Bell's imagination. If he could manipulate an electrical current to match the same pattern as a sound wave, the electrical current would carry that sound wave from one location to another.

By 1876 Bell had almost figured out a system. His initial design consisted of a tin mouthpiece fitted with a membrane and an electrically charged needle. As the sound of a speaker's voice made the membrane vibrate, the needle moved along a cup of acidic water. The resulting vibrations traveled through a wire to a receiver, where they were translated back into sound. Bell and his assistant, Thomas Watson, knew they had something when Bell called through the mouthpiece for Watson in the next room, and Watson heard him loud and clear.

Perfecting the Technology

Bell submitted a patent on February 14, 1876, and unveiled the telephone at the Centennial Exposition in Philadelphia that summer by reciting the famous "To be or not to be" soliloquy from *Hamlet*. For the first time in history, a human being could communicate with another virtually instantaneously regardless of distance. It was irresistible—by 1877, just a year after Bell filed his patent, major East Coast cities were already laying telephone wire.

With his newfound international fame, Bell focused on capitalizing on the telephone. He organized the Bell Telephone Company in July 1877 and later that same month married a former student, Mabel Hubbard. The two traveled to Europe to demonstrate the invention. Upon return, Bell dealt with the first wave of many patent lawsuits challenging his ownership of telephone technology. There would be nearly 600 similar legal challenges in the years to come, but Bell held out and won them all.

Bell's career as an inventor didn't end with the telephone. Later in life he experimented with metal detectors, created designs for hydrofoil boats, and engineered early aircraft with his co-inventors at the Aerial Experiment Association. He was also ahead of his time exploring green technologies. At his home in Nova Scotia, Bell sketched out plans for everything from composting toilets to solar panels. When he died on August 2, 1922, all telephone service throughout the United States and Canada was shut down for a minute to honor his life.

World War I era public service advertisement

Alexander Graham Bell makes the first telephone call from New York to Chicago in 1892, just 16 years after he invented the telephone.

BELL DEVELOPED THE BASIC TECHNOLOGY FOR THE TELEPHONE AS A WAY TO HELP DEAF STUDENTS VISUALIZE SOUND.

Duplication Sensation

CHESTER CARLSON

(1906–1968)

Xerography

Chester Carlson with the first model of his invention

How fitting that two of Chester Carlson's favorite childhood playthings were a rubber stamp set and a toy typewriter. The physicist, inventor, and patent attorney grew up to invent xerography—a process known today simply as copying.

The path was slightly circuitous. When Carlson graduated from college with a degree in physics, in 1930, he was unable to land work in his chosen field. The best he could find was a position as a patent clerk at a New York electronics company, where day in, day out he hand-copied sketches and charts that accompanied the firm's many patent filings.

Through scientific journals, Carlson learned that the Eastman Kodak Company was experimenting with a wet-document duplication process similar to developing photographs. As far as he could tell, no one was pursuing a dry version of the concept, and he began researching materials that could duplicate documents through the absorption of light. His investigations soon outgrew his apartment in Jackson Heights,

Queens. He spent his savings on an Astoria rental where he set up a lab and hired an assistant to work out the fundamentals of electrophotography.

The Hard Sell

Carlson's first major success came on October 22, 1938. He printed "10-22-38 Astoria" on a glass slide and rubbed a cotton cloth against a sulfur-coated zinc plate to create an electrostatic charge. Carlson then pressed the plate onto the slide and held it up to a light in a darkened room. He removed the slide, sprinkled the plate with a developing powder, and pressed wax paper to the plate. The paper read "10-22-38 Astoria."

Carlson immediately filed to patent the process, envisioning its huge commercial potential. Few agreed; from 1939 to 1944 he unsuccessfully pitched the idea to more than 20 companies, including IBM. Crucial support to develop the process further came in 1944 from the nonprofit research and development organization Battelle Memorial Institute.

A Deal for Dry Writing

Finally, in 1947 the Haloid Photography Company, in Rochester, New York, took a chance on Carlson's invention. The product needed a name, and a consultant suggested "xerography," from the Greek words for "dry writing." Inspired by "Kodak," with its bookending *Ks*, Haloid called its first copy machine a Xerox.

Xerox copiers sold moderately in the 1950s; they made black-and-white copies on regular paper that the user had to individually feed into the machine. The company introduced its first fully automated model, the 914, in 1959. The 914 became the era's most quickly adopted piece of technology. By 1968, Xerox was selling nearly $1 billion a year worth of copiers.

That sum didn't mean much to Carlson, however: late in his life he and his wife, Dorris, became practitioners of Buddhism and espoused its virtue of nonattachment. He gave $150 million of his earnings to pacifist, civil rights, and Buddhist organizations, including funding for the Rochester Zen Center and Dai Bosatsu Zendo Kongo-ji, a Zen monastery in New York's Catskill Mountains. When he died in 1968, United Nations secretary general U Thant gave a memorial address honoring Carlson's moral character.

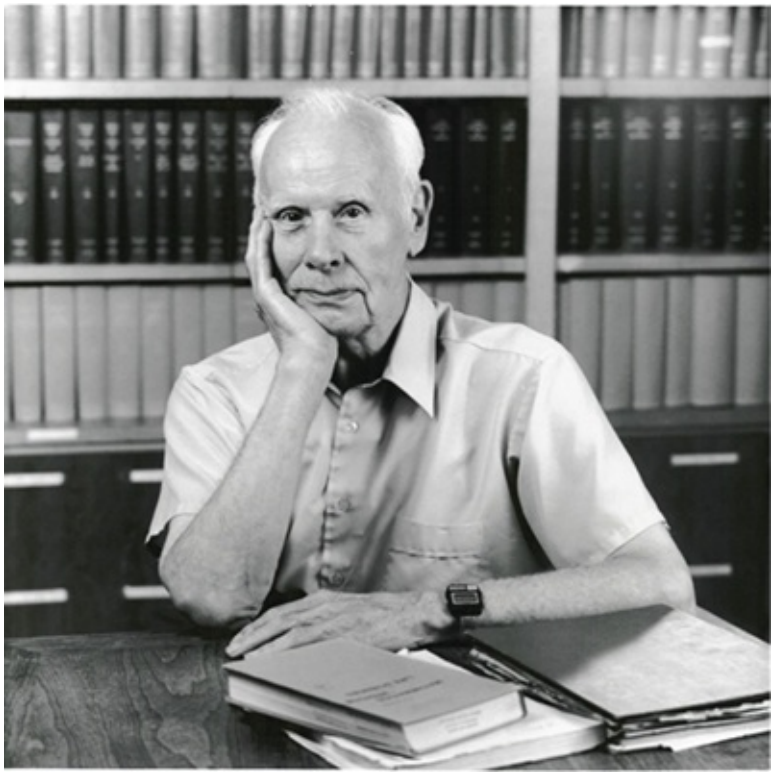
***FORTUNE* MAGAZINE HAILED CARLSON'S MOXIE AND SAVVY IN A RETROSPECTIVE ON HIS INVENTION THAT CALLED IT "THE MOST SUCCESSFUL PRODUCT EVER MARKETED IN AMERICA."**

Zero to Hero

GEORGE STIBITZ

(1904–1995)

Binary computing



George Stibitz, shown here in 1990, is one of the fathers of modern digital computing.

George Stibitz was a born inventor. At the age of eight, he nearly set fire to his family's Dayton, Ohio, house by experimenting with the circuits of an electric motor. Recognizing their son's curiosity about all things technical, his parents sent him to a special high school with rigorous academics. After college, Stibitz took a job at the Bell Telephone Laboratories in New York City in the early 1930s.

Relay the Information

A big problem in the telecommunications industry at the time was how to quickly perform the mathematical calculations necessary for setting up telephone networks. Stibitz intuited that a key component would be a relay—a metallic device that allows electrical currents to flow through it in two different positions (open and closed).

Using telephone equipment borrowed from his Bell Lab employers, a dry cell battery,

flashlight bulbs, and some aluminum strips made from a tobacco can, Stibitz built the first electromechanical relays. He coupled the switches with electrically conductive material, creating a primitive computer that could solve simple equations using a binary code of ones ("on," represented by a lighted bulb) and zeros ("off," represented by an unlighted bulb).

Friends of Stibitz dubbed this early computer the "K-Model" because he mostly constructed it at home on his kitchen table. The technology paved the way for binary digital computers, which operate on Stibitz's system of ones and zeros.

Remote Computing

In 1939 Stibitz debuted the Model 1 Complex Calculator, capable of performing eight-digit division in 30 seconds—fast for the time. In a 1940 demonstration before the American Mathematical Society, he sent remote commands via teletype from Dartmouth College in New Hampshire to his latest computer (the Complex Number Calculator) in New York City.

The computer was able to solve problems long distance and transmit back the answers. By converting data into simple electronic pulses and back into data from a distance, Stibitz performed the first remote computer task and the first instance of digital, or binary, computing.

As the world embraced the computer age, Stibitz began applying his digital expertise to medicine. He joined the faculty of Dartmouth's medical school in 1964, using computers to track the movement of breath and the body's filtering of drugs and nutrients.

Breaking the Code

HEDY LAMARR

(1914–2000)

Spread spectrum communication

WESTERN EUROPE EDITION

THE STARS AND STRIPES

Unofficial Newspaper of U.S. Forces in the European Theater

Vol. 2—No. 128 1 Fr. Monday, Nov. 19, 1945

Hedy Adds New Twist to War

Actress Invents Control Device While Toying With Torpedo Idea, Has Patent to Prove It

Hedy Lamarr

HOLLYWOOD, Nov. 18 (AP)—It could not have been a press agent's stunt, because the timing was too perfect, but the report from London that film actress Hedy Lamarr had patented a radio steering device for torpedoes at least had a patent to back it up.

In an interview, Hedy modestly admitted she did only "creative work on the invention," while the composer and author, George Antheil, "did the really important chemical part."

Hedy was not too clear about how the device worked, but she remembered that she and Antheil sat down on her living room rug and were using a silver match box with the matches simulating the wiring of the invented "thing".

She said that at the start of the war "British fliers were over hostile territory as soon as they crossed the channel, but German aviators were over friendly territory most of the way to England... I got the idea for my invention when I tried to think of some way to even the balance for the British. A radio controlled torpedo, I thought would do it."

Hedy asserted that the "control" device works on aerial as well as submarine torpedoes.

She said it works on anything and added that it was "lots of fun planning the invention and watching them pick, sort and put together all the little thingamabobs that went into the device." She said it was lots more fun being scientific than going to the movies.

She coyly dodged a query as to whether any company was interested in producing the device but did admit that as far as she knew nobody has ever used it yet for any practical purpose.

Lamarr's invention received worldwide coverage, including this article in *Stars and Stripes*, the official newspaper of the U.S Armed Forces.

In Hollywood and in movie theaters across the country, Hedy Lamarr was a screen siren, billed as "the most beautiful woman in the world" and the star of films like *Algiers* and *Samson and Delilah*. But in the 1940s, to help the Allies defeat the Nazis, Lamarr left her mark in a much more significant way: she invented the technology that led to everything from cell phones to GPS.

More Than a Script Girl

Lamarr's unlikely career started in her native Vienna, where she was discovered by a producer in the 1920s. After a stint in Berlin, she got involved in Vienna's growing film industry, working as a script girl and later as an actress, eventually wedding the wealthy arms dealer Friedrich Mandl.

Lamarr later claimed that during their four-year marriage, Mandl kept her virtually a prisoner in their home. She eventually escaped, making her way to Paris, getting a

divorce, and meeting Louis B. Mayer, the American film producer. Mayer promoted the young starlet, and she was cast opposite the biggest actors of the day, including Clark Gable and Spencer Tracy.

This is when Lamarr became interested in using scientific knowledge to solve problems and develop new technologies. In her time away from the movie set, she experimented with inventing products, such as a tablet that created an instant carbonated beverage when dropped in water.

During World War II, Lamarr wanted to contribute in some way to the Allied effort and teamed up with George Antheil, a composer and inventor she had met at a dinner party. Together, the friends devised a system to break up communications between radio-controlled torpedoes and their control centers. The method, called synchronized switching, used multiple frequencies to code signals so that the Nazis could not "jam" them and send the torpedoes off course. The U.S. Navy deemed the technology too difficult to implement at the time, but it was later used during the Cuban Missile Crisis in 1962 (nine years after Lamarr became a U.S. citizen).

Modern Applications

Decades later, Lamarr's invention became the foundation for spread spectrum technology, a key component of modern wireless communications like cell phones, code-division multiple access (CDMA), Bluetooth, and Wi-Fi.

Lamarr's life unraveled in her later years. She was divorced six times, and her finances were strained. She was arrested for shoplifting multiple times, then became a recluse, communicating with others only via phone. She died in Florida in 2000 at age 86. Lamarr and Antheil were posthumously inducted into the National Inventors Hall of Fame in 2014.

CDMA cell phone technology, based on Hedy Lamarr's invention, exponentially increased call capacity.

DURING THE 1930S, LAMARR ACCOMPANIED HER FIRST HUSBAND, A WEALTHY AUSTRIAN ARMS DEALER, AT BUSINESS MEETINGS AND LEARNED ABOUT MILITARY TECHNOLOGY.

Laser Sharp

JAMES T. RUSSELL

(b. 1931)

Optical digital recording and playback

James T. Russell tinkers in his basement laboratory in 2005.

James T. Russell, a laser scientist at the Pacific Northwest National Laboratory in Richland, Washington, loved to listen to classical compositions. In 1965 the phonograph was the best option for hearing recorded music, but Russell didn't like how the player's stylus wore out so fast. He tried alternatives—in one instance, he experimented with a cactus needle—then hit upon an idea from his work: use a laser.

Birth of the Disc

Russell encoded sound digitally as microscopic pits and flats on a glass disc that a laser could read without wearing out any material. He filed a patent for the system, which Philips Consumer Electronics developed further to store video on 12-inch discs. Philips and Sony Corporation teamed up and standardized the CDs at 74 minutes—

long enough to fulfill Sony CEO Akio Morita's mandate to fit all of Beethoven's Ninth Symphony on one disc. CDs were marketed as replacements for vinyl records—perfect sound without skips or scratches. The first CDs finally went on sale in 1982 with two options: ABBA's *The Visitors* and Billy Joel's *52nd Street*.

Optical Instruments and Other Interests

In the years following his breakthrough invention, Russell continued to work in the field of compact disc technology. He developed ways to store and access information besides music on a CD-ROM, earning 26 patents for the technology alone. He was also instrumental in creating the first videodisc in 1973. He even envisioned a Netflix-like world, suggesting that television networks mail their programs directly to viewers on discs rather than produce them for broadcast.

Today, Russell continues to work on improving bar code scanners and other optical instruments, as well as developing designs for transit systems and alternative housing to end urban sprawl. One of the best-known is his "linear city," a metropolitan center populated with half-mile-tall towers and connected by high-speed railroads.

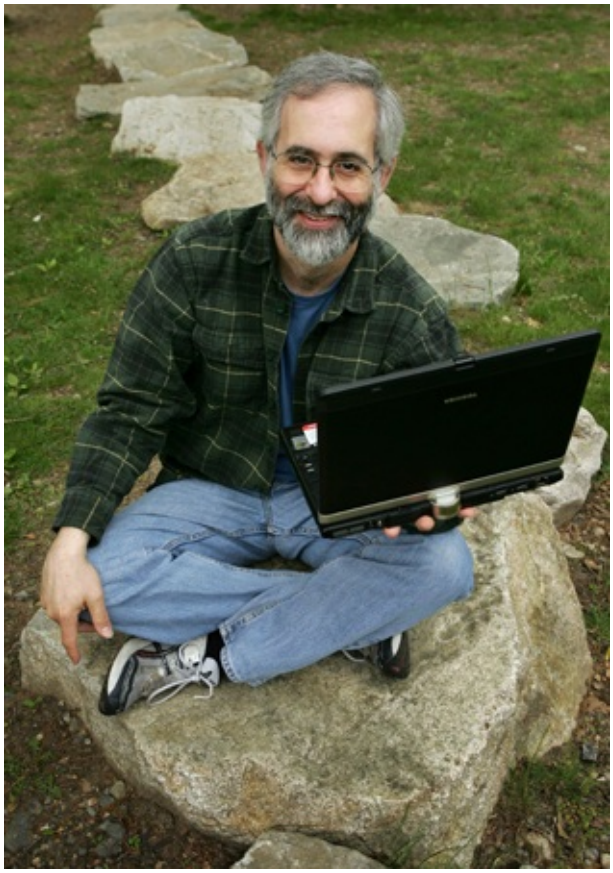
Sales of music CDs peaked in 2000, with 2.5 billion sold that year.

Go Figure

DAN BRICKLIN

(b. 1951)

Electronic spreadsheet



Dan Bricklin, inventor of the personal computer spreadsheet, sits with a laptop computer near his Newton, Massachusetts, home in 2006.

The electronic spreadsheet traces its beginnings to a 1978 computer programming class for entrepreneurs at Harvard Business School. Student Dan Bricklin was watching a lecturer rewrite all his figures on a chalkboard to fix one incorrect input when he thought that there had to be a better way to process information. With his friend Bob Frankston helping with the programming, Bricklin began searching for solutions.

The Digital Ledger

A computer hobbyist who built the machines from scratch and developed software for them, Bricklin had been programming computers since his high school days in the

1960s. He spent two months on the information-processing problem. Then in 1979, he reached an answer: he combined another hobbyist's word-processing program with a calculator program. The result was an "electronic blackboard and electronic chalk," as he described it.

Bricklin's initial coding could handle a matrix of 5 columns and 20 rows. He called his dynamic data organizer a "spreadsheet" because the screen of lines, boxes, and numbers reminded him of the oversized pages of a bookkeeper's ledger. Bricklin named the program VisiCalc and formed a company with Frankston under the same name to sell it.

Business Friendly

The spreadsheet marked the first time computers offered a user-friendly business tool. VisiCalc instantly performed calculations in an easy-to-read interface and was quickly embraced in the American office. The software helped spur sales of computers like the Apple II and the IBM PC—in the early 1980s specifically—because the machines could run VisiCalc as well as spreadsheet successors such as Lotus 1-2-3 and Microsoft Excel. Bricklin later explained the program's popularity: "[It] took twenty hours of work per week for some people and turned it out in fifteen minutes and let them become much more creative."

Bricklin's work didn't end with the spreadsheet. In the 1990s he focused on diversifying his company, Software Garden Inc., with programs for developing software, laser printing, and data display. Recently Software Garden has branched out into apps for smartphones and tablets. Bricklin is known as something of a guru in the technology sector; in addition to lecturing, he hosts "Dan Bricklin's Software Licensing Podcast" and is the author of *Bricklin on Technology,* a book about the relationship between people and computers.

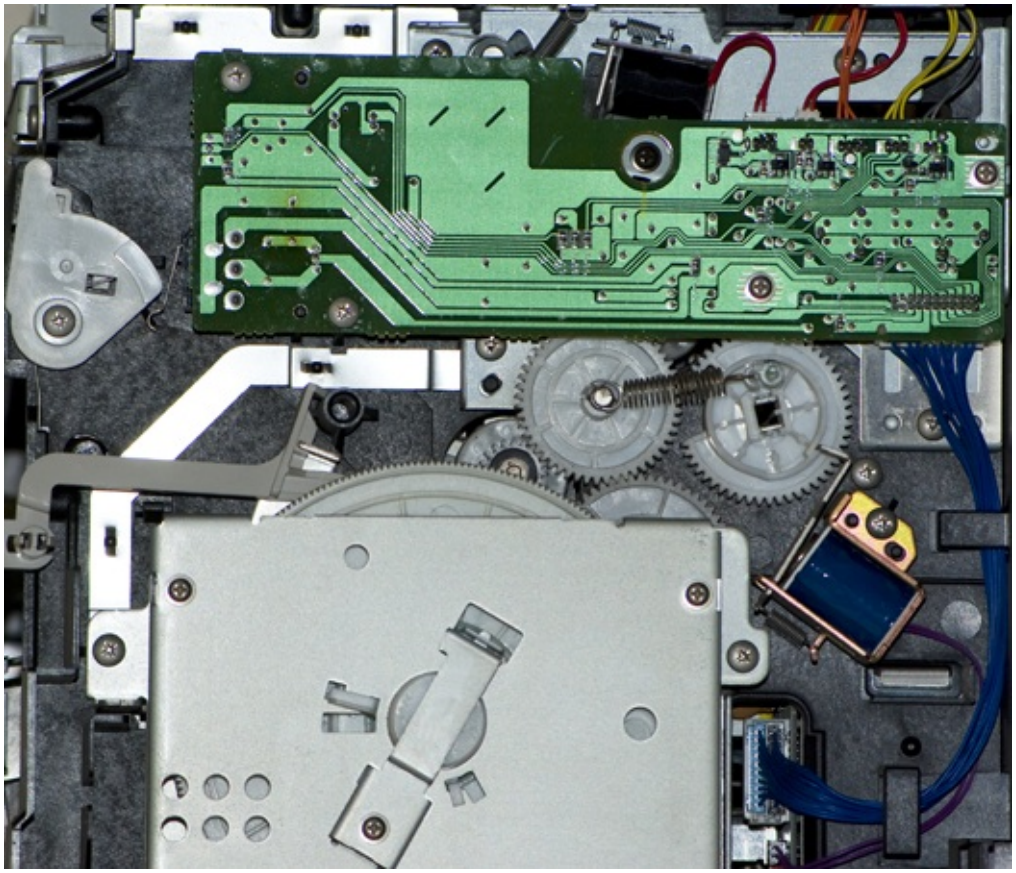
BRICKLIN WAS A COMPUTER HOBBYIST WHO STARTED PROGRAMMING IN HIGH SCHOOL. HE DESCRIBED HIS SPREADSHEET INVENTION AS AN "ELECTRONIC CHALKBOARD."

The Scan Artist

GARY STARKWEATHER

(b. 1938)

Laser printer



Close-up of the inner workings of a laser printer

Laser printer inventor Gary Starkweather was all set to pursue electrical engineering when a chance job assignment intervened. While in college, Starkweather took a position working for a physics professor who specialized in the study of light. Starkweather discovered he was fascinated by lenses and went on to pursue a graduate degree in optics. After a short-term position at eye-care provider Bausch & Lomb, he landed a job as a research engineer at Xerox's Webster Research Center in Rochester, New York, in 1967.

The Laser and the Spinning Drum

The laser printer began as a stealth side project. At the time, the printing process was

The laser printer began as a stealth side project. At the time, the printing process was based on copying an original document. One day Starkweather looked around the research lab at the massive mainframe machines tasked with making facsimiles of documents and wondered whether there wasn't a less cumbersome method. He hit on the idea of having a computer create the originals instead.

The key to this, Starkweather realized, would be to use a laser beam to define the image to be printed on the copier drum. The stumbling block: price. Because lasers were so expensive—about $3,000 apiece—Starkweather's supervisors rejected his plan to develop the idea. But Starkweather was convinced that laser prices would fall and recruited some coworkers to secretly build a laser printer from a modified Xerox photocopier. In the team's prototype, light from a laser bounced off a spinning drum with eight mirrored sides. As paper passed beneath the drum, the laser "wrote" what was to be copied.

Going West

Intrigued by Starkweather's project, executives at Xerox's Palo Alto Research Center (PARC) in Palo Alto, California, invited the engineer to the West Coast to develop it. In 1971, he produced the first functioning laser printer, dubbed SLOT, for "Scanned Laser Output Terminal." It was used internally at PARC via networked computer terminals. After a few years honing the design, the company debuted a commercially available model, the Xerox 9700.

Starkweather was unable, however, to convince Xerox to back his next idea, a personal laser printer for home use. But as Xerox focused on the office market, Starkweather's hunch turned out to be right. Today, laser printers are so inexpensive that copier makers earn more from the sale of toner cartridges than the printers themselves. The inventor left Xerox in 1987, first taking a job with Apple and then Microsoft before retiring in 2005. He stays involved in the technology world by judging student science competitions and mentoring up-and-coming engineers.

In addition to the laser printer, Gary Starkweather has been a pioneer in color management technology, which standardizes color across devices.

Bring It on Home

HENRY EDWARD ROBERTS

(1941–2010)

Personal computer

Henry Edward Roberts's Altair 8800, which debuted in 1974

There are many engineer contenders for the title of inventor of the home computer, but Henry Edward Roberts stands out for an unlikely reason: he almost didn't enter the field at all. Roberts was in college and planning to become a doctor when a mentor advised him to get an engineering degree first. After graduation, Roberts served a stint in the Air Force and by then thought it was too late to go medical school. He took a job as an electrical engineer at Kirtland Air Force Base and devoted himself to supporting his young family.

The First PC

To supplement his salary, Roberts began selling mail-order model rocket kits out of his garage in Albuquerque in the late 1960s. Finding it difficult to build up a client base, he tried the same thing with electronic calculator kits. It was a wise decision: the business venture was netting $100,000 per month by early 1973. There were more twists and turns. As calculators began to flood the market in the mid-1970s, their cost dropped tremendously. Roberts soon found his company, Micro Instrumentation and Telemetry Systems (MITS), in debt. To stay afloat, he began selling build-your-own-computer kits. In his bank loan application, Roberts said he thought he could sell 800 of them—though secretly he believed it would be closer to 200. He received financing,

and in 1974 he set to work designing the Altair 8800—a small, programmable model his daughter named after something she saw on *Star Trek*.

Cover Feature

While other makers marketed early model computers to businesses or scientists, Roberts's focused on consumers. He used Intel 8080 microprocessors bought in bulk discount to keep the cost of his kit down. Starting in late 1974, he sold the machine for $439 as a kit and $639 fully assembled.

The Altair was featured in the January 1975 issue of *Popular Electronics* magazine. The model Roberts had built for the cover shoot never arrived at the editorial offices; under deadline, without time to rebuild an Altair from scratch, MITS had to create a fake model with flashing LED lights. Nevertheless, the story broke the product in a big way: MITS received a thousand orders for it in February 1975 alone. The Altair sold so rapidly that MITS had to hire staff just to help process the orders.

Desktop Revolution

Soon Roberts heard from two young men, Bill Gates and Paul Allen, who wanted to sell him a programming language for the Altair 8800. Roberts took them up on their offer, and Gates and Allen completed the entire program, or compiler, in 30 days. They called the program Altair BASIC and founded a company called Micro-Soft to sell it. The PC revolution had begun.

Roberts retired early, taking up organic vegetable farming in rural Georgia and fulfilling his dream of becoming a doctor. He was even elected to the Alpha Omega Alpha medical honor society for his work in rural medicine. He died in 2010, after a long battle with pneumonia. Among his final visitors was Bill Gates.

Roberts with the Altair 8800 computer in 1977

WHEN ROBERTS DIED IN 2010, BILL GATES AND PAUL ALLEN POSTED A JOINT TRIBUTE TO THEIR "FRIEND AND MENTOR": [HE] "WAS WILLING TO TAKE A CHANCE ON US . . . AND WE HAVE ALWAYS BEEN GRATEFUL TO HIM."

Hitting Send

RAY TOMLINSON

(1941–2016)

Email

The Museum of Modern Art added the @ symbol to its collection in 2010, crediting Ray Tomlinson. Here he is in his office in Massachusetts in 1999.

The engineer who developed the message system that defines modern office life did so in secret because he worried his boss would reprimand him for shirking work assignments.

In 1968 Ray Tomlinson was working for a research-and-development firm contracted by a division of the Department of Defense to help build the ARPAnet computer network, the precursor to the Internet. While assigned to the project, Tomlinson wrote a program called SNDMSG (send message), which his work colleagues used to exchange short notes. The first electronic mail, or "email," was sent between two computers sitting side by side, with a note that read "QWERTYUIOP," the first row of the keyboard. Genius, except for one problem: the messages could only be read at the workstation of its recipient.

Email @ccess

Over the next few years, Tomlinson refined the electronic mail system so the messages could be accessed from any computer on the network simply by signing into a user

could be accessed from any computer on the network simply by signing into a user account. To reach the right place, messages had to be assigned the name of the recipient and a location. Tomlinson used this setup: name@host computer name. (The "@" symbol was chosen because it would not be confused with characters in a person's name. Tomlinson later called it "the only preposition on the keyboard.") Email caught on quickly at Tomlinson's firm and on ARPAnet. Concerned his managers would disapprove, Tomlinson asked his coworkers to keep it a secret. But word got out, and by 1973 three-quarters of all traffic on ARPAnet was email.

Tomlinson didn't patent his invention, preferring to share it freely with the world. In a 2009 National Public Radio interview, Tomlinson said he had some idea in the early 1970s of his invention's revolutionary potential: "What I didn't imagine was how quickly that would happen."

Tomlinson has received many awards for his game-changing work, including the George R. Stibitz Computer Pioneer Award, an IEEE Internet Award, and an induction into the Internet Hall of Fame.

Meet the Whiz

PALMER LUCKEY

(b. 1992)

Virtual reality

Palmer Luckey with his Oculus Rift virtual reality device

Before he revolutionized the world of virtual reality, Palmer Luckey was a precocious teen who spent his spare time dissecting and reassembling small electronics, Tesla coils, and gaming equipment in his parents' garage. As a home-schooled teenager in Long Beach, California, he collected over 50 head-mounted gaming displays. While comparing and contrasting their strengths and weaknesses, he decided to try to create something better.

Opening the Field of Vision

From 2009 through 2012, Luckey studied journalism at Cal State Long Beach and worked at a technology-development lab at the University of Southern California. In his spare time, he continued his obsession with gaming headsets and began to work on prototypes for a new virtual reality device. Luckey created a headset with 90-degree field of vision, which he eventually upgraded to 270 degrees. The model got lighter and more sophisticated.

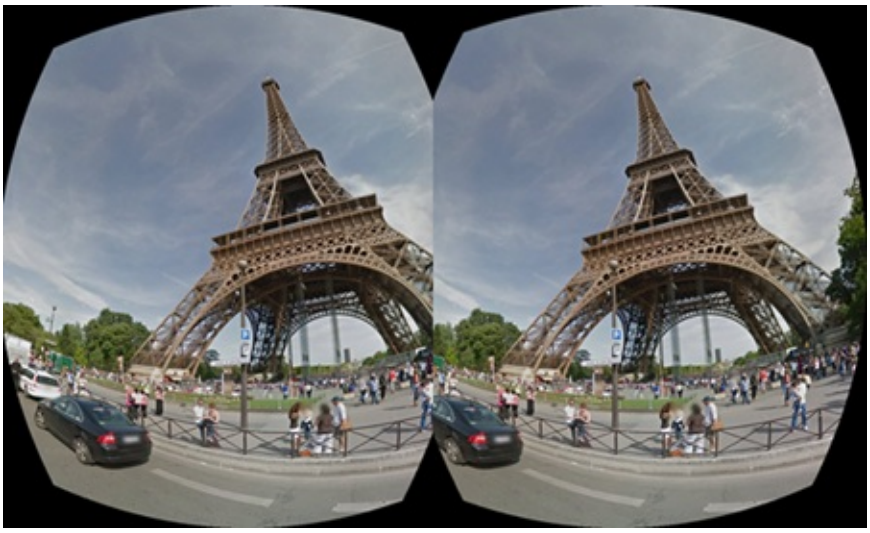
Through online forums, word of Luckey's device—now called the "Oculus Rift"—spread through the tech community. (The name is thought to be a nod to "oculus,"

Latin for eye, and the gap between the real and virtual worlds.) Among those interested was video game developer John Carmack, who requested a prototype directly from Luckey. When Carmack debuted his slightly altered version of the Rift at the 2012 Electronic Entertainment Expo, Luckey received a surge of new attention. He soon dropped out of college to work on the Rift full time. To raise money, he launched a Kickstarter campaign, promising to give donors kits so they could build their own Rift. The campaign raised $2.4 million and attracted the attention of major tech investors.

The Rift That Keeps on Giving

Oculus Rift overcomes latency—the lag time between a user's movements and the images on the screen—by taking 1,000 readings per second from a gyroscope, accelerometer, and magnetometer, effectively tapping the visual cortex. Besides gaming and social media, virtual reality holds promise in medicine and education, according to proponents such as Facebook co-founder Mark Zuckerberg. In fact, Zuckerberg was so impressed by Luckey's invention that Facebook acquired Oculus for $2 billion in 2014.

A retail version of the Rift was released in May 2016, featuring state-of-the-art optics and built-in headphones. It was one of the first virtual reality devices specifically targeted to consumers as opposed to the high-end, bulky prototypes of the past. In spite of his newfound wealth, Luckey has stuck with many of his old habits. He's often spotted in a Hawaiian shirt and shorts at tech events, held onto his 2001 Honda Insight even after the Facebook deal, and prefers fast-food joints over California's haute cuisine.



The problem with earlier virtual reality devices was that they made the user nauseous due to the lag in images.

LUCKEY WAS NAMED A "PIONEER" IN *TIME* MAGAZINE'S 2016 LIST OF THE 100 MOST INFLUENTIAL PEOPLE.

HOME

Ben Franklin. Clarence Birdseye. Tony Fadell. These Americans have revolutionized the way we live.

Inventors influence every area of our lives, from the way we work to the way we spend leisure time with our families.

Renaissance Man

BENJAMIN FRANKLIN

(1706–1790)

Bifocals, lightning rod, and more

In this Currier & Ives lithograph, Benjamin Franklin and his son William use a kite and key during a storm to prove that lightning was electricity, in June 1752.

By the time Benjamin Franklin was 16, he had already worked as a soap-and candlemaker, a printer, and a writer, and his eclectic career had been set in motion. In his mid-20s, Franklin entered public service, organizing the Union Fire Company in Philadelphia, and soon he was elected to the Pennsylvania assembly. At the same time, Franklin pursued science and invention—the Franklin stove, bifocals, daylight savings time, to name a few—and worked to expand human understanding of electricity.

In the American Grain

Yet perhaps this statesman and scientist's greatest invention was the American character itself. He embodied traits such as courage, optimism, and dedication and emphasized those in *Poor Richard's Almanack,* a publication he wrote and produced for more than two decades. Filled with aphorisms such as "Lost time is not found again" and "Diligence is the mother of good luck," the almanac steered readers to hard work and steady habits.

Going Electric

While visiting Boston in 1746, Franklin read about some scientific experiments with

While visiting Boston in 1746, Franklin read about some scientific experiments with electricity. An avid weather buff, he was always studying storms and speculating about their inner workings. The more he learned, the more he began to believe that lightning might be a form of electricity. He thought he could prove this theory using a metal rod eight to 10 feet long that could attract lightning and a grounding wire to transmit the energy generated by the strike.

At the time, Christ Church in Philadelphia was planning to build a metal steeple, and Franklin thought the structure would be ideal to test his lightning-rod hypothesis. But construction dragged on, and by June 1752, the steeple had yet to be installed. Franklin came up with a different tack using a metal key attached to a kite. He wrapped his hand in silk ribbon and flew the kite during a storm. The key attracted electricity and traveled down the wet hemp kite string, "charging" the string and transferring the charge to the key. Lightning rods have since been installed on millions of structures and prevented countless fires.

Double Vision

Franklin needed glasses since he was about 30, but as he aged, his vision got progressively worse, to the point that he had trouble with both reading and seeing distances. He had two types of glasses, one pair for up close and the other for far away. Having to constantly switch back and forth between the two annoyed Franklin but inspired an idea: a split lens where the bottom part of the lens would be set to a magnification allowing him to see things better close up, while the top part would be set to improve his distance viewing.

He called his invention "double spectacles," and by 1779 he'd found two opticians to produce them. Franklin shared the idea with his circle of friends, who also ordered double spectacles. But it wasn't until 1790, when a book about Franklin and his inventions was published, that bifocals became popular in the United States.

A 1767 portrait of Franklin that is part of the White House art collection

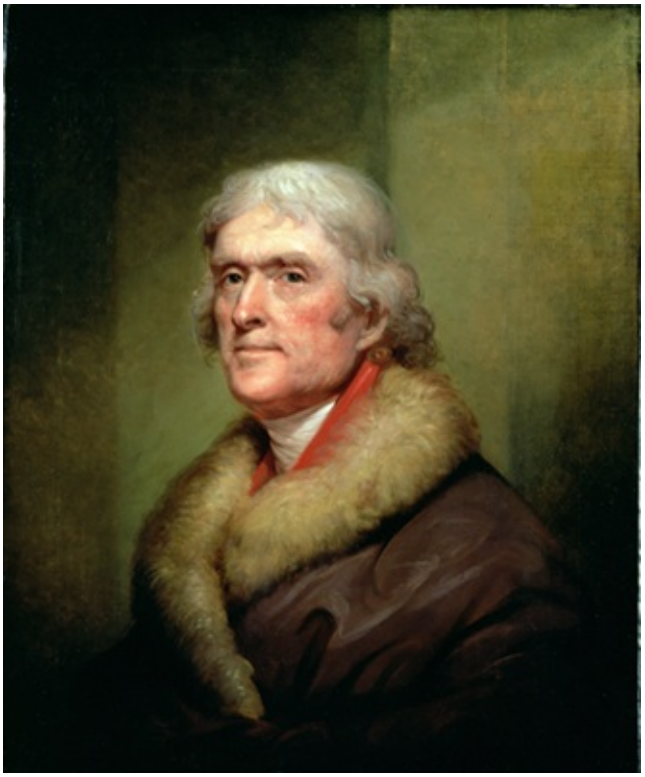
WE HAVE FRANKLIN TO THANK FOR DAYLIGHT SAVINGS TIME. HE SUGGESTED IN A 1784 LETTER TO A PARIS NEWSPAPER THAT MAKING PEOPLE RISE AND GO TO BED EARLIER WOULD SAVE MONEY ON CANDLES AND OIL LAMPS.

Architect of a Nation

THOMAS JEFFERSON

(1743–1826)

Domestic and agrarian arts



Thomas Jefferson, shown in an 1805 portrait by artist Rembrandt Peale

Thomas Jefferson was a man of contradictions: a bon vivant with dark secrets, a farmer who was equally at home in the fields and in the Enlightenment-era salons of Paris, and a proponent of mankind's freedom and equality who nonetheless owned slaves. Born at his family's Shadwell, Virginia, plantation, Jefferson was the third of 10 children. He grew up to author the Declaration of Independence, serve two terms as president, and found the University of Virginia.

The Young Agrarian

The pastoral settings and cultured atmosphere of Shadwell and nearby Tuckahoe Plantation (where the Jefferson family also lived for several years) were instrumental in shaping Jefferson's character. He became interested in agriculture, took up horseback riding, and excelled at languages and playing the violin.

After graduating from the College of William and Mary, in Williamsburg, Virginia, in 1760, Jefferson studied law and established himself as an attorney. He also inherited a fortune from his father, including over 3,000 acres of farmland in Virginia's Piedmont region. Jefferson began constructing his Monticello plantation home near Charlottesville. The structure was completed by 1782, but he continued improving Monticello until the end of his life.

A Student of Monticello

Between 1785 and 1789, Jefferson served as American ambassador, appointed to France. Here he soaked up the French culture, attending intellectual salons, observing its art and architecture, and participating in its vibrant social life. His time in Paris, as well as excursions throughout Europe, inspired many ideas that he would take back with him to America.

In 1794, following his tenure as the first U.S. Secretary of State, Jefferson began an extensive remodeling of Monticello based on the European architectural trends. He added imposing columns and skylights. He created the building's signature domed roof. And in the process, he created a new form of American architecture. When Monticello was finally completed in 1809, it was acknowledged as a masterwork.

Jefferson developed many inventions as he remodeled Monticello. Among them was an iron and moldboard plow based on European models. The plow could till fields in a downhill direction while safeguarding against soil erosion. Indoors, he improved the dumbwaiter, a small elevator that traveled between floors of a home and delivered food to a room.

Jefferson's time abroad also gave him a new appreciation of European wines and foods. During his travels in northern Italy, Jefferson drew and wrote extensively about the local cuisine and fell in love with pasta, which he referred to as macaroni. He probably did not introduce Americans to the noodle, but Jefferson likely helped popularize it by serving it to guests in the White House when he was president from 1801 to 1809.

Another of Jefferson's inventions, a letter-copying device with two pens attached that he called a "polygraph," sits on his desk at Monticello.

Cool Headed

OLIVER EVANS

(1755–1819)

Refrigeration, automated gristmill

This 1920 image captures the dawn in American home life of the refrigerator and the telephone.

Inventor and businessman Oliver Evans conceived the first design for a refrigerator, drew up plans for a solar boiler, helped create the assembly line, and advanced the development of steam engines, but his prolific career was marked by battles and frustration.

Through the Mill

Born into a large family in colonial Delaware, Evans apprenticed himself to a wheelwright at age 16. By his late 20s, he had begun to work in his brothers' Newport gristmill and devised an ingenious system to automate the process of grinding wheat into flour.

The new water-powered process made milling far more efficient; it eliminated human labor and led to cheaper bread. More importantly, it transformed production into one

labor and led to cheaper bread. More importantly, it transformed production into one continuous process rather than a series of jobs, a concept that would help spur the Industrial Revolution. After Evans secured a patent for the gristmill design, Thomas Jefferson and George Washington both commissioned Evans to make improvements to their own mills.

The system caught on, but as the patent was set to expire in 1805, millers who didn't want to pay royalties fought against its extension. In 1808 an extension was granted and signed by President Thomas Jefferson, but in the intervening three years many millers had implemented Evans's designs. Evans retaliated with a wave of lawsuits, many of which he won. But the battles drained him emotionally and financially, and he channeled his frustrations into an account of his experience titled *The Abortion of a Young Steam Engineer's Guide*.

Keeping Cool

Evans's 1805 book also described a steam-driven machine for cooling water or making ice. The description became the basis for two technologies—refrigeration and air conditioning—that would be essential to modern life a century later. This vapor-compression system transfers heat from an enclosed space or substance to the outside by forcing a liquid refrigerant to expand into vapor (a process that absorbs heat energy), then compressing it again to liquid (which releases heat, discharged to the outside).

In 1834 Jacob Perkins, who had worked with Evans, patented an ether-based vapor-compression device for cooling and freezing liquids that was based on Evans's principles.

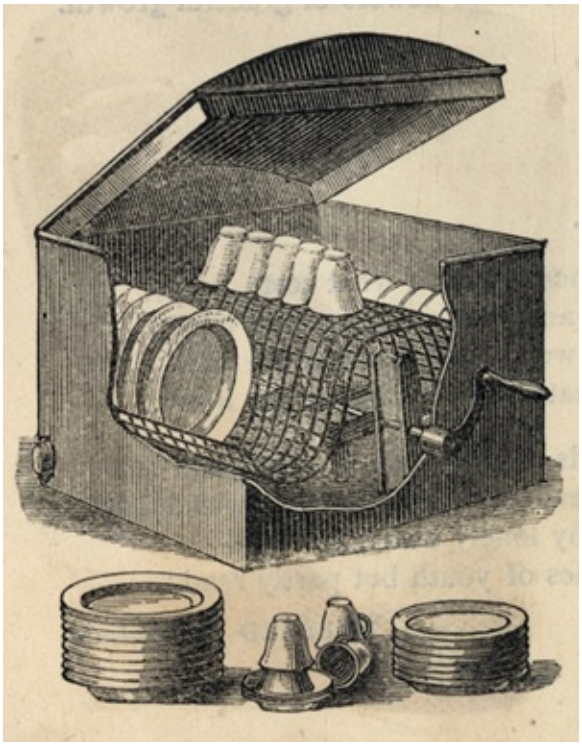
A 19th-century engraving of Oliver Evans

Clean-Up Act

JOSEPHINE GARIS-COCHRANE

(1839–1913)

Automatic dishwasher



This early dishwasher design was inspired by Josephine Garis-Cochrane's model, before she replaced the hand crank with an electric motor.

The invention of the automatic dishwasher can be traced to one woman's frustration with household work. In the mid-1800s, Josephine Garis-Cochrane was a wealthy Illinois housewife in a pique after a dinner party. One of her staff members had chipped several china dishes while washing them, and Garis-Cochrane vowed to invent a machine to do the job—just as there was for other household chores from sewing to mowing.

The Best Helping Hand

The great-granddaughter of the inventor of a version of the steamboat, Garis-Cochrane began researching her idea at the local library. Soon she had a rough sketch of a machine that would clean dishes held in racks with pressurized water. She designed a hand cranked dishwasher in 1886 and hired a mechanic to help her build it. The dishes

hand cranked dishwasher in 1886 and hired a mechanic to help her build it. The dishes sat in wire baskets set inside a wheel mounted within a copper tub. When cranked, the wheel turned, and hot, soapy water sprayed over the dishes.

Cleaning Up

Garis-Cochrane's husband died soon after, leaving her with a mountain of debt. Encouraged by her wealthy friends, Garis-Cochrane patented her invention and began selling it through magazine advertisements. When an electrified version of the machine was demonstrated at the 1893 World's Columbian Exhibition in Chicago, it took off with restaurants and hotels. (At $100, early dishwashers were a hard sell for the home market.) She started the Garis-Cochran DishWashing Machine Company, which later joined KitchenAid and was eventually acquired by Whirlpool. The dishwasher became a common household appliance in the 1950s.

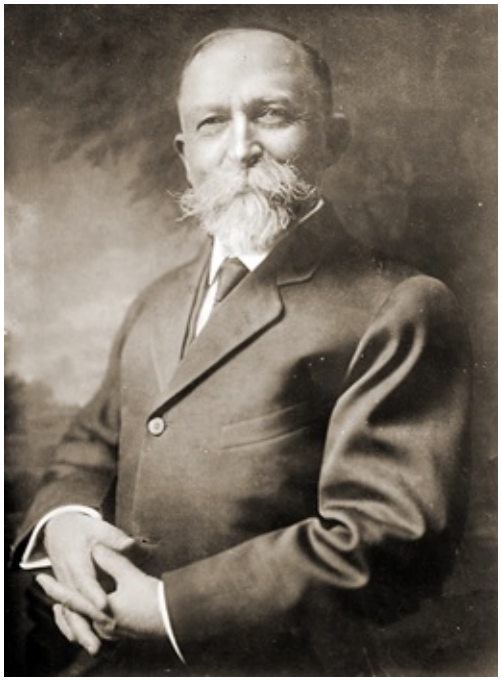
Eventually, Josephine Garis added an to her married name; she used a combination of her maiden name and original married name to refer to her dishwasher company.

Breakfast Champion

JOHN HARVEY KELLOGG

(1852–1943)

Ready-to-eat cereal



A 1913 portrait of John Harvey Kellogg

John Harvey Kellogg was one of America's first health and fitness gurus. A devout follower of the Seventh-Day Adventist Church, Kellogg was committed to the idea of an "indwelling divinity" that resided within human beings. He maintained that a healthy lifestyle would "guard the temple" of the body, and advocated vegetarianism, exercise, and sober living without alcohol, tobacco, or caffeine. In his passion for wellness, Kellogg also came to invent the centerpiece of the balanced breakfast: a morning bowl of cereal.

Healthy Visionaries

Kellogg had Ellen White, a cofounder of Seventh-Day Adventism, to thank for the inspiration. She believed the righteous path in life was to eat two meatless meals a day and experienced powerful visions related to health and diet. On Christmas Day 1865, she had a vivid mental image that she should build a wellness center. A year later, the church established the Western Health Reform Institute in Battle Creek, Michigan,

where Adventists had begun to settle.

In 1875, Kellogg was made the institute's medical director. Part of his mission was to convince patients to give up eating meat, which he thought was riddled with bacteria. To make the food served at the institute more appetizing, Kellogg and his wife, Ella Eaton, a trained dietitian, began experimenting with new recipes for healthful foods.

Not Flaking Out

In 1894, the Kelloggs mistakenly let a batch of cooked grain sit overnight in the lab. Their team ran the wheaty mush through a roller, creating flakes, and found that baking the bits improved their taste. The dish was served with milk to patients as "Granose." The Kelloggs kept experimenting with the recipe, eventually hitting on a formula that combined corn and rice. With patients clamoring to buy batches, Kellogg began producing limited quantities. He filed a patent for flaked cereal and the process that formed them in 1895.

One of the institute's patients, C.W. Post, saw a business opportunity and began manufacturing his own dry cereal in 1898. Post's "Grape-Nuts" were a hit and fueled a cereal boom. It wasn't until 1906 that Dr. Kellogg's brother, W.K. Kellogg, started the Battle Creek Toasted Corn Flake Company. The one-story wooden factory eventually grew to become the Kellogg Company, the world's largest cereal manufacturer.

From the beginning Corn Flakes were marketed as a health food and a convenience.

WHAT'S THE BEST WAY TO GET HEALTHY? JOHN HARVEY KELLOGG ADVISED HIS PATIENTS TO STAY AWAY FROM COFFEE, SPICES, AND VINEGAR.

Cool Customer

WILLIS CARRIER

(1876–1950)

Air conditioning

Willis Carrier holds a thermometer inside an igloo display, demonstrating air conditioning at the 1939 World's Fair.

Inventor Willis Carrier always credited a simple lesson of his mother's for opening his mind. When he was a boy, he was unable to understand the concept of fractions. His mother cut apples into different-size pieces to demonstrate it visually. Carrier maintained that this was the most important lesson of his life because it taught him how to clearly and effectively solve problems.

The Young Engineer

After receiving a master's degree in mechanical engineering in 1901, Carrier took a post with the Buffalo Forge Company, a fan and ventilation business based in Buffalo, New York. He was given the responsibility of designing steam heating systems to dry industrial stores of lumber and coffee.

In 1902, Buffalo Forge was asked by a Brooklyn printing shop to curb excessive humidity levels that were disrupting the production process. The printers needed to ventilate a room while lowering its temperature.

Standing on a train platform one morning, Carrier was enveloped in mist. Inspiration struck: fog was condensed water vapor, the same as the steam Carrier was using in his heating systems. If he could dry air by sending it through hot coils, could he dry air by passing it over coils filled with a coolant? The process would draw humidity from the air by forcing it to condense around the coils. Carrier had invented "temperature and humidity control," or, as he rebranded it in 1906, "air conditioning."

Conditioned Response

Supported by Buffalo Forge, Carrier continued to develop the technology. By 1914 he had founded his own company. Initially, it was mostly manufacturers who were interested in buying air conditioning, but that changed in 1924 when the J.L. Hudson Company department store chain purchased a unit for its Detroit location. Movie theaters adopted air conditioning, advertising the novelty comfort as much as the movies. Post–World War II, air conditioning became a standard option in cars, and eventually residences.

Carrier today is still one of the world's major air conditioning manufacturers. Carrier systems preserve the interiors of such landmarks as the Sistine Chapel, the Great Hall of the People in Beijing, and George Washington's Mount Vernon estate.

Intimate Companion

MARY PHELPS JACOB (CARESSE CROSBY)

(1891–1970)

Brassiere

Mary Phelps Jacob—later Caresse Crosby—led a spirited life. One of her most extravagant purchases was a 10th-century Italian castle, the Castello di Rocca Sinibalda, located outside Rome.

Scandalous and free-spirited, Mary Phelps Jacob was more than just a clever young inventor of the bra. She was a key figure in the post–World War I bohemian era, moved to Paris, changed her name to Caresse, and published early works of some of the most important authors in Western literature.

Birth of the Bra

Born in New York State in 1891 to an upper-crust family, Jacob lived a privileged life of private schools and parties. In 1913, she was dressing for a debutante ball in New York City and was unhappy with the way her corset flattened her chest. Jacob asked her maid to bring her some ribbon, two pocket handkerchiefs, and a needle and thread, which she turned into a garment she dubbed a brassiere (from a French term for "arm").

Though not particularly supportive, the risqué lingerie allowed Jacob to move more

freely than a corset and impressed her friends. Jacob patented her "backless brassiere" the following year and formed a small company to make them, but soon sold the rights to a Bridgeport, Connecticut, corset maker for $1,500—the equivalent of about $35,000 a century later.

In Her Cups

At 24, Jacob married her longtime boyfriend, Richard Rogers Peabody—he, too, from one of America's most distinguished families. But when Peabody went off to serve in the war, Jacob fell hard for a banking heir named Harry Crosby. Jacob, 28, and Crosby, 22, shocked their social circle by embarking on a very public affair. By 1922, Jacob had divorced her husband and married Crosby. The newlyweds set sail for Paris, where a number of Jazz Age artists and writers had relocated.

Even among the hard-partying nonconformists who were living in Paris, including Ernest Hemingway, F. Scott Fitzgerald, and Gertrude Stein, the Crosbys were over the top. They took numerous lovers, hosted dinner parties from their bed, and spent money with abandon. At her new husband's request, Jacob changed her first name to Caresse, which Harry thought more sensual.

The Crosbys were pivotal figures in the 1920s Paris American expatriate bohemian scene. Maintaining an open marriage, they each conducted several well-publicized affairs, openly took drugs, and even entered into a suicide pact (Harry died in one with a mistress in 1929). They also founded Black Sun Press and were among the first to publish works by their friends Ernest Hemingway, Henry Miller, Anaïs Nin, and D.H. Lawrence. Another husband and several high-profile affairs later, Jacob died in Rome in 1970.

From its simple beginnings with handkerchiefs and ribbon, the brassiere has developed into an item with $15 billion annual global sales.

CARESSE CROSBY, DISTANTLY RELATED TO ROBERT FULTON, ONCE REMARKED SHE INHERITED HER TALENT FROM HIM. "I CAN'T SAY THAT THE BRASSIERE WILL EVER TAKE AS GREAT A PLACE IN HISTORY AS THE STEAMBOAT, BUT I DID INVENT IT."

Both Sides Now

LLOYD COPEMAN

(1881–1956)

Two-sided toaster, rubber ice cube tray, and more

Lloyd Copeman had nearly 700 patents to his name.

Inventor Lloyd Copeman caught the tinkering bug early. At age 10, he rigged up a machine that could turn a grindstone automatically. For the bathroom in his schoolhouse in Farmers Creek, Michigan, he is said to have designed a remote-controlled paddle that could whack an unsuspecting visitor. Over the course of his lifetime, Copeman would amass some seven hundred patents.

Toasts of the Times

The practice of toasting bread, whether in a pan or on a stick, dates to Roman times. But with the advent of electricity in the early 20th century, inventors began experimenting with more efficient means

experimenting with more efficient means.

In 1909 the first electric toaster was produced by Frank Shailor of General Electric. He created a heating element that could hold a high temperature without breaking. The problem with Shailor's toaster was that it only toasted one side of the bread at a time. The bread had to be turned by hand—a dangerous task in the early days of electrical wires, which would sometimes get so hot that they would burst into flames.

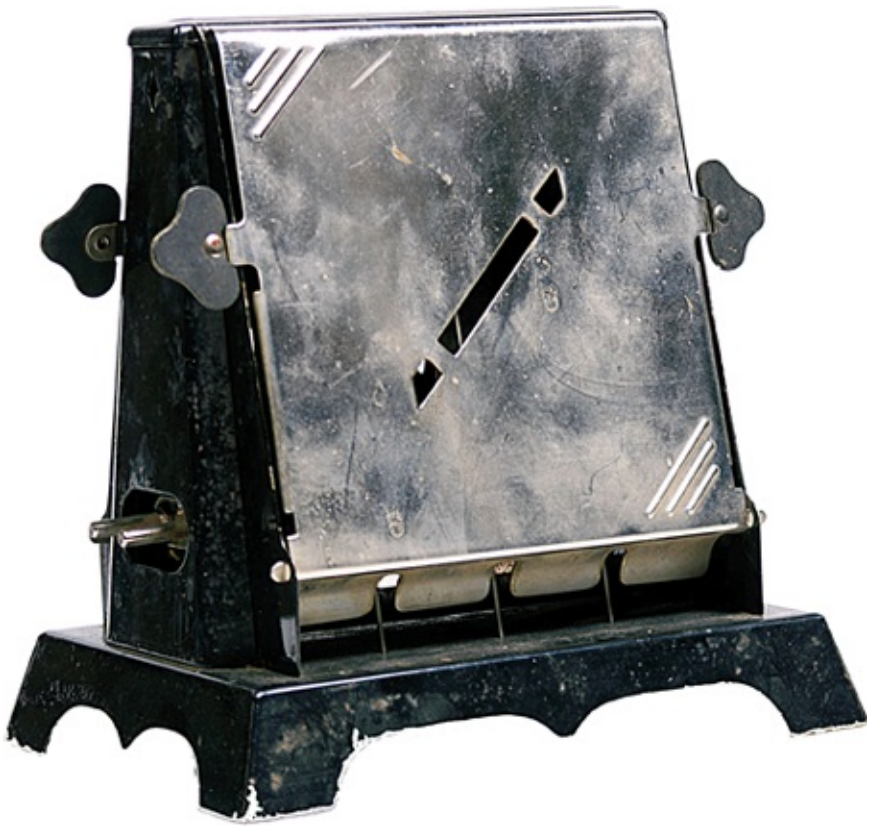
Turning Point

It was Copeman's wife, Hazel, who gave him the idea for a two-sided toaster after happening upon a window display of the one-sided variety. Hazel wondered aloud whether a device could be built that would automatically turn the toast. Copeman went to work to design such a machine.

Copeman patented his invention in 1914, and his company, the Copeman Electric Stove Company, began manufacturing them. They were much safer than previous models and marketed as the "toaster that turns toast." Westinghouse Electric purchased Copeman's company in 1918 and continued to make the appliances.

Freezing Out the Competition

Copeman patented several other inventions, including a clothesline for hotel rooms (the "Flexo-Line") and his most lucrative, the rubber ice cube tray. The idea for the tray came to him as he was walking in the woods one winter day and noticed that slush and ice did not stick to his rubber boots. The tray inspiration earned him the equivalent of $10 million in today's dollars. Copeman died in 1956, but his creativity lives on through his granddaughter, the singer Linda Ronstadt, a 12-time Grammy Award winner who has sold 100 million albums.



Copeman's two-sided design inspired electric toasters such as this one, from the 1920s.

The Mix Master

FRED WARING

(1900–1984)

Blender

Fred Waring demonstrates his signature blender.

Fred Waring was not only "The Man Who Taught America How to Sing" as a singer, bandleader, and popular radio personality. He also taught it how to blend—food and beverages, that is.

In the Mix

The blender that eventually bore Waring's name started with Stephen J. Poplawski, a Polish immigrant living in Racine, Wisconsin. In 1922 Poplawski attached a motor with blades to the bottom of a cup, making the first blender. He founded the Stevens Electric Company to manufacture the device for soda fountain bars at drugstores, where soda jerks literally had to "shake up" milkshakes. Ten years later Poplawski

where soda jerks literally had to "shake up" milkshakes. Ten years later Poplawski patented a machine that could liquefy fruits and vegetables. It took further tinkering by another Wisconsin native, Frederick Osius, to improve upon the idea and get it ready for home use.

Throughout the 1930s, Osius worked and reworked his design for the mass-market liquefying blender, first patenting it in 1933. He needed financial backing to continue his work and heard that Waring was interested in new gadgets. Osius talked his way backstage at the Vanderbilt Theater in New York, where the famous singer was celebrating after a live broadcast. Osius was able to easily persuade Waring, in part because the singer had an ulcer and his doctor had recommended he eat a puree of raw vegetables. He decided to lend his support to the tune of $25,000.

Whirlwind Takeoff

Unfortunately, six months after Waring and Osius agreed to a deal, Osius still hadn't perfected his blender. Waring hired a new designer to continue the project. The Miracle Mixer (soon to be renamed the Waring Blendor) debuted in 1937. By the 1950s, after a great publicity push by Waring, the blenders with his name were in more than a million homes. In addition to kitchen use, the blender became an important tool for scientific research. Dr. Jonas Salk used the Waring Blendor in his research that led to the polio vaccine.

DR. JONAS SALK USED THE WARING BLENDOR IN HIS RESEARCH THAT LED TO THE POLIO VACCINE.

Fresh From the Freezer

CLARENCE BIRDSEYE

(1886–1956)
Frozen food

Clarence Birdseye experimenting with freezing carrots

From the time he was a boy, Brooklyn native Clarence Birdseye was keen on botany and zoology, and when it came time for college, he chose to study the subjects at Amherst. Making tuition was difficult, however, and Birdseye dropped out to work for the U.S. government, identifying and classifying America's native plants and animals. In 1912 he joined the mission of the *Strathcona*, a charitable hospital ship that plied the coastal waters of Labrador, bringing medical care to remote communities.

Inuit Intuition

During his journeys, Birdseye noted how native Inuit froze freshly caught fish by exposing the fish on slabs of ice, a process whose results were much more palatable than the frozen fish Birdseye had sampled in New York. Birdseye wondered if the process could be applied to other foods.

process could be applied to other foods.

When he returned to New York in 1915, Birdseye began to experiment and discovered what the Inuit had already intuited: freezing quickly at very low temperatures instead of over many hours preserves the textures of foods and kills more harmful bacteria.

Freezing Out the Competition

In 1922 Birdseye conducted fish-freezing experiments at the Clothel Refrigerating Company in New York. Birdseye continued with freezing experiments as an employee of Clothel. He then founded his own fish-freezing business, but it was short-lived. Birdseye improved his technique, inventing a new type of freezer, and formed a different company to deploy it. The next year, 1925, Birdseye filed to patent the process in which food was packed in waxed cardboard boxes, pressed between metal plates, and chilled to temperatures as cold as -50˚F. He sold his business to the company that ultimately became General Foods and was brought on to run its Birds Eye Frosted Foods division.

The first Birds Eye quick-frozen foods, including vegetables, fruits, seafood, and meats, were sold in Massachusetts; the products went nationwide in the 1940s after Birdseye leased refrigerated cars for rail transport. By that time Birdseye had also developed a refrigerated display case for grocery stores.

Always Exploring

Toward the end of the 20th century just about every grocery store in America had a frozen foods section, bringing seafood to inland communities and making summer produce available year-round. Energetic and full of wonder, Birdseye continued until his death in 1956 to experiment and invent. “Change,” he wrote, “is the very essence of American life.”

Today, the U.S. frozen food industry is a $56 billion business. Birds Eye tops all sellers of frozen vegetables in the country.

CLARENCE BIRDSEYE ONCE SAID, "FOLLOWING ONE'S CURIOSITY IS MUCH MORE FUN THAN TAKING THINGS EASY."

Shreddin’

LES PAUL

(1915–2009)

Electric guitar

Les Paul with his guitar around 1946.

Before there were the heroes of rock ‘n’ roll, there was Les Paul. Like the Greek god Apollo, who gave Orpheus his first lyre, Paul endowed musicians with an amazing instrument: one of the world’s first electric guitars. The invention changed the rules of the music world and created a whole new art form in the process.

The Wizard of Waukesha

Growing up in Waukesha, Wisconsin, Paul ironically was an inept musical student who frustrated his early teachers: they felt he lacked the aptitude and talent to learn anything but the most basic skills. Yet Paul was determined and practiced on whatever instruments he could find—acoustic guitar, harmonica, and banjo among them. As a teenager he played in country combos that toured the Midwest and called into radio

teenager he played in country combos that toured the Midwest and called into radio shows to play guitar passages under the name "The Wizard of Waukesha."

Paul moved to New York in the 1930s and started his own jazz band. Electric music was becoming increasingly popular at the time and coincided with an upswing in demand for guitars loud enough to be heard in commercial recordings and at packed dance venues. The confluence of the expanding uses of electricity and the need for bigger sound in dance halls got Paul thinking about designing an electrically amplified guitar.

The Log

By the late 1930s, Paul began building guitars with electrical pickups (devices that "pick up" the vibrations of guitar strings and convert them to electrical signals to be amplified) and solid bodies. "What I wanted was to amplify pure string vibration, without the resonance of the wood getting involved in the sound," he explained. Paul's prototype was nicknamed "The Log" for its ungainly appearance. In fact, when he went to the Gibson guitar company to show them his new product, they likened it to a "broomstick with pickups."

Paul continued to tinker with his invention over the next decade. In 1951, Gibson president Ted McCarty worked with Paul to redesign "The Log." The result was the first Les Paul model single-body electric guitar. It debuted in 1952.

You Say You Want a Revolution

Rock pioneer Chuck Berry turned Les Paul into a household name when he played the "Les Paul" model guitar on "Roll Over Beethoven" in 1956, and again in 1958 on "Johnny B. Goode." By the 1960s, the guitar's popularity had surged, played by rock stars like Eric Clapton of the Yardbirds and Paul McCartney of the Beatles.

Paul went on to create other innovations embraced by the rock world, such as tape delay and multi-track recording. After a period of semiretirement in the 1970s (during which he released only two albums in collaboration with country artist Chet Atkins), Paul returned to the scene in 1984 when he began a residency at the New York club Fat Tuesday. He continued to play weekly sets until his death in 2009.

Consumers worldwide bought 1.1 million electric guitars in 2015.

Exciting Electrons

PERCY SPENCER

(1894–1970)

Microwave oven

One of the earliest proponents of Spencer's microwave technology, chemist Robert Schiffmann has served as a microwave cooking consultant for more than 150 companies. Here Schiffmann is seen in a humorous image, examining a plate of french fries with a stethoscope.

When the local paper mill in Percy Spencer's hometown in rural Maine installed electricity at the turn of the century, it was a turning point for the community. The move also changed Spencer's life. Captivated by the new technology, the teenager began to study it in his free time, and the hard work paid off. When it came time to wire the rest of the mill, Spencer was one of three people chosen, even though he had never received any technical training.

A Sweet Discovery

While serving in the Navy during World War I, Spencer kept educating himself, learning about wireless communications and radio technology and poring over books about trigonometry, calculus, and metallurgy. Upon his discharge, he worked for a manufacturer of commercial and military radio equipment, and eventually was hired as an engineer at the Raytheon Corporation in Cambridge, Massachusetts. There, Spencer oversaw the company's increased production of power tubes—vacuum tubes

that could be used to generate or amplify power—and magnetron tubes, the central components in radar devices that use a stream of electrons to detect objects.

A Radiant Mind

Spencer was at Raytheon working on a magnetron in 1946 when he discovered one day that a candy bar in his pocket had melted. The physics were clear to him: radiation from the magnetron had raised the internal temperature of the candy, causing it to soften. If he could control the electromagnetic radiation, he would have a new way to cook food at a much faster rate than a conventional oven.

Spencer placed different foods near the magnetron to see what the effect would be: more than a few eggs exploded, and he succeeded in creating the first microwave popcorn.Eventually, the engineer attached an electromagnetic field generator to a metal box for a device that heated food incredibly fast. In 1954, Raytheon offered the first microwave oven for commercial use.

It weighed 750 pounds, stood six feet tall, and cost $5,000. Thirteen years later, Amana, a division of Raytheon, introduced the first affordable microwave for the home with a price tag of $495. Called the Radarange, it was compact enough to fit on a kitchen counter. By 1975, prices had dropped significantly, and sales of microwaves surpassed gas ovens. Today, 90 percent of American homes have microwave ovens.

THE IDEA FOR THE MICROWAVE OVEN WAS BORN BY ACCIDENT WHEN SPENCER DISCOVERED THAT STRAY RADIATION HAD MELTED A CANDY BAR IN HIS POCKET.

Pick of the Litter

EDWARD LOWE

(1920–1995)

Kitty litter

Founder of Kitty Litter, Edward Lowe is shown in a 1986 advertisement for Tidy Cat. Lowe's invention sparked an entirely new industry, and Lowe supported entrepreneurship by others through the Edward Lowe Foundation.

In 1947, Edward Lowe, a 27-year- old Navy veteran, was working at his father's sawdust company in Cassopolis, Michigan, when he was approached by a neighbor with a request: did Lowe have any sand on hand that she could use to fill her cat's litter box?

Instead of sand, Lowe gave the neighbor a package of fuller's earth, a type of clay that his father was offering industrial customers to absorb grease on factory floors in lieu of sawdust. The clay worked so well in the cat box that Lowe decided to market it as Kitty Litter and sell it for 69 cents a bag.

Mines for Felines

A local pet store owner was unconvinced he could find customers for clay as long as sand was free, so Lowe told him to give away bags of his Kitty Litter. Soon cat owners were hooked, and sales took off.

Lowe spent the next several years crisscrossing the country, promoting Kitty Litter from the back of his Chevy coupe. An astute marketer, Lowe launched the Tidy Cat brand in 1954 to sell in supermarkets, while he positioned Kitty Litter as a boutique brand for pet stores and veterinarians. Lowe's cat box filler grew into a multimillion-dollar business with its own clay mines. The operation included a research and development center in Cassopolis, Michigan, known as the All-American Cattery to study feline bathroom habits.

In 1990 Lowe sold his company to a group of venture capitalists for $200 million. After his death, it was purchased by Ralston Purina Company of St. Louis, Missouri, which merged with the Swiss food corporation Nestlé in 2001.

Remote Character

TONY FADELL

(b. 1969)

Nest, self-learning thermostat, iPod

Tony Fadell displays the Nest thermostat, which entered its third generation in September 2015.

Smartphone and digital-media pioneer Tony Fadell was an entrepreneurial kid: his first job was an egg-delivery business in the third grade, and, as he once tweeted in response to the Labor Day–themed hashtag #FirstJob, he "learned a ton" on his sixth-grade paper route.

Early Opportunities

While a student at University of Michigan in the early 1990s, Fadell cofounded his own company, Constructive Instruments, which specialized in children's computer software such as MediaText to help students create multimedia compositions. Upon graduating, he worked in the design sectors of various tech companies, pioneering many personal organizer devices.

In 1999, Fadell tried unsuccessfully to launch a second company, Fuse, focused on consumer electronics. Among his ideas was a hard disc based music player. While Fuse did not secure enough funding to go ahead, all was not lost: Fadell's music-player concept caught the attention of Apple founder Steve Jobs, who brought him on in 2001 to assist with the design of the iPod. Fadell went on to work on 18 different versions of

the device. He was charged with designing the hardware and software for the first three generations of the iPhone.

Apple and After

Burnt out by almost eight years at Apple, Fadell left the company in 2008 to travel and reassess his relationship to the tech industry. While building a vacation home, he was frustrated by the choices of available thermostats and began work on a sensor-driven, programmable thermostat that could be controlled from a smartphone. In 2010, Fadell cofounded Nest Labs with another former Apple employee, Matt Rogers, to produce and market the device.

The thermostat established Nest Labs as a leader in cutting-edge home products. The company has since branched out to make smoke alarms and security cameras for the home that can be accessed remotely. The company was sold to Google in 2014 for $3.2 billion (and Fadell left his post as Nest CEO in 2016, parting paths with Google except to advise).

Fadell has over 300 patents to his name and has received multiple awards for his designs and inventions. In 2014, *Time* magazine named him one of their "100 Most Influential People in the World." With all of his success, what is Tony Fadell's advice to would-be inventors? "Our challenge is to wake up each day and say: how can I experience the world better?" he said in his 2015 TED Talk, "The First Secret to Great Design."

Fadell was hired by Steve Jobs in 2001 to help design the original iPod.

TONY FADELL SAYS, "IF YOU DON'T HAVE AN EMOTIONALLY ENGAGING DESIGN FOR A DEVICE, NO ONE WILL CARE ABOUT IT."

HEALTH

Since the 1950s more Nobel Prizes in Medicine have been awarded to scientists in the United States than to those in any other country.

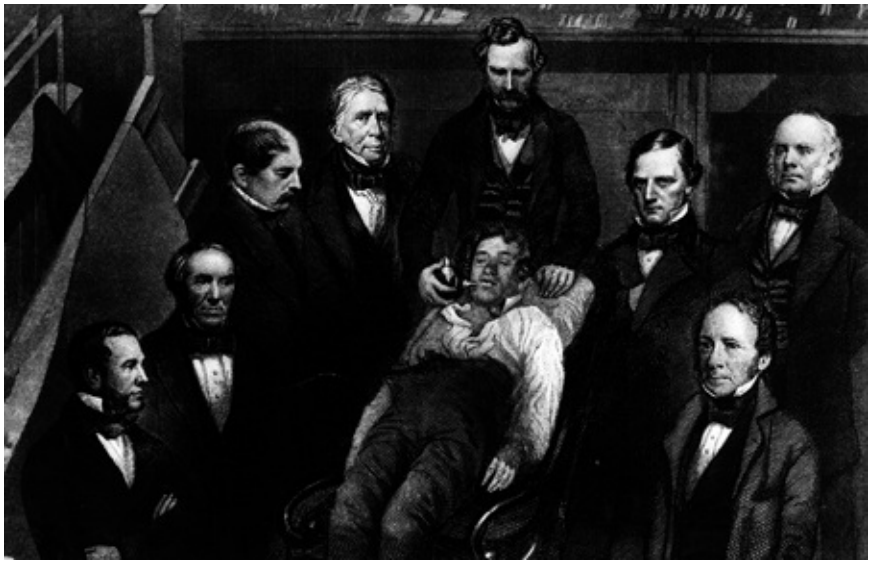
Painting of William T. G. Morton's famous public demonstration of ether anesthesia during surgery at Massachusetts General Hospital on October 16, 1846.

Ether Way

HORACE WELLS AND WILLIAM T. G. MORTON

(1815–1848) (1819–1868)

Anesthesia



William T. G. Morton's public demonstration of pain-free surgery under ether anesthesia.

It took some hard-partying Victorians and a few American doctors to help kick-start the development of modern-day anesthesia.

The story dates to the invention of ether in Germany in 1540. For centuries afterward, ether was not used surgically, but instead as a treatment for ailments such as scurvy or pulmonary inflammation. In the 1800s, the famously restrained Victorians discovered that inhaling ether loosened their inhibitions. Some even held "ether frolics" where people took turns breathing in the vapors and laughing at each other's antics.

Across the pond in the United States, Dr. Crawford Long, who sometimes threw ether frolics in his medical offices, realized that ether had potential as an anesthetic and used it in an operation to remove a tumor from a patient's neck.

From Anesthesiology to Addiction

But it was two American dentists, Dr. Horace Wells and Dr. William T. G. Morton, who publicly demonstrated anesthesia techniques—and suffered painful personal repercussions as a result. Connecticut-based Wells began using nitrous oxide, or laughing gas, as a dental anesthetic in 1844. In 1845 he badly botched a laughing gas demonstration and fled to Paris in shame.

On his return he found his one-time protégé, Morton, of Boston, had stolen the spotlight by establishing ether as the anesthetic of choice. A few years later, while

experimenting with yet another anesthetic—chloroform—Wells became an addict. He committed suicide at age 33.

False Claims

Morton, too, slid from acclaim to infamy. He introduced his audience to the potential of ether in 1846, at a public performance at Massachusetts General Hospital. The demonstration made both Morton and the hospital operating theater famous. Dubbed the Ether Dome, the theater was designated a National Historic Site in 1965.

Yet Morton's glory was short-lived. In the years following his ether triumph, the dentist tried to say he had invented the anesthetic and patented ether under a brand name, Letheon. He was shunned by the medical community for seeking to profit from a substance that could help so many patients.

Morton spent much of the rest of his life trying to prove that he was the rightful inventor of ether as an anesthetic.

He died, deeply in debt with legal fees, at age 48.

William T. G. Morton (top) and Horace Wells pioneered the use of ether as the first general anesthetic.

No Hands

WILLIAM STEWART HALSTED

(1852–1922)

Rubber medical gloves and more

Today's stringent hospital safety codes require sterilization procedures and gloves for all operations.

William Halsted was just a middling student as a young man, but that changed once he entered medical school in New York City. Halsted mastered anatomical terminology, took his physician's exam a year early, and soon introduced a practice that would change medicine: sterilization. Halsted was influenced by the British surgeon Joseph Lister, who promoted careful antisepsis, or the practice of maintaining a clean, sterile environment during surgery. Halsted believed that microscopic organisms could cause disease and made hand sterilization mandatory for surgical attendants at New York's Bellevue Hospital in 1877.

Addiction and a Second Chance

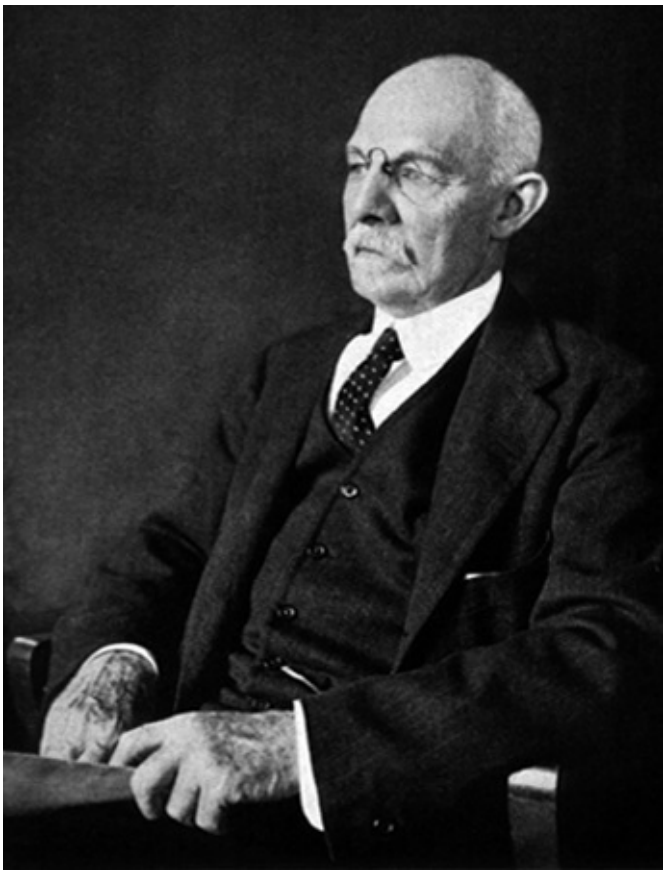
Halsted continued to advance science. In 1881, at age 29, he performed a blood transfusion—using his own blood—on his ailing sister. The following year he performed one of the first successful gallbladder surgeries on his own mother. His zeal to advance the medical field, however, would prove to be his downfall.

At the time, cocaine was being tested as an anesthetic and to further research Halsted experimented by injecting the drug into his nerves. He quickly developed an addiction and left medicine to enter a rehabilitation facility in Rhode Island. There, Halsted was weaned off cocaine, but with morphine. He struggled with substance abuse for the rest of his life, even as he continued to work.

In 1886, Halsted's friend, pathologist William Welch, helped him secure a job at Johns Hopkins Hospital, in Baltimore. Halsted instituted the same sterilization procedures as he had at Bellevue. His head nurse, South Carolina–born Caroline Hampton, complained of severe contact dermatitis on her hands and arms from the corrosive disinfectant mercuric chloride. Since she was "an unusually efficient woman," as Halsted later wrote, he asked the Goodyear Rubber Company to make a pair of thin rubber gloves for her. They worked well, and Halsted ordered more. He and Hampton married in 1890.

The Innovator

The same year, Halsted became first chief surgeon at Johns Hopkins. He innovated important surgical procedures to treat breast cancer, hernias, and thyroid disease. The trustees of Johns Hopkins established the School of Medicine in 1892. They were wary of granting Halsted a full professorship due to his history of addiction, but he succeeded in changing their minds, becoming the school's first professor of surgery. He went on to create a surgical training program that became the model for residencies in the United States.



William Halsted in his later years

AMONG HIS MANY ACCOMPLISHMENTS, HALSTED INTRODUCED THE MEDICAL CHART TO TRACK PATIENTS' VITAL SIGNS AND WAS ONE OF THE FOUNDING PROFESSORS AT JOHNS HOPKINS.

Life Blood

CHARLES RICHARD DREW

(1904–1950)
Blood bank

Drew examines blood samples in his lab.

The founder of the blood bank may have been a world-class athlete in high school and a star student in college, but as an African American in the 1930s, he was unable to find a medical school to accept him. He worked for two years teaching biology and coaching at Morgan College, in Baltimore, before deciding to seek opportunities outside the country.

Plasma Transfusions

Drew enrolled at McGill University's medical school, in Montreal, Canada, graduating second in his class in 1933. He returned to the United States hoping for a residency at the Mayo Clinic but was not offered one; the white patients of such institutions routinely refused to be seen by black doctors. He accepted a position as a professor of surgery at Howard University, a black college in Washington, D.C., in 1935.

surgery at Howard University, a Black college in Washington, D.C., in 1935.

In 1938 he was awarded a fellowship at Presbyterian Hospital in New York and studied for a PhD at Columbia University. Drew began researching ways to make blood transfusions more efficient. Along with other colleagues, he figured out ways to separate blood cells from plasma, the clear, liquid portion of blood. Plasma is easier to transport; it can be stored longer and is well suited for emergency situations.

Drew proved that plasma transfusions could be used in patients of any blood type. He invented a technique for drying plasma and reconstituting it. He also began a blood-banking program at Presbyterian Hospital in New York, establishing himself as a leader in the field.

Joining the War Effort

By 1940 Adolf Hitler was on the march in Europe, and Drew joined the war effort. As head of a program called Blood for Britain, he designed a system to collect blood in the U.S., process it into plasma, and ship it overseas. Based on the success of Blood for Britain, Drew was asked to direct a pilot program for a national blood bank with the American Red Cross. Here he pioneered the use of mobile blood donation stations, commonly known as "bloodmobiles."

The program expanded when the United States entered World War II in 1941. Drew helped recruit some 100,000 donors to amass more than 13 million pints of blood for transfusions to American soldiers in combat. The effort earned Drew recognition as the "father of the blood bank."

When the military requested that blood from African Americans be labeled and segregated from that of white donors, making Drew unable to participate in the very program he helped create, he resigned in protest. He returned to Howard University and promptly became the chief surgeon at Freedmen's Hospital. He spoke out eloquently against institutional prejudice, especially the controversial practices of the American blood bank. "It is unfortunate that such a worthwhile and scientific bit of work should have been hampered by such stupidity," he said at an awards ceremony in 1944.

Baby's First Test

VIRGINIA APGAR

(1909–1974)

Neonatal assessment

No better system for assessing infant health has emerged since the Apgar scoring system was first developed over 60 years ago.

Virginia Apgar excelled at school growing up and could have pursued many careers, but family tragedy may have pushed her toward medicine. One of her brothers died young, of tuberculosis, while another battled chronic illness. She immersed herself in the sciences as an undergraduate, studying zoology, physiology, and chemistry, then entered the Columbia University College of Physicians in New York at a time when there were few women in the medical field. After graduating at the top of her class, Apgar decided to specialize in anesthesia, which traditionally had been handled mostly by nurses.

Between 1938 and 1948—while she was building an anesthesiology division at Presbyterian Hospital in New York—an increasing number of women began going to the hospital to deliver their babies. Nevertheless, hospital delivery methods were hardly ideal. Laboring mothers were typically given general anesthesia, and there was no way to monitor the baby's vital signs during labor or after delivery. Infants continued to die in the first 24 hours of life—a problem Apgar believed could be addressed with a systematic check at birth.

systematic check at birth.

Apgar Invents APGAR

Apgar urged her physicians to carefully look over each newborn to be sure it was breathing and thriving. When a resident stopped her one day in the hospital cafeteria to ask how to conduct the assessment, Apgar jotted down five key things medical workers should check within a minute of birth: the baby's heart rate, respiration, color, muscle tone, and reflexes. Babies were scored in each category on a scale of 0 (meaning "absent") to 2 (meaning "present"), with 1 somewhere in between. Those with total scores between 7 and 10 were more likely to survive; those with lower scores needed immediate intervention.

In 1953 Apgar published a paper introducing the score to assess a newborn's condition. The system was widely adopted, and, much to Apgar's delight, her name was turned into an acronym for the five criteria: Appearance, Pulse, Grimace, Activity, and Respiration.

After leaving Columbia in 1958, Apgar joined the March of Dimes, speaking and writing widely. Along with journalist Joan Beck, she authored a 1972 bestselling book,*Is My Baby All Right?*

Virginia Apgar developed her assessment to counter the high infant mortality rate at the time.

Eliminating a Scourge

JONAS SALK

(1914–1995)

Polio vaccine

While an injection may not be fun, the polio vaccine has saved countless lives. Today polio vaccination campaigns continue in vulnerable areas throughout the world.

The man who developed the world's first polio vaccine almost didn't go into medicine. Born in 1914 in the Bronx, New York, Jonas Salk was the eldest son of Russian Jewish immigrants who had little schooling. Salk, however, was the product of an excellent public school education and initially intended to study law and then run for political office. But when he graduated college in 1934, it was with a degree in chemistry; medical school and an internship at New York's Mount Sinai Hospital followed. Salk then received a fellowship to study flu viruses at the University of Michigan, which started him on the path of medical research.

Attacking the Virus

Polio has existed since ancient times. In the United States, other viruses—including influenza—were far more prevalent in Salk's day and killed more people. But by the 1920s, the country had seen several waves of polio, and the disease was terrifying. Some

1920s, the country had seen several waves of polio, and the disease was terrifying. Some who contracted it became permanently paralyzed; others were unable to breathe and had to remain in massive ventilators, known as iron lungs, while they recuperated. Still others died.

What made polio even more frightening was that no one knew how it was contracted. People were afraid of swimming and other public activities. It was later discovered that the disease spread via coughs and sneezes, and also through contact with the stool of the infected person.

In 1947 Salk was made the director of the Virus Research Laboratory at the University of Pittsburgh School of Medicine. A grant from the National Foundation for Infantile Paralysis (later known as the March of Dimes) provided him the initial round of funding for research of a polio cure.

It took seven years and testing on one million children (nicknamed "Polio Pioneers"), but by April 1955 Salk had found his cure. The vaccine he developed was based on the then novel and controversial idea that a live virus was not required to induce immunity; a dead virus could also stimulate a protective immune response. The vaccine was soon widely available.

The People's Vaccine

The announcement that Salk had developed an effective vaccine against the disease was met with nationwide rejoicing. *The New York Times* front page on April 13, 1955, cheered the successful conclusion of the largest medical field trial in history. "Salk Polio Vaccine Proves Success; Millions Will Be Immunized Soon; City Schools Begin Shots April 25," proclaimed a jumbo headline. "The world learned today that its hopes for finding an effective weapon against paralytic polio had been realized," began the lead article. Within several years of the vaccine's introduction, new polio cases plunged from an annual average of 45,000 to fewer than a thousand.

Hailed as a hero, Salk went on to found a research facility, the Salk Institute of Biomedical Studies, in La Jolla, California. But one thing he didn't do was patent his vaccine. In a 1955 television interview with journalist Edward R. Murrow, Salk said that the medical breakthrough, which had been publicly funded, belonged to the people. Making a dramatic comparison with something else that could not be privately owned, he asked Murrow rhetorically, "Could you patent the sun?"

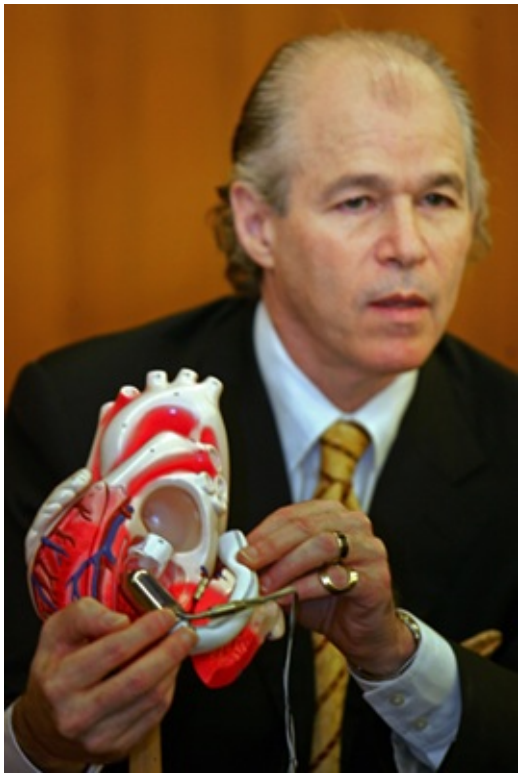
Jonas Salk, developer of the polio vaccine, in the laboratory, mid-20th century

AFTER THE POLIO VACCINE WAS INTRODUCED, THE NUMBER OF NEW CASES PLUNGED FROM AN ANNUAL AVERAGE OF 45,000 TO FEWER THAN A THOUSAND.

Pump It Up

ROBERT JARVIK

(b. 1946)
Artificial heart



Robert Jarvik holds the Jarvik 2000, a left-ventricular assist system.

Perhaps Robert Jarvik was destined for a career in the medical sciences. As a child, he was able to observe his physician father perform surgeries, and by the time he graduated high school, he had already designed an automatic stapler to close sutures. In college, Jarvik chose to become an architect but was inspired to switch to premed when his father developed heart disease. His path to medical school was by no means an easy one; after being rejected by several American schools for his average grades, Jarvik tried his luck in Italy. He attended but did not complete course work at the medical school of the University of Bologna, returning to the United States in 1971 and eventually earning a degree.

The Jarvik-7

In the 1970s, experimental artificial hearts had succeeded in keeping a human patient

In the 1970s, experimental artificial hearts had succeeded in keeping a human patient alive only for a couple of days and animals for a week or two. But Jarvik, then a scientist at the University of Utah, believed he and his colleagues could create a permanent implantable heart for use in humans. Eventually, the team unveiled a device called the Jarvik-7, and in 1982 a retired Seattle dentist named Barney Clark, whose heart was failing, agreed to be the first recipient of the device, even knowing he might not survive for long.

The Jarvik-7 was hardly perfect. Though it was small enough to fit inside a person's chest, it was powered by an outside machine called a driver. Since the person had to be attached to the external machine by a series of tubes, this limited his or her mobility and made the design impractical. It also was unable to keep people alive for very long. Clark lived for a little over three months; a second patient who received a Jarvik-7 survived for a little under two years. Recipients were susceptible to complications, including strokes and infections, and required intensive medical care.

Further Developments

Because of the associated hazards, the federal government placed limits on the use of artificial hearts in 1985 and cut off research funding in 1988. Jarvik pressed on, forming Jarvik Research, Inc., in New York City to continue his studies. Since 2000 he has focused on a left-ventricular assist system, a device that helps weakened hearts pump blood from the ventricle to the aorta and then throughout the body.

More than 350 patients have used the Jarvik-7 since 1982. They are still in use today: a smaller version of the Jarvik-7 can buy time for patients awaiting a heart transplant. Another model is reserved for people with end-stage heart failure who are not transplant candidates.

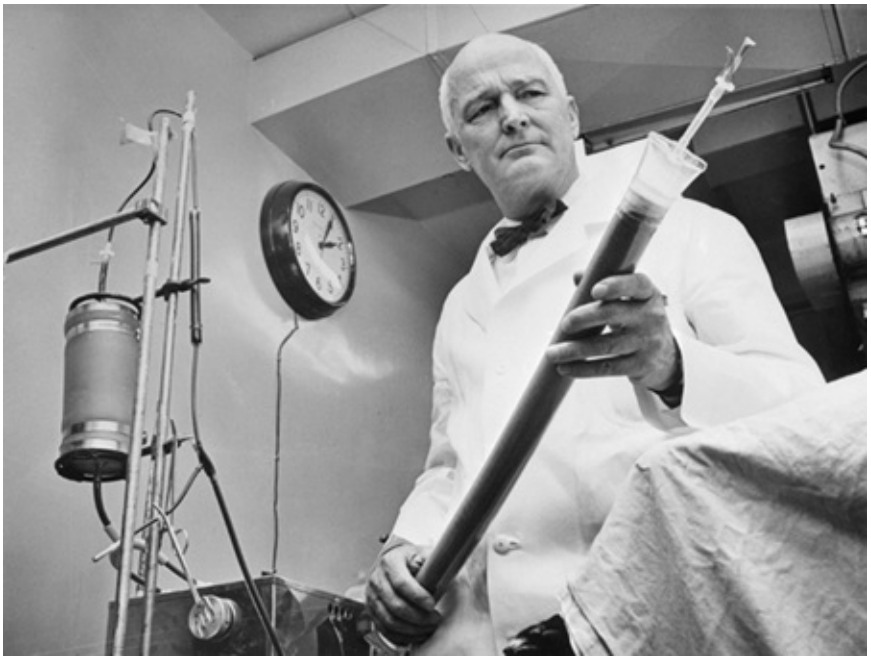
Jarvik isn't the only powerful intellect in his family. His uncle, Dr. Murray Jarvik, studied smoking addiction and was one of the inventors of the nicotine patch, while his wife, the columnist Marilyn vos Savant, was recognized to have the highest known IQ by the *Guinness Book of World Records*.

Breathe Easy

JOHN GIBBON

(1903–1973)

Heart-lung machine



John Gibbon, the inventor of the first successful heart-lung machine

John H. Gibbon Jr. came from a long line of medical professionals. His grandfather, great-grandfather, and great-great-grandfather were all doctors, and one of his great-uncles was a noted Confederate surgeon during the Civil War. Though Gibbon Jr. wanted to break with family tradition and pursue a career as a writer, his father convinced him to stay the course. Gibbon Jr. followed his father's advice, and in 1930 he was made a surgical fellow at Harvard Medical School, doing work at nearby Massachusetts General Hospital.

Twenty-three-Year Commitment

One of Gibbon's first assignments was to assist Dr. Edward Churchill, a surgeon who pioneered treatments for thyroid and heart conditions, in an emergency procedure to remove blood clots from a woman's heart. While the two doctors successfully removed the coagulations, the woman did not survive the surgery due to blocked lung circulation. The experience inspired Gibbon to create a machine that could

temporarily function as a patient's cardiovascular system during heart surgery, oxygenating and pumping blood while the patient's own heart was being repaired.

Though Gibbon's colleagues were skeptical of his project, he devoted himself to it for the next 23 years, working on the idea in his spare time. He eventually met and married Mary Hopkinson, a medical researcher, and the two began collaborating. After a stint serving in World War II, Gibbon was named chief of surgery at Jefferson Medical College Hospital in Philadelphia. There, he teamed up with IBM engineers to perfect a prototype.

Refining the Process

On May 6, 1953, Gibbon performed surgery to repair a heart defect in an 18-year-old patient named Cecelia Bavolek. For 26 minutes, after he stopped her heart to repair it, Gibbon's machine did its work, circulating Bavolek's blood and keeping her alive. When the surgery was finished, her heart restarted, and she made a full recovery.

Gibbon was demoralized after losing two patients in similar operations that same year. But later inventors, notably Dr. John W. Kirklin at the Mayo Clinic in Rochester, Minnesota, refined the machine. By the late 1950s, Kirklin's tweaks to Gibbon's invention had helped improve survival rates, allowing for significant advances in heart surgery.

Gibbon died of a heart attack in 1973 while playing tennis, most likely the result of a lifetime of smoking. His work led to many surgical procedures, from coronary bypass surgery to successful repairs of congenital heart defects.

The heart-lung machine temporarily takes over the cardiopulmonary functions.

BEFORE GIBBON'S INVENTION, CARDIAC SURGEONS HAD NO OPTION BUT TO OPERATE ON A BEATING HEART; PATIENTS OFTEN DID NOT SURVIVE.

A Surprising Trio

JOHN ROCK, GREGORY PINCUS, AND MARGARET SANGER

(1890–1994) (1903–1967) (1879–1966)

Birth control pill

Oral contraceptives were promoted as a natural means of birth control because they used progesterone, a naturally occurring hormone, to control cycles.

It was an unlikely team that rewrote the rules of women's reproductive health. Activist Margaret Sanger, scientist Gregory Pincus, and doctor John Rock all came from different backgrounds, belief systems, and areas of expertise, but their collaborative efforts led to one of medical history's most revolutionary inventions: the birth control pill.

Paving the Way

The anti–birth control movement started after the Civil War, when New York salesman Anthony Comstock, a fervent Christian, was offended by the lust he observed while out on his beat. By 1873 he had convinced Congress to pass a bill that made it illegal to own anything sex-related, including contraceptives.

Sanger, a nurse on the Lower East Side of Manhattan, had seen up close the fate of women who lacked access to birth control. Her own mother died of tuberculosis when Sanger was just 19, her body weakened by the stress of 11 childbirths and seven miscarriages. In her day job, Sanger worked with women who had self-induced abortions, some of whom died from the procedure. Appalled by high maternal mortality, she launched a campaign to overturn the Comstock laws around 1914.

Sanger opened the country's first birth control clinic in 1916 but was arrested and

Sanger opened the country's first birth control clinic in 1916 but was arrested and sentenced to time in a workhouse for violations of the Comstock laws. In the 1930s Sanger again defied the Comstock law by ordering a diaphragm from Japan. She was instrumental in winning a 1936 U.S. Circuit Court of Appeals decision that made it possible for doctors to distribute contraceptives across state lines—a ruling that paved the way for the legitimization of birth control.

Meetings of the Minds

As the 1940s progressed, Sanger began work in New York founding the International Committee on Planned Parenthood, a women's health organization. About the same time, endocrinologist Dr. Gregory Pincus was directing the Worcester Foundation for Experimental Biology, in eastern Massachusetts, and conducting research on hormones. Pincus's work focused on mammalian reproduction and the effects of hormones on fertility. He caused a sensation in 1934 when he orchestrated the successful in vitro fertilization of a rabbit but was pilloried in the press by critics who thought his research could lead to dangerous experiments with "test tube babies."

At a dinner party in 1951, Sanger met Pincus and persuaded him to work on a human birth control pill. She enlisted heiress and activist Katharine McCormick to contribute over $2 million in funding for the project, and Pincus began testing the hormone progesterone and its effects on ovulation. He confirmed that the hormone prevented ovulation in animals in 1952—a finding that would be the basis for the pill.

Later that year, Pincus tapped Dr. John Rock to help him with clinical trials for the contraceptive. As a Catholic, Rock was an unlikely convert to the birth control cause. But his experience as a gynecologist, where he witnessed the suffering caused by unwanted pregnancies, convinced him that accessible contraceptives could help alleviate the poverty and health risks related to childbirth.

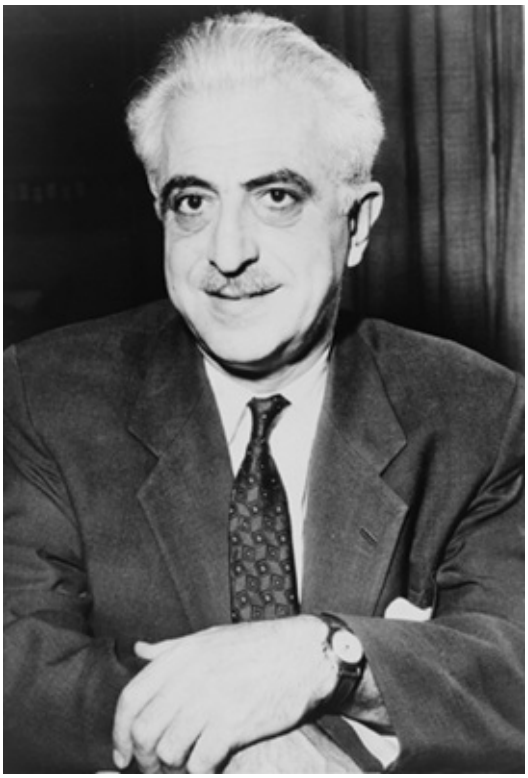
Birth of "The Pill"

Pincus and Rock had to circumvent state laws forbidding birth control to carry out the necessary trials of their progesterone-based oral contraceptive. First they claimed that they were studying infertility so they could administer the first human trials, in Massachusetts, in 1954. Two years later they continued their tests on a larger scale in Puerto Rico. The island was selected for its proximity to the United States, the fact that it had no bans on contraception, and its extensive network of birth control clinics. It also afforded scientists the opportunity to test the pill on women of different backgrounds.

After these trials, the Food and Drug Administration (FDA) initially approved the pill in 1957 to treat menstrual disorders. In 1960, the FDA authorized the tablet as a safe means of birth control. "The Pill" was not only the first oral contraceptive but also the

first medication approved to prevent a condition rather than treat an illness. Within a few years millions of women were using the product. According to the Guttmacher Institute, a nonprofit organization focusing on reproductive health, more than half of all women who use the pill rely on it, at least in part, for noncontraceptive purposes such as help with cramps, migranes, or acne.

Pincus went on to conduct important research on the use of synthetic hormones for emergency postcoital contraception before dying of a rare blood disease in 1967. Rock also continued to work on the birth control issue, penning the 1963 book *The Time Has Come: A Catholic Doctor's Proposal to End the Battle Over Birth Control*.



Gregory Pincus in a 1960s portrait

John Rock in his obstetrics and gynecology office

Margaret Sanger at her writing desk in the 1920s

THE ONE WEEK OF SUGAR PILLS, ALLOWING MENSTRUATION, WAS NOT MEDICALLY NECESSARY BUT AROSE FROM ROCK'S CATHOLIC FAITH AND WHAT HE BELIEVED TO BE NATURAL.

Emergency Care

JAMES ELAM

(1918–1995)

CPR

James Elam's early work in mouth-to-mouth resuscitation laid the groundwork for his later collaboration on CPR.

Dr. James Elam was always interested in helping people breathe. It may have come from a personal experience he recounted often: born prematurely, the infant Elam weighed less than two pounds. The physician who delivered him told his mother to "spank him every time he stops breathing." She took the advice, and Elam survived—a rare thing for a premature baby in those days.

Professional Challenges

Elam's first professional challenge after completing medical school was treating a polio epidemic in Minnesota, where he had gone to seek further training. He needed a way to revive polio patients who had stopped breathing. At the time, the most common resuscitation method involved lifting a patient's arms above his head, then pressing them back down against his chest to inflate and empty the lungs. But polio paralyzed

them back down against his chest to inflate and empty the lungs. But polio paralyzed the body, so Elam experimented with mouth-to-mask ventilation as well as a technique he knew midwives used to get newborns breathing: blowing into the nose or mouth.

Word of Mouth

Though the mouth-to-mouth technique seemed to work well, no one had adequately studied it to make sure it was safe. With further research, Elam proved that even though an exhaled breath contained carbon dioxide, it still had enough oxygen to keep a nonbreathing person alive. In the early 1950s, Elam teamed with Dr. Peter Safer, the chief of anesthesiology at Baltimore City Hospital, in Maryland. The two collaborated and perfected the method of mouth-to-mouth resuscitation in 1957. Their method made it possible for people to administer treatment outside of hospitals, without equipment such as ventilators.

Rescue Breathing

In 1959, the New York State Health Commissioner Herman Hilliboe requested that Elam write an instructional method to spread word of the new emergency care technique. The resulting booklet, titled *Rescue Breathing*, was distributed nationally. Elam and Safar also contracted a Norwegian toymaker to design an anatomically correct doll to help people practice the technique. The doll, known as "Rescue Annie," is still in use today.

By 1960, Safar had teamed up with researchers from Johns Hopkins Hospital, also in Baltimore, who had shown that chest compressions can circulate blood in patients whose hearts had stopped. Safar and his partners promoted a two-part rescue technique now known around the world as cardiopulmonary resuscitation, or CPR.

Tag Team

ROSALYN YALOW AND SOLOMON BERSON

(1921–2011) (1918–1972)

Radioimmunoassay

Yalow and Berson in the laboratory where they conducted their groundbreaking research As it did for many women, World War II opened the door in unexpected ways for medical researcher Rosalyn Yalow. A secretary in New York City when the conflict broke out, Yalow was able to enter a physics doctoral program once thousands of young men deployed to Europe and the Pacific. After the war, when the U.S. government began exploring how radioactive elements could be used in medical research, Yalow was well-positioned to contribute.

Medical Physics

Yalow joined the Bronx Veterans Administration Medical Center in 1947 as a nuclear medicine researcher. She was interested in applying the physics of radioactive isotopes to medical questions but needed someone who understood internal medicine to help advance her research. When she met Solomon Berson, a physician and scientist with a colorful past as both a musician and chess aficionado, she knew immediately she'd found her partner. The two joined forces and spent the next 22 years studying how radioactive materials could measure miniscule amounts of substances in the human body.

Their first project was aimed toward helping people with diabetes. Diabetics cannot produce enough insulin, the hormone that turns sugar into energy, so it must be injected. To study the path insulin takes in the body, Yalow and Berson added a

injected. To study the path insulin takes in the body, Yalow and Berson added a radioactive isotope of iodine to a molecule of insulin. As insulin passed through the body, the tiny amount of radiation given off by the isotope allowed them to track the insulin's movement and see how long it was retained. Their findings led to the replacement of livestock-based insulin with human insulin, which could be processed much faster.

Tracing and Tagging

Yalow and Berson's experiments with diabetics led to the development of their most lasting achievement, the radioimmunoassay technique. This is a diagnostic test that can detect minute amounts of substances in the blood and is used to test patients for everything from cancer tumor markers to thyroid problems to pregnancy hormones. Physicians tag whatever substance they want to measure in a patient with a radioactive label that makes it traceable. The mixture of substance and label is then added to a solution containing the substance's antibody, which is then added to a sample of the patient's blood. Based on the way that the elements of the mixture separate into radioactive and nonradioactive groups, a researcher can measure the amount of the substance in the blood.

Yalow and Berson were both awarded professorships after their breakthrough. When Berson died in 1972, Yalow renamed their laboratory in the Bronx the Solomon A. Berson Research Laboratory. She did this so that his name would be on every research paper she subsequently published. In 1977 Yalow became only the second woman in history to win the Nobel Prize in Physiology or Medicine.

Whole blood serum is prepared for hepatitis testing through radioimmunoassay.

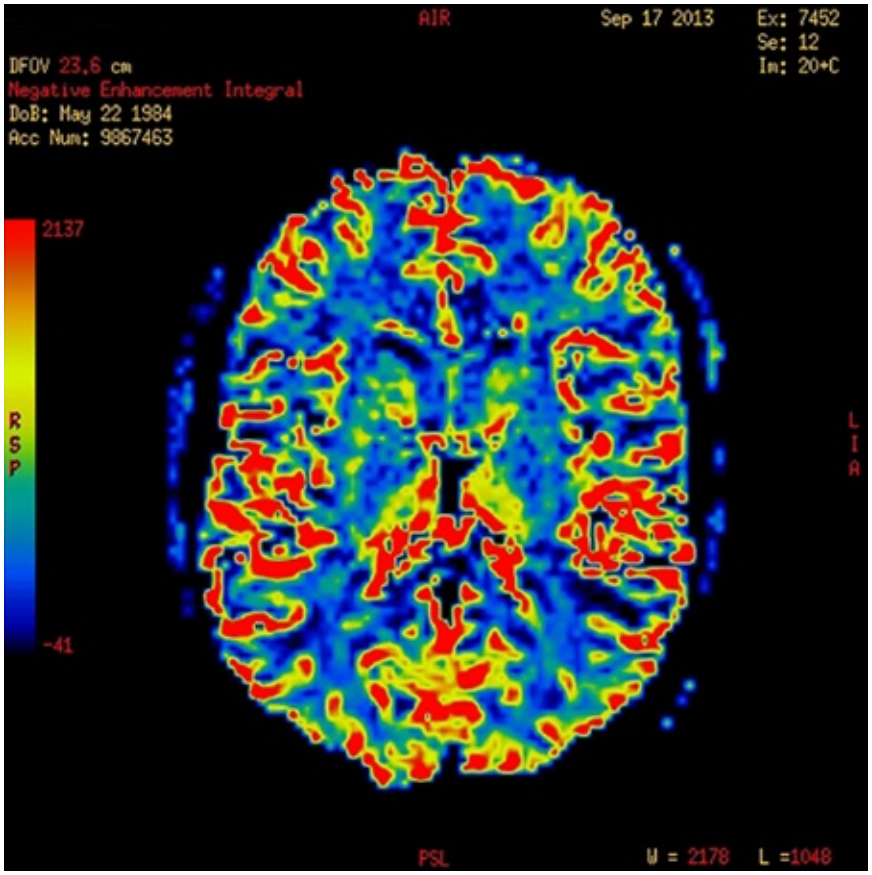
YALOW'S INSPIRATION WAS THE POLISH-FRENCH CHEMIST AND PHYSICIST MARIE CURIE, WHO CONDUCTED PIONEERING RESEARCH ON RADIOACTIVITY.

Inside Look

RAYMOND DAMADIAN

(b. 1936)

Magnetic resonance imaging



MRI of a normal brain

Armenian American physician and inventor Raymond Damadian is generally credited with developing the first magnetic resonance imaging (MRI) machine. But unlike many in the scientific community, Damadian was a creationist, believing that the universe resulted from a divine act rather than evolution. Some of Damadian's supporters feel that these beliefs may have cost him a Nobel Prize.

Intense Pain

A bout of intense abdominal pain led Damadian to create the MRI machine. When he took ill in the early 1960s, x-rays could produce images of bony structures. But the only way to know what was going on internally with a person's soft tissue was to operate

way to know what was going on internally with a person's soft tissue was to operate. Though his symptoms eventually improved when he cut down on his caffeine consumption, Damadian was intrigued with how to capture images of a body's soft tissues.

Flipping Out

Over the next decade, Damadian explored how a magnetic field and radio waves could be used to render images of the body's internal organs. Subjected to a magnetic field, the nuclei of atoms—including the plentiful hydrogen atoms of the watery human body—align themselves in either parallel or antiparallel fashion. Radio waves can "flip" these nuclei. As the radio waves are withdrawn, the nuclei "flip" back into alignment at different rates. This "relaxation time," readable by the radio waves the nuclei emit as they move, varies among the different tissues of the body. Damadian used this process to differentiate cancerous tumors in rats. He published his concept in 1971.

Seeing It Through

In 1977, Damadian and colleagues at Downstate Medical Center, in Brooklyn, New York, used their primitive imaging machine—the "Indomitable," they called it—to produce a rough picture of a graduate student's heart and lungs. The method, however, was impractical, as it relied on a point-by-point reading of the entire body.

Working separately at Long Island's State University of New York at Stony Brook, chemist Paul Lauterbur made magnetic resonance imaging feasible. Lauterbur created a way of building up an image by applying a magnetic field that varies in strength across the body. The process allowed the scanner to map exactly where the signals originated. Lauterbur's gradient field is used in MRI technology today.

MRI revolutionized diagnostic imaging as a noninvasive method for peering under the skin to closely examine such structures as the organs of the chest and abdomen, the spinal column and nerves, the tendons and ligaments, and even the brain.

The work earned Lauterbur, along with English physicist Peter Mansfield, the 2003 Nobel Prize in Physiology or Medicine. There was controversy about this, as some scientists felt that Lauterbur and Mansfield's technological advances would have been impossible without Damadian's earlier research. His original MRI machine is now in the collection of the Smithsonian.

Raymond Damadian played a key role in developing MRI.

Mood Booster

DAVID WONG

(b. 1936)

Prozac

Wong's testing proved that fluoxetine could increase feelings of well-being.

David Wong, one of the key researchers who invented Prozac at Eli Lilly and Company, arguably ended up on the team because of his grandmother—at least in part. When Wong was job hunting after finishing his doctorate in chemistry, he remembered the Lilly logo on the diabetes medicine his grandmother took and decided to apply for a position at the company. Lilly hired him as a senior biochemist in 1968.

It was a good decision. Prozac became one of Lilly's all time bestsellers, and Wong would also do pioneering work on another of Lilly's top earners, the antidepressant Cymbalta.

In Collaboration

While there were early antidepressants, many were marred by side effects: compromised vision, dizziness, and constipation among them. Two scientists at Eli Lilly had been working on antidepressants since the early 1960s: Ray Fuller and Bryan

Molloy. Fuller had experimented with rats to see how their serotonin (the chemical in the brain that produces feelings of happiness) reacted to different drugs. Molloy researched how antidepressants could function without disrupting acetylcholine, the neurotransmitter responsible for muscle stimulation, among other things.

Giving Others a Lift

When Wong joined the antidepressant team in 1971, he was responsible for testing the chemical compounds Molloy had devised in his research. The method Wong used was a bit unorthodox but worked for his purposes: he removed the nerve endings from ground-up rat brains so they would function just like living nerve cells. When he used these to test Molloy's compounds, he discovered that one of the compounds, called fluoxetine, blocked the nerve ending from reabsorbing the neurotransmitter serotonin. The team tested the compound further on a living rat and found it achieved the same effect—meaning that more serotonin was available in the brain, and therefore more feelings of happiness.

Fluoxetine was trademarked under the name Prozac. Lilly introduced it to the public in 1988. Propelled by a massive marketing campaign, Prozac became a blockbuster. By 1990, less than three years after its debut, Prozac was Lilly's top-selling medication and the most widely prescribed antidepressant in the United States. Antidepressants as a category became a mass social phenomenon, the most commonly prescribed drug for Americans ages 18 to 44. The drug's patent expired in 2001, and now it competes with generic and brand name alternatives.

Prozac ushered in a new era in psychopharmacology.

PROPELLED BY A MASSIVE MARKETING CAMPAIGN, PROZAC BECAME A BLOCKBUSTER. BY 1990, LESS THAN THREE YEARS AFTER ITS DEBUT, PROZAC WAS LILLY'S TOP-SELLING MEDICATION.

TRANSPORTATION

The United States is vast—about 3.8 million square miles. So what is the quickest and most efficient way to move people, goods, and raw materials across the land?

Orville and Wilbur Wright's *Flyer I*—the world's first power-driven flying machine—used spruce, ash, and muslin fabric in its construction.

Power Player

ROBERT FULTON

(1765–1815)

Steamboat

Robert Fulton never lived to see transatlantic steamboat travel take off.

The man who helped create the American shipping economy of the 19th century began his career as an artist. Robert Fulton was a portrait and landscape painter in 18th-century Pennsylvania. But a lifelong interest in drawing machinery, coupled with an explosion in canal-building, prompted Fulton to experiment with boat design and engineering.

Running Out of Steam

The first workable steam engine was created by Scottish inventor James Watt in 1775. The development ushered in an era of automation, where eventually everything from farm implements to factory machinery was power-driven. While a number of inventors attempted to attach Watt's steam engine to boats, none were successful.

In 1787, American inventors John Fitch and James Rumsey built a rowboat with a steam engine—the motor powered two poles, which made a row of oars turn in the water. After George Washington and Benjamin Franklin witnessed a demonstration of the boat, Fitch and Rumsey were awarded a government contract to develop the idea. But the duo was unable to improve on their initial design and Fitch, frustrated by

failure, committed suicide in 1798.

French Connection

Fulton was the man to perfect the steamboat. He already had designed canal boats, introduced improvements to canal mechanisms, and even built the first working submarine, the *Nautilus*. In 1802, while living in France, he met Robert Livingston, an American minister who came from an old, moneyed New York family and who had exclusive rights to steamboat use on the Hudson River. Fulton and Livingston formed a partnership to build a boat for commercial transport and developed the prototype in France.

When Fulton tested the steamboat on the Seine River in 1803, it sunk in a violent storm. He rebuilt it and tested it again later that year. This time it sailed successfully. Fulton returned to America in 1806 to build a full-size ship for the Hudson.

Onward to Albany

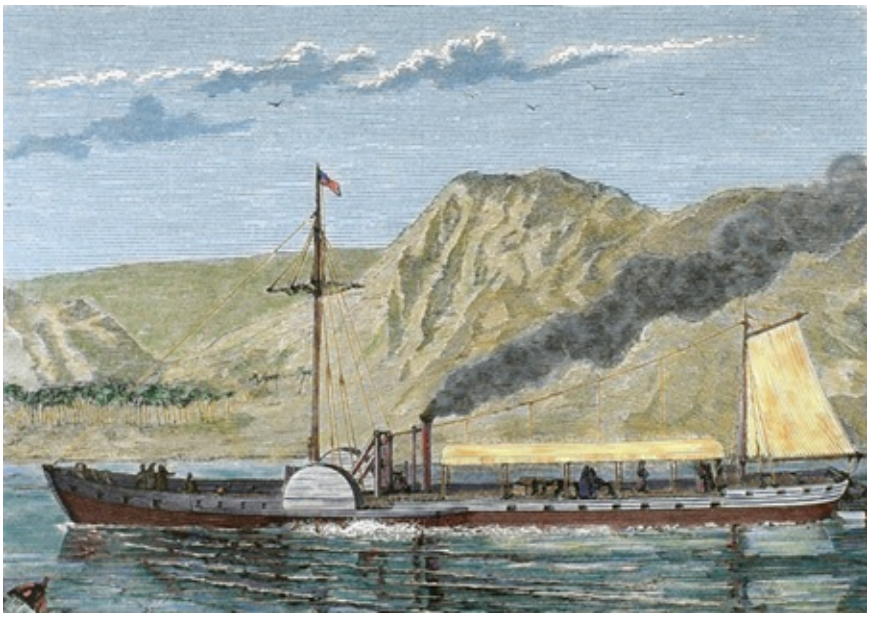
Fulton's American model incorporated some new elements. Instead of using oars to propel the boat, Fulton equipped it with a waterwheel. He ordered a special 24-horsepower Watt engine and had it shipped from England to the shipyard on the East River in New York. When the vessel was completed in 1807, Fulton christened it the *Clermont* after Livingston's home on the Hudson.

On August 17, the 150-foot-long ship was ready for its inaugural voyage. It sailed from New York to Albany, 150 miles up the river, in 30 hours with an overnight stop. With its smokestacks and noisy paddlewheels, the ship scared fishermen on the banks of the river who had never seen anything like it. The *Clermont* returned to New York and, with some modifications, was ready for passenger travel within a month.

Trade Transformation

The first steamboat to cross the ocean was built by Moses Rogers and made a 25-day trip from Savannah, Georgia, to Liverpool. By 1818, such voyages were becoming routine. The steamboat would transform the American shipping economy.

Fulton, however, never got to see the far-reaching effects of his invention. Walking across the frozen Hudson River with his friend Thomas Addis Emmet one night in 1815, Emmet fell through the ice; Fulton rescued him, but in the process was soaked with cold water and contracted pneumonia and then tuberculosis. He died soon thereafter, leaving behind a wife and four children.



This 19th-century colored engraving shows Fulton's steamboat, the *Clermont*, on the Hudson in 1807.

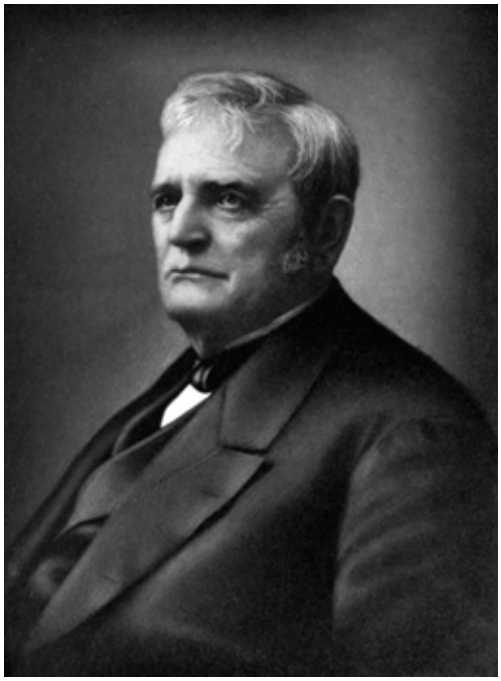
A TRAINED ARTIST WHO SPECIALIZED IN PORTRAITS AND LANDSCAPES, ROBERT FULTON BEGAN DRAWING MACHINERY BEFORE HE EVER CONSIDERED BUILDING IT.

Having a Field Day

JOHN DEERE

(1804–1886)

Tractor and plow



The company John Deere founded to manufacture farm machinery is still headquartered in Moline, Illinois.

John Deere was just a boy when his father, a tailor, disappeared, and he was raised in Rutland, Vermont, by his mother. Deere worked as a blacksmith's apprentice and was soon known as one of the most talented smiths in the state. Declining business opportunities in the Northeast prompted Deere to head west in 1837. He established himself in Grand Detour, Illinois, with his wife and their five children following him out the next year.

Digging In

At his new shop, Deere noticed that he was constantly making repairs to plows. The thick, sticky prairie dirt jammed their cast-iron and wooden parts, and operators had to stop work almost hourly for cleaning. His clients were frustrated. Deere began to conceive of a plow that could better till the prairie soil.

A childhood memory served as fodder. Deere remembered watching his father polish sewing needles with sand, and that the needles rarely got stuck or jammed. In his shop

in Grand Detour, Deere already had begun to make pitchforks from steel and noted how the metal rarely caked with dirt and mud. Steel, it appeared, would be an effective material for plow blades. In 1837 he polished a broken steel sawmill blade to a high sheen, then fashioned it into a plow blade. He gave it a curved rather than straight edge so it could better dig into the dirt and lift the soil.

Growth of the Soil

Deere sold the steel-bladed plow to a local farmer, who shared his new purchase with peers, many of whom wanted one of their own. With local investors he formed a company and opened a factory in Moline, Illinois, to keep up with demand. By 1849 he was producing 2,000 steel plows annually, and by 1857 the company was offering nine different models to handle different terrains.

After buying out his initial investors, Deere brought his son Charles on board. Charles took over day-to-day operations of the company in 1858, freeing his father to engage in civic affairs. In his later life Deere was the director of the town library, became a trustee of his church, and even served as Moline's mayor for two years.

Teaming Up for the Tractor

Even before Deere's death in 1886, steam engines had begun to replace draft animals on the American farm scene. By 1891, inventor John Froelich of Waterloo, Iowa, revolutionized the machinery by swapping out the steam engine with a gas-powered internal combustion engine. Although the word "tractor" would not come into use until 1901, Froelich's invention of what he called a "traction engine thresher" was in fact the first modern tractor. It could harvest 10 times faster than a horse-drawn plow. Deere & Company bought Froelich's company in 1918.

Driving Force

CHARLES GOODYEAR

(1800–1860)

Vulcanized rubber

Years after Goodyear died, an industrialist founded a tire company and named it after the inventor as a tribute.

In the 1830s, the world fell in and out of love with rubber—but one man remained enamored. Charles Goodyear, a Philadelphia hardware merchant, became obsessed with the substance and remained so, even when his rubber experiments led to financial hardship and debtors' prison. "There is probably no other inert substance which so excites the mind," Goodyear opined.

Early Rejections

In 1834, Goodyear was in bankruptcy when he approached the Roxbury India Rubber Company of New York with an invention: a valve to use with rubber life preservers. Goodyear's idea was ingenious. His timing was not. Though manufacturers had been promoting the natural waterproof gum from Brazil as a wonder material that could protect shoes and boots, the kinks had not yet been worked out. No one could figure out how to keep the rubber from melting in the summer heat and freezing in the winter. Roxbury was giving up on the substance and advised Goodyear to do the same.

Yet the inventor was adamant. Even with unpaid bills that landed him behind bars, Goodyear continued to experiment with rubber, sometimes while incarcerated. He mixed it with whatever substances he could find, from witch hazel to cream cheese, and whatever tools were at hand—including a rolling pin brought in by his wife. Upon

release, Goodyear moved to New York to escape his creditors, had some small successes with rubber, and was given a medal by a New York trade show for his efforts.

The ups and downs continued. When Goodyear discovered that nitric acid improved rubber's durability, he lined up an investor to back production. The financial crisis in 1837, however, scuttled the deal, and Goodyear had to feed his family by fishing off the Staten Island Harbor. He moved back to Massachusetts, where new backers contracted with the government to produce 150 mailbags for the U.S. Postal Service using the nitric acid–based rubber. Goodyear produced the order, but the rubber melted when he left the sacks too long in an overheated room.

The Breakthrough

In 1839, Goodyear finally had his breakthrough. He took a sample of rubber mixed with sulfur to a general store in Woburn, Massachusetts. While waving the fist-sized sample around to make a point, Goodyear accidentally threw it onto a stove. This time the rubber didn't melt—it charred. Around the edge was a springy, dry rim of gum elastic, suggesting that the heat and sulfur had some how transformed the rubber. But what was the right temperature? Goodyear continued his experiments, heating bits of rubber in sand and streams of steam.

And there were more hardships. Goodyear's infant son died, and his finances strained. To support his work, he had to pawn his watch and sell his household furniture. Finally, in 1840, Goodyear hit upon a process of steam under pressure and heat that produced uniform rubber that was weatherproof and durable.

Poor Dealings and Posthumous Fame

Still, Goodyear was haunted by infringers and bad business decisions. A patent obtained in 1844 failed to prevent manufacturers from pirating his idea, and even with the help of famed lawyer Daniel Webster, Goodyear was unable to recover the lost income. By not securing foreign patents in a timely manner, Goodyear opened the door for another inventor, Thomas Hancock of England, to "reinvent" rubber in 1843. Hancock filed a British patent for "vulcanized rubber," named for Vulcan, the Roman god of fire.

When Goodyear died in 1860, he was $200,000 in debt. His biggest success came with the rise of the automobile, decades later, when vulcanized rubber made it possible to create sturdy tires. In 1898, industrialist Frank Seiberling started a car-tire company and named it the Goodyear Tire Company in honor of the original inventor of vulcanized rubber.

Starting in 1925, Goodyear began using its fleet of blimps as an advertising and public relations vehicle.

Vulcanized rubber found its greatest market in automobile tires.

CHARLES GOODYEAR WAS WILD ABOUT RUBBER. HE ONCE REMARKED, "THERE IS PROBABLY NO OTHER INERT SUBSTANCE WHICH SO IGNITES THE MIND."

Cable Guy

JOHN ROEBLING

(1806–1809)
Suspension bridge

The Brooklyn Bridge, which opened in 1883, was the first steel-wire suspension bridge.

The inventor of the modern suspension bridge is best remembered as a brilliant civil engineer. But John Roebling was also a renaissance man who studied under philosopher Georg Hegel, had a deep interest in natural philosophy, and even planned to establish a utopia.

The Prussian-born Roebling discovered his interest in math and engineering early, studied with prominent architects and engineers at the University of Berlin, and became enamored with suspension bridges. After graduation, Roebling took a job building public roads in Westphalia, and he tried to convince his superiors to execute one of his designs, albeit unsuccessfully.

A Youthful Passion

In 1831, Roebling emigrated to America with Carl, his brother, and Johann Adolphus Etzler, an early proponent of renewable resources. The three planned to start a utopian community in rural Pennsylvania, though differences forced the group to split. Instead, John and Carl started an agricultural collective called Saxonburg, in western Pennsylvania. As it turned out, farming didn't suit Roebling, and in 1837, he returned to engineering. He took a position helping to build a network of canals across

to engineering. He took a position helping to build a network of canals across Pennsylvania. As part of the job, Roebling designed a strong wire rope to haul barges that replaced the weak hemp rope of the time, and he received a patent for the invention in 1842. The rope would prove a key element of his suspension bridge designs.

Cables and Piers

In 1845, Roebling completed his first major cabled-bridge project, an aqueduct that spanned the Allegheny River in Pittsburgh. He followed this up with a suspension bridge over the Monongahela River, also in Pittsburgh. As Roebling's fame spread, he was chosen to construct more and more projects. In 1848 it was four suspension aqueducts on the Delaware and Hudson Canal, and in 1851 he was hired to create a bridge spanning the Niagara River near the famous Niagara Falls.

Today, Roebling is practically synonymous with the Brooklyn Bridge, linking the boroughs of Brooklyn and Manhattan over the East River in New York City. This was also the project that took his life. During the first year of construction, 1869, Roebling was directing the positioning of the bridge's towers from a dock. His foot was crushed by an incoming ferry, and the engineer lost his toes. After the amputation, the only medical treatment Roebling allowed was flushing the wound with water. Twenty-four days later he died of tetanus. His son, Washington, oversaw the rest of the construction. The bridge opened in 1883 and remains a landmark of American engineering.

It took 14 years to build the Brooklyn Bridge and cost $375 million in today's money.

A portrait in oil on canvas by Théobald Chartran of Washington Augustus Roebling, who finished his father's creation of the Brooklyn Bridge and went on to build the Golden Gate Bridge in San Francisco

JOHN ROEBLING ONCE DESCRIBED HIS VISION FOR THE 3,460-FOOT-LONG BROOKLYN BRIDGE AS "THE PERFECT

EQUILIBRIUM OF NATURE.”

He Put It Together

HENRY FORD

(1863–1947)

Assembly line/affordable cars

Henry Ford in 1919, a year after he represented Democrats as a peace candidate in Michigan's U.S. Senate race
Henry Ford, the founder and president of the Ford Motor Company, was a man of contradictions. He opposed unions, believing they stifled production to increase employment opportunities. Yet some of his practices were inarguably pro-labor: he doubled the standard daily wage of his employees and was a generous, paternal boss. He was known for his anti-Semitic views, but he was among the first industrialists to hire African Americans, women, and those with disabilities. A pacifist in the early years of World War I, Ford became a leading military supplier.

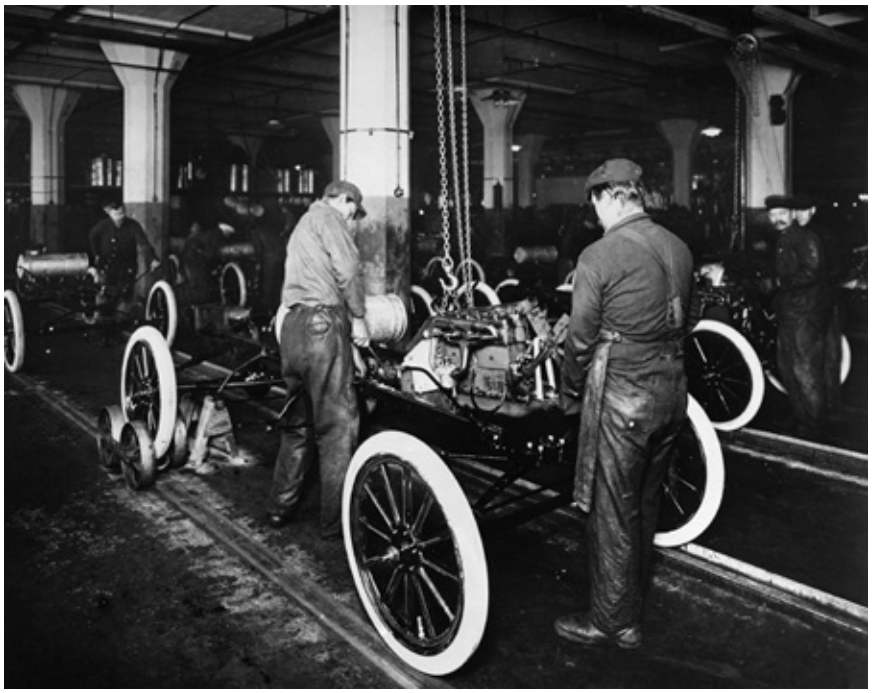
Luxury Models

Growing up in Dearborn, Michigan, Ford was a natural mechanic. By age 13, he already had begun working as a watch repairman, and at 16, he secured an apprenticeship working on steam engines in Detroit. After marrying Clara Bryant, Ford briefly tried his hand at farming, but when that didn't work out, he took a job as an engineer working for Thomas Edison at Edison Illuminating Company of Detroit. Ford rose quickly through the ranks and was named chief engineer in 1893. Here he made his first designs for "horseless carriages," or automobiles, such as the Ford Quadricycle. In 1903 Ford broke away from Edison and formed the Ford Motor Company.

In those early days of the auto industry, manufacturing was complicated because there was no standard engine design, and cars were assembled one at a time by teams. Once a vehicle was done, the team moved on to the next. The time-and labor-consuming process made cars so expensive that only the very wealthy could afford them. One of Ford's earliest models sold for $1,300, or about $36,000 today. But Ford had his sights set on the mass market: there were more middle-class people than rich people, he reasoned, and if he could produce a car that every one could afford, he would get very wealthy. The challenge was how to lower the cost while ensuring quality and reliability.

Legacy of the Line

Ford executive Charles Sorensen and a foreman named Charlie Lewis came up with a solution for their boss by turning the manufacturing process inside out. Instead of creating cars one by one, Sorensen and Lewis adapted a production line where laborers performed a single process, such as attaching bumpers or steering wheels, over and over. By repeating the single task, the workers became quite proficient. The "assembly line" for car production slashed the time it took to make a Model T from 12 hours to six. Prices quickly came down. In 1908, when Ford introduced the Model T, the sticker price was $850; by 1912 it was down to $575; and by 1924, Fords were retailing at $265 apiece. Ford may not have invented the automobile, but for most Americans, he did something even more important: he made it possible to afford one.



The assembly line made it possible for Ford to sell 15 million Model Ts in 1927, half the global car market.

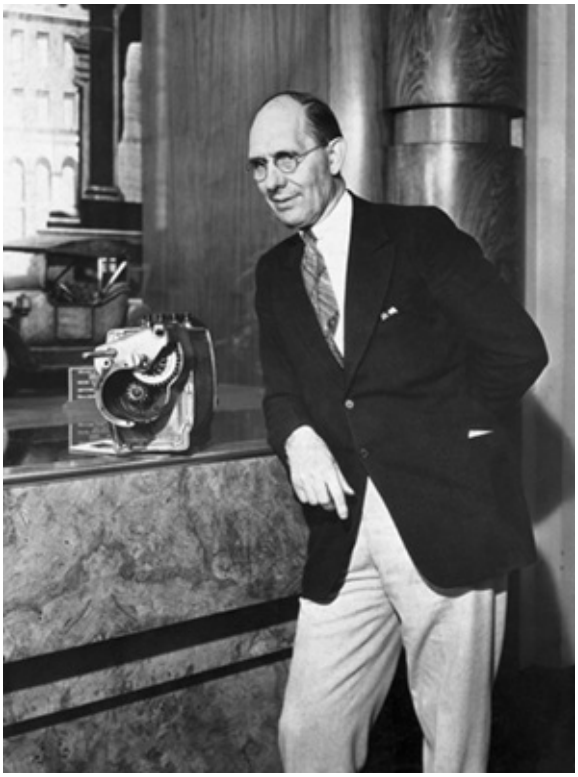
ALTHOUGH TOYOTA HAS SURPASSED FORD AS THE WORLD'S LEADER IN CAR SALES, THE INDUSTRIAL PROCESS FORD CREATED SET THE STANDARD FOR MANUFACTURERS OF ALL TYPES AROUND THE GLOBE.

Crankless Wonder

CHARLES KETTERING

(1876–1958)

Automatic transmission



Charles Kettering was not only a prolific inventor but a witty aphorist as well. “Ninety-nine percent of success is built on failure” and “If you have always done it that way, it is probably wrong” are among his quotes.

It is impossible to pigeonhole inventor, engineer, and businessman Charles Kettering. The technologies Kettering created not only changed the automotive and railroad industries, they also helped advance medicine, aviation, and even cash register design. Among Kettering’s inventions: the automatic transmission, synthetic aviation fuel, artificial fever therapy, a treatment for venereal disease, an incubator for premature infants, an engine-driven generator, quick-drying automotive paint, and shock absorbers.

After earning an engineering degree in 1904, Kettering landed a job as a staff inventor at the National Cash Register Company (NCR). Over the next five years, Kettering developed and patented more than 100 technologies for NCR, including an electrically

operated cash register that not only rung up purchases, but eventually, with the addition of computer chips, could store sales reports. The innovation helped pave the way for NCR to become a leader in the field (today it is one of the largest U.S. manufacturers of cash registers) and propelled Kettering's career in mechanical design.

Kettering soon turned his attention to the nascent automobile industry. At the time, cars had to be started manually with a crank. Turning the crank moved the pistons until the engine built enough momentum to run, but it was also dangerous—the crank could recoil unexpectedly and hit the person operating it. The founder of Cadillac Motor Car, Henry Leland, even had a friend who was killed in such an accident.

A Real Self-Starter

Kettering drew inspiration from his electric cash register. He thought of how a small motor allowed the register drawer to be opened with the push of a button. He designed a motor and other components that would start, light, and ignite the engine as a self-contained system. With another NCR employee, Kettering formed Dayton Engineering Laboratories Company (Delco) in 1909 to manufacture the system. Cadillac itself had attempted to make a self-starter, but Delco's was better. Cadillac tapped Delco's technology for a push-button starter in 1912, placing an initial order for 12,000 units. Soon, electric ignitions were standard equipment in nearly every new U.S. automobile.

Later Career

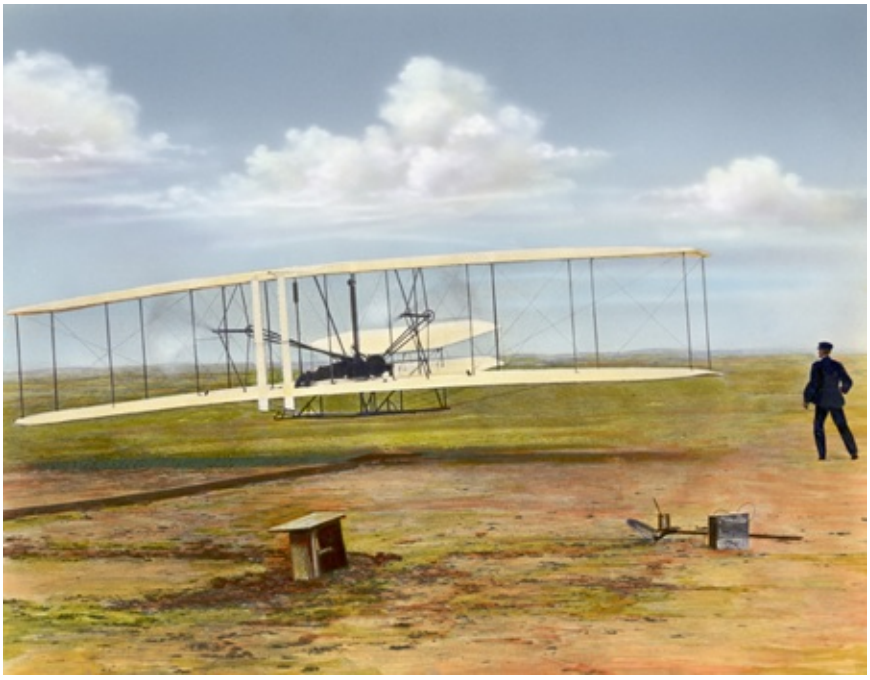
In 1916, Kettering sold Delco to United Motors, a company that soon became General Motors. Kettering was named the head of research and oversaw hundreds of projects until his retirement in 1947. He also explored projects outside of the automotive field, such as a lightweight diesel engine for trains, and Freon, used in refrigeration and air-conditioning. Kettering's home in Dayton, Ohio, was even the first house in the country to be air-conditioned. With his deep roots in Ohio, the town where he and his wife and son lived was named for him in the 1950s. Today Kettering's former home, Ridgeleigh Terrace, is a National Historic Landmark.

Reaching for the Sky

ORVILLE AND WILBUR WRIGHT

(1871–1948)/(1867–1912)

Airplane



This colorized photograph shows the Wrights at Kitty Hawk.

As children in Dayton, Ohio, brothers Orville and Wilbur Wright were fascinated with the idea of flying machines. They devoured books about hot air balloons, gliders, and manned kites. In adulthood, the men opened a bicycle showroom and repair shop, which by the 1890s was successful enough to provide the money and time to pursue their dream of building an airplane.

Wing Warping

To learn the principles of flight, the Wrights studied birds and the way they used their wings to turn and change direction. Applying the concepts to a box kite, the brothers created a system they dubbed "wing warping" that relied on cables to mimic bird motions and to twist the tips of the kite's wings.

During the late 1890s, the Wright brothers tested their idea for a propeller-powered airplane by building six-foot-long box kites with wings and working with unmanned gliders. They eventually moved their base of operations from Ohio to Kitty Hawk,

North Carolina, because they determined the area had ideal wind conditions for flight trials.

Taking Flight

As the Wrights refined their design, they realized that if they stabilized the plane's tail and connected it to the wing-warping cables, they could keep the aircraft aloft for a longer period of time. They hoped to prove their theory with *The Flyer*, a 700-pound machine with wing warping, a rear stabilizer, and a motor-driven propeller.

The Wrights launched *The Flyer* on December 17, 1903, from a downhill track to provide momentum. With Orville Wright at the wheel, *The Flyer* traveled 20 feet above the ground for 12 seconds and covered 120 feet. It was the first manned mechanical flight in history. The plane made three more flights that day; the longest was Wilbur's at 59 seconds and 852 feet.

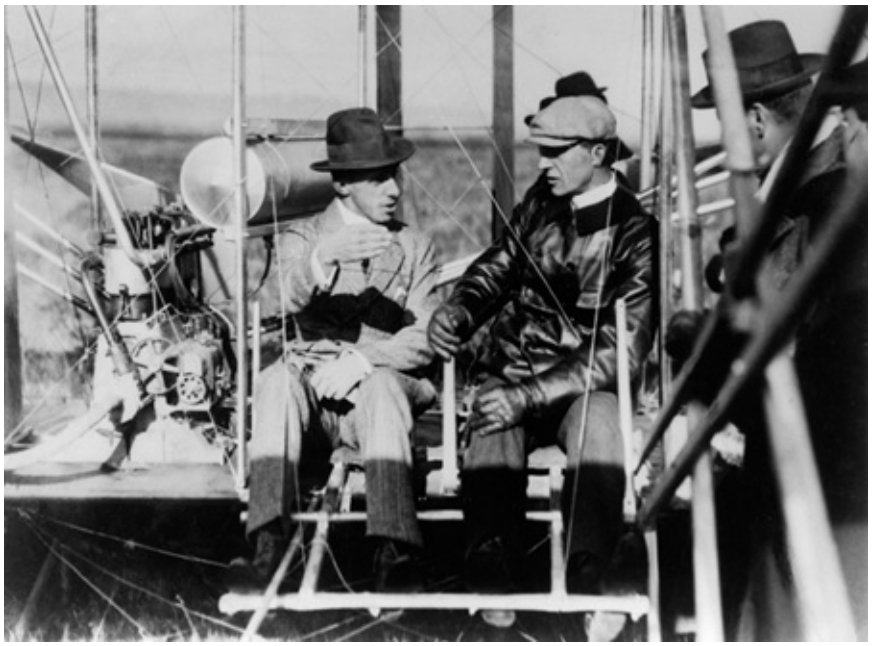
Post-Flight

To further develop their airplane, the Wrights needed funding. Unable to attract investors in the United States, Wilbur traveled to Europe in 1908. He was followed by Orville and younger sister Katharine in 1909, and soon the brothers were fixtures across the continent, demonstrating their flying machine, offering rides to prominent statesmen, and securing contracts to build aircraft. Word crossed the Atlantic, and by the time the Wrights returned to America in 1909, the groundwork was laid for the Wright Company, headquartered in Dayton, Ohio.

Orville, more the right-brained of the two, worked intensively refining designs, while Wilbur, with the savvier business mind, became president. The arrangement was short-lived, however, as the stresses of the day-to-day operations and a flurry of patent fights took their toll on Wilbur. Worn down, he contracted typhoid fever in 1912 and died of the disease a month later, at age 45. Orville carried on as president of the business, which he sold in 1916.

He lived to see the dawn of the jet age he helped inspire. In 1944, he flew a Lockheed Constellation on a test run at Wright Field in Dayton—the powerful propeller plane provided troop transportation in World War II and in Vietnam and was the first model of plane to be "Air Force One."

The Wright brothers' feat earned them international fame. This French magazine, celebrating their flight, was one of countless accolades.



King Alfonso XIII of Spain (left) sits in the cockpit of one of the Wrights' planes with Wilbur.

THE TWO BROTHERS HAD VERY DIFFERENT PERSONALITIES. ORVILLE WAS EXTREMELY SHY WITH STRANGERS, WHILE WILBUR WAS OUTGOING AND GREGARIOUS. WILBUR ALWAYS SPOKE FOR THE TWO IN PUBLIC.

Blazing a Trail

GARRETT MORGAN

(1877–1963)

Gas mask and traffic light

Garrett Morgan, shown in his 40s, made a fortune in hair products.

Garrett Morgan may be best remembered for inventing the gas mask, but an equally impressive accomplishment was convincing the U.S. public that the device would save lives of firefighters and civilians. While touring cities in the 1910s to promote the mask, Morgan, an African American, found audiences were resistant. So he hired a white actor to pose as "the inventor," and he dressed himself as "Big Chief Mason," a Native American character and sidekick. Morgan built a fire using tar, manure, and sulfur inside a tent, then entered the structure wearing the gas mask. He emerged 20 minutes later unharmed. The strategy worked, and sales took off.

Adventuresome Spirit

The son of slaves, Morgan was born in Kentucky and attended school until he was in the fifth grade. He left home as a teenager in the 1890s to seek better opportunities across the Ohio River in Cincinnati. It wasn't easy. Morgan at first survived by working odd jobs, and after moving to Cleveland, he found work as a handyman. Discovering he

had an aptitude for machines, Morgan opened a sewing machine and shoe repair shop in 1907. He got married the next year and began raising a family.

Helping Firemen

Endlessly curious, Morgan found inspiration for new inventions in everyday life. When a needle overheated one day, he tried to make a lubricating liquid to reduce the friction between the needle and cloth. After discovering that the liquid straightened human hair, he formed G. A. Morgan Refining Company to sell the compound. A few years later, considering the risks firemen faced doing their jobs, he came up with the idea for a gas mask. In essence, it was a hood with two tubes—one which went to the ground to suck in cool air and a second tube to provide an escape for exhaust. The tube to the ground used a wet sponge to filter out smoke and cool the air.

The idea was ingenious, but the public was not ready to embrace the ideas of an African American. In 1916, workers in Cleveland while digging a tunnel under Lake Erie encountered a pocket of natural gas, which caused an explosion. Morgan and his brother used the masks to save two workers' lives and recover four bodies. Fire departments from across the country ordered Morgan's safety hood, then canceled when they learned Morgan was black. It wasn't until America entered World War I and the Army bought masks for U.S. soldiers facing chemical warfare that the devices were embraced.

Show Stopper

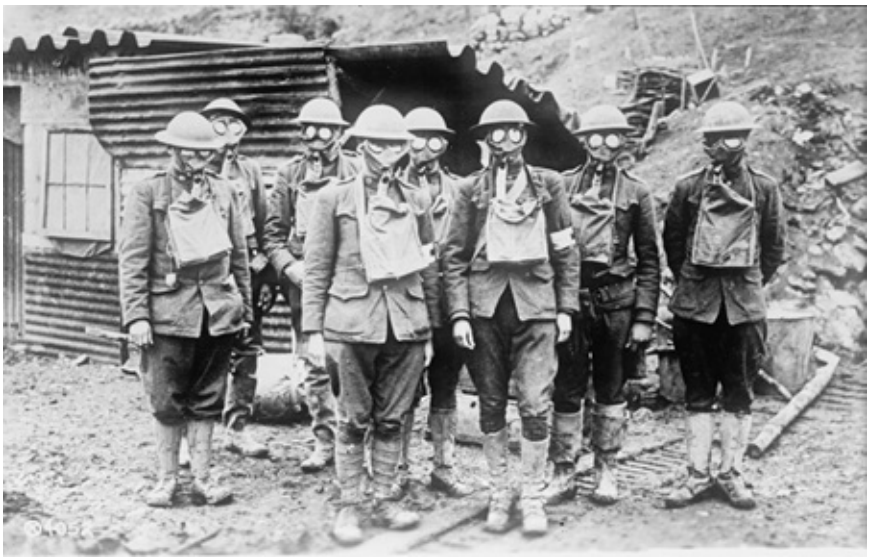
Meanwhile, Cleveland, where Morgan had his shop, was on the move. Pedestrians, street cars, horse-pulled wagons, and automobiles all shared the same narrow streets. A busy downtown intersection inspired Morgan's next big idea. Some of the crossings were outfitted with manually operated traffic signals that switched between just two positions—"stop" and "go."

There was no signal warning drivers, walkers, or horse riders to get out of an intersection before traffic started in the opposite direction. Morgan witnessed a number of accidents before he realized what was needed—a transitional period between stop and go.

In 1923, Morgan received a patent for a three-position traffic signal. The signal pole was electrically rigged and had a transitional light between "stop" and"go" that told drivers to slow down as they approached an intersection . . . or to get out of the way so they didn't block it. Morgan sold the rights to his invention to General Electric for $40,000.

Social Justice

Morgan became one of the wealthiest inventors of the early 20th century and devoted much of his later life to promoting civil rights. He was an early leader in the National Association for the Advancement of Colored People (NAACP) and contributed heavily to African American colleges. When blacks were not allowed to advertise in white newspapers, he started his own, the *Cleveland Call,* to focus specifically on African American concerns. Toward the end of his life he was finally credited for his heroism at Lake Erie, though the city of Cleveland never gave him pension benefits for injuries incurred during the rescue.



The gas masks used in World War I were developed from Morgan's design.

There are more than 300,000 traffic lights in the United States.

MORGAN, WHO LEFT SCHOOL AFTER FIFTH GRADE, USED HIS GREAT WEALTH TO ADVANCE CIVIL RIGHTS AND EDUCATIONAL CAUSES.

Flying High

EL DORADO JONES

(1860–1932)

Airplane muffler

A rare likeness from a 1931 *Modern Mechanics* article

It is one of the engineering world's unlikeliest of connections: with a speech at the 1893 Chicago World's Fair, suffragette Susan B. Anthony helped spur the invention of the airplane muffler.

In the audience that day was a former school teacher and insurance saleswoman, 33-year-old El Dorado Jones of Moline, Illinois. Inspired by Anthony's words, Jones began to realize her life could take a different path and that there was money to be made creating and patenting products that other people sold. She decided to become an inventor and found she had a knack for it.

Café Inspiration

Over the next 20 years, Jones patented a moisture-blocking saltshaker, a travel iron, a compact ironing board, and many more gadgets. In 1913 she opened a factory in Moline, Illinois, to make her inventions, hiring only women over the age of 40—a group she felt was ignored and exploited.

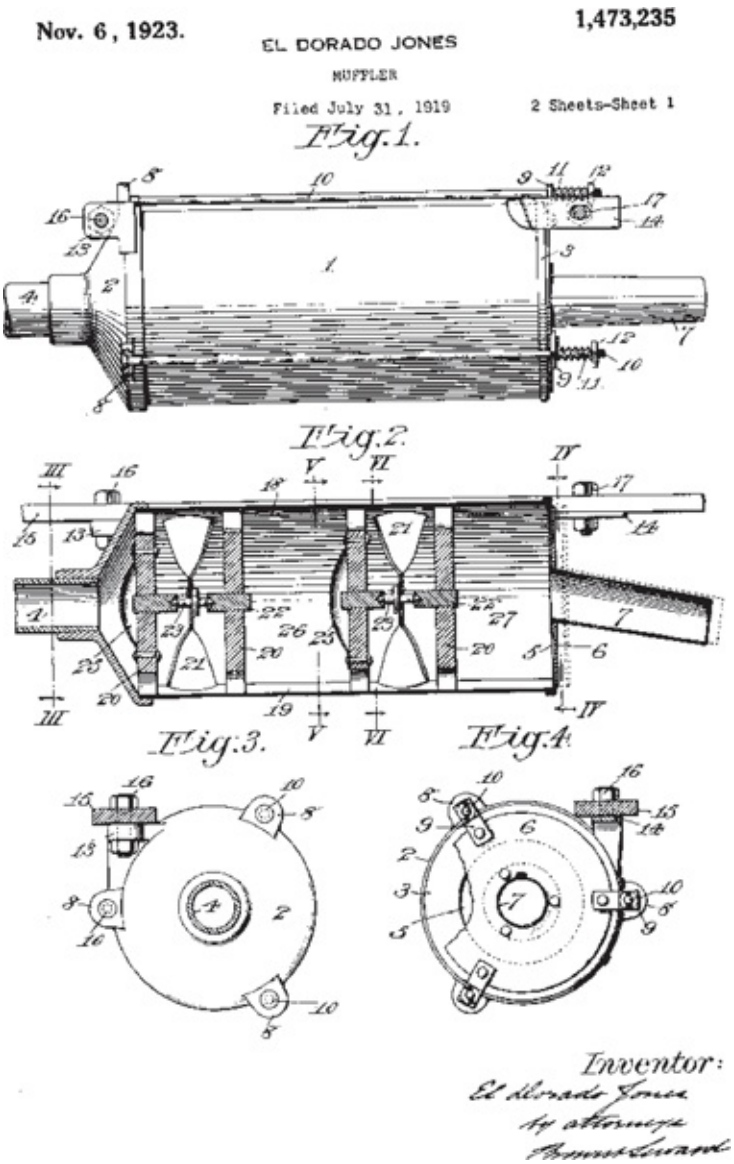
Her most memorable creation, however, was due to some perfectly timed eavesdropping. Sitting in a café in 1919, Jones overheard two men discussing the mass-

market potential for air travel—if only there were a way to make planes quieter. At the time, a commercial flight amounted to a chartered propeller plane flight today: it was expensive; the plane was tiny, seating only one or two people; and it was very loud. Jones resolved to find a solution, and by 1923, she had not only come up with a muffler design, she had patented it.

Fiercely Independent

But Jones's distrust of men worked against her. If an airline or financial institution sent a male representative, she would refuse to meet. She temporarily shelved the project, then tried to revive it in 1930, paying to have the muffler tested on a biplane outside New York City. What little capital she once had dwindled away; in 1932, she was living on public support in a dingy apartment in the East 30s. When a friend called on her for dinner, she discovered that Jones had died the night before. The inventor still had not sold the airplane muffler, and few realized her contribution to the industry. In reporting her death, the *New York Times* referred to her "success in several walks of life," but noted that she had failed altogether in recruiting investors to her airplane muffler invention.

The American Women's Association in New York City had to arrange Jones's funeral. The industry adopted her silencing invention within a decade of her death, and 21st-century muffler patents still cite her work of almost 100 years ago.

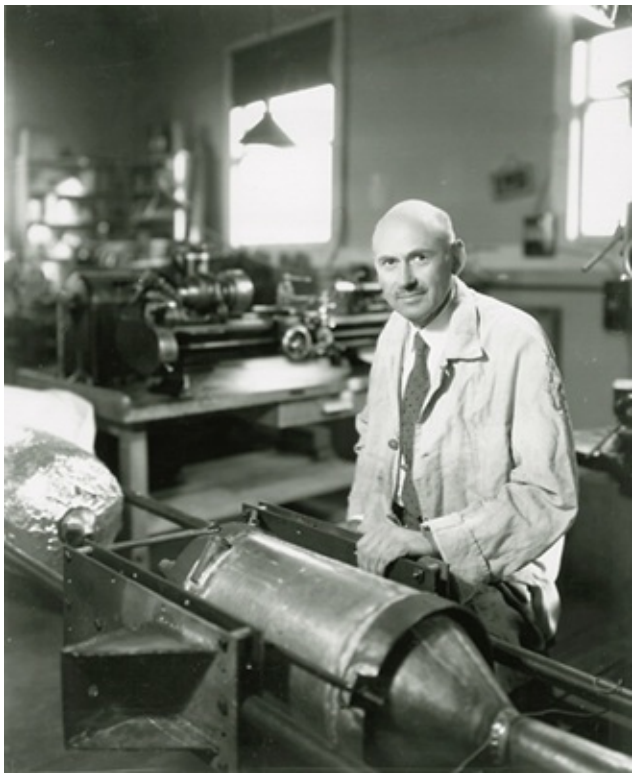


The patent art for El Dorado Jones's muffler, which used a series of blades like little pinwheels to breakup sound waves Shooting for the Moon

ROBERT GODDARD

(1882–1945)

Liquid-fueled rocket



Nine years after his first successful launch, Goddard made a rocket faster than sound.

Growing up in Massachusetts, Robert Goddard loved reading works of science fiction, such as *From the Earth to the Moon* by Jules Verne, in which three men traveled to outer space in a capsule shot from a cannon. The boyhood pastime would inform the rest of Goddard's life, steering him to a career as an engineer, inventor, physicist, and leading rocket scientist.

Early Efforts

In 1904, Goddard enrolled in Worcester Polytechnic Institute (WPI), created after the Civil War to train entrepreneurial scientists and engineers for the rigors of the new industrial age. Goddard was very popular, voted "Brightest Student" in a poll by the yearbook, which he edited, served in student government, and sang in the glee club. He also began his life's work, experimenting with crude rockets that used gunpowder as a propellant. In one failed attempt, he even tried to fire a rocket from the basement of WPI's physics building. It was clear to the young student that gunpowder, which only converted 2 percent of available energy into motion, had major drawbacks, but he also was sure that once he discovered the right fuel, rockets could reach the moon or beyond.

Just the Right Distance

Throughout the 1910s and 1920s, as Goddard developed designs for rockets and theoretical calculations for their flight, he concentrated on solving the fuel problem. By

1926, Goddard had calculated that a combination of gasoline and liquid oxygen would work best because the oxygen would help the gasoline burn in the combustion chamber. The challenge was striking the right temperature: for the fuel to ignite, the liquid oxygen had to be heated to extremely high temperatures but not so hot as to interrupt the combustion. Goddard's solution was a rocket with an oxygen tank that was close—but not too close—to the combustion chamber. The completed projectile was 7 feet tall and weighed 10 pounds. On March 16, 1926, Goddard launched it in Auburn, Massachusetts. The rocket shot 41 feet in the air, then crashed—but it worked.

Man on the Moon

Funded by benefactors such as the Guggenheim family and aviation pioneer Charles Lindbergh, Goddard committed the rest of his life to rocketry. He relocated to Roswell, New Mexico, in the 1930s, and in the flat, desolate desert landscape launched 31 rockets in 15 years. Eventually Goddard's missiles reached heights of a mile and a half and speeds faster than sound. His designs provided a road map for engineers who created the propulsion system to power Saturn V, NASA's rocket that propelled the Apollo missions. He was right: with just the right fuel—liquid fuel of his own invention—man could reach the moon. His advances netted him more than 200 patents.

On the Safe Side

SAMUEL ALDERSON

(1914–2005)

Crash test dummy

Alderson was posthumously inducted into the National Inventors Hall of Fame in 2013.

With Samuel Alderson's résumé, it was only natural he would steer the design of crash test dummies. As a young man, Alderson logged many hours in his Romanian immigrant father's sheet-metal shop. He went on to study with one of the creators of the atomic bomb, Robert J. Oppenheimer, and worked with missile-guidance technology during World War II. After the war, he spent time at IBM developing a prosthetic limb in the mid-1940s.

Sierra Sam

Post-war, the aeronautics and automobile industries used some unorthodox ways to test the effects of acceleration and deceleration on the body. In some cases, brave individuals volunteered to be strapped into rocket sleds; in others, inventors would use human cadavers to test car prototypes; even living animals like pigs would be belted into vehicles. While these methods saved hundreds of lives, it was difficult to collect reliable data with so many different body types.

Alderson went to work with Sierra Engineering in 1949 to provide better simulacra for data collection. Sierra created the first version of the crash test dummy for the U.S.

Air Force. Using rocket sleds to simulate a 600-mile-per-hour flight, Sierra scientists "piloted" the sleds with the doll they dubbed "Sierra Sam." It matched the height and weight of an adult male in the 95th percentile—if a taller, heavier man could withstand the seat, they figured, then anybody could. Soon Alderson founded his own engineering firm, Alderson Research Laboratories, based in New York, and in 1952 contracted with the Air Force to design a dummy to test the crash impact of aircraft ejection seats. Alderson kept busy with aviation work, but it would be another decade before the crash dummies would be embraced by the car industry.

Next Generation

It was consumer advocate Ralph Nader's 1965 book, *Unsafe at Any Speed*—on the failure of the auto industry to introduce certain safety measures—that provided the impetus. Prompted by waves of consumer anger, the U.S. National Highway Traffic Safety Administration began to search for better ways of testing automobiles. The auto industry took notice of Alderson's work, and ARL won contracts with GM and Ford to make dummies to test the impact of car accidents. As the decade drew to a close, ARL and Sierra became intense competitors. Alderson introduced the V.I.P., a dummy with a steel rib cage and flexible joints and neck. It closely resembled an average man's weight distribution and response to acceleration. Sierra countered with their version, the "Sierra Stan." GM parlayed with both companies, and its engineers standardized the best elements of both designs into the Hybrid I dummy. Modifications resulted in the Hybrid II and III. The Hybrid III is today's industry standard. It provides engineers valuable, realistic data about what happens during a car crash, leading to ways to build safer cars with crumple zones, seatbelts, and airbags.

Alderson's career in prosthetics and simulated bodies included "medical phantoms"—mixed creations of flesh and synthetics used for medical and space research. Alderson continued his work on dummies for the health care field until months before he died in 2005. A son, who grew up with skeletons and mock body parts around his childhood home, recalled his father's assessment of his livelihood: "It's an oddball business."

Crash test dummies are the standard for testing automobile safety.

EXPERTS ESTIMATE THAT MORE THAN 300,000 LIVES HAVE BEEN SAVED BY AUTOMOBILE SAFETY FEATURES PERFECTED WITH CRASH TEST DUMMIES.

Rocket Man

ELON MUSK

(b. 1971)
SpaceX/Tesla Motors

Elon Musk founded Tesla Motors in 2003.

When director Jon Favreau wanted to inspire *Iron Man* lead actor Robert Downey Jr., he sent him to spend 10 days with an inventor who has pushed more boundaries than the eccentric Tony Stark. Entrepreneur Elon Musk is known for his pioneering work in space travel, electric cars, solar power, and other high-tech industries that are changing the ways humans interact with the earth—and perhaps even other planets, too.

Paying It Forward

Musk was born in 1971 in Pretoria, South Africa. He was a computer prodigy and designed his first computer game at age 12. He left South Africa for Canada at age 17,

then relocated to the United States to attend the University of Pennsylvania and earned two bachelor's degrees. Musk entered a PhD program at Stanford University but left after two days to pursue his own projects. The first of these was a company called Zip2, an early incarnation of Internet directory sites that provided information on businesses. After selling Zip2, Musk self-financed an online banking site called X.com. One of its most popular features was a money-transfer service that allowed people to send payments online. Musk's company merged with another called Confinity to create PayPal.

Into the Stratosphere

But that was just the beginning. In 2002, also the year he became a U.S. citizen, Musk founded SpaceX, an exploration company aiming to make space travel affordable—and ultimately to create a "space faring civilization" with people inhabiting Mars. While SpaceX's first three attempts to launch rockets failed, it succeeded on its fourth, and the result was a $1.6 billion contract from NASA for the launching of 12 rockets to the International Space Station. In 2004, Musk focused on more terrestrial concerns when he started Tesla Motors to produce affordable, electric cars to decrease the auto industry's reliance on fossil fuels. Tesla vehicles have earned record-high safety and consumer ratings. The company's announcement of the M3 mid-priced model in April 2016 was met with 100,000 preorders, a $14 billion commitment from future buyers. Tesla, named for the eccentric engineer Nikola Tesla, is currently building more lithium ion batteries and increasing the number of "supercharger stations" across North America. Musk also works with his solar energy company, Solar City, to develop solar power systems throughout the United States and oversees research and development of Hyperloop, a high-speed transit system.

Musk became a multimillionaire in his late 20s during the Internet boom.


SpaceX was the first private company to send a spacecraft to the International Space Station.

ELON MUSK HAS BEEN CALLED "THE REAL LIFE IRON MAN" FOR HIS PIONEERING EFFORTS IN SPACE TRAVEL, ELECTRIC CARS, SOLAR POWER, AND OTHER HIGH-TECH VENTURES.

One of a Kind

It is the Age of Jobs. Music. Computing. Phones. Even personal expression itself seems to occur in a world that Steve Jobs fairly dragged into being.

It is not the supremacy of devices he engendered; it is more the ethos that aesthetics matter. Jobs brought design to the cultural center. He also talked a lot about it—and consumers who made his company intermittently the largest in the world were persuaded that outward beauty may sometimes reflect inner harmony.

PICTURE CREDITS

Front cover: Nathan Lazarnick/George Eastman House/Getty Images, Bernard Gotfryd/Getty Images, Archive Photos/Getty Images, Getty Images; Title page: Bettmann/Getty Images; 2: Dan Tuffs/Getty Images; 4–5: Easy_Company/istockphot.com; 6: (left) Mary Evans Picture Library, (lower right) Popular Science via Getty Images; 7: (left) Northwind Picture Archives, (right) Library of Congress; 8: Everett-Art/Shutterstock; 9: Science Source; 10: (top) Bettmann/Getty Images, (bottom) Hulton Archive/Getty Images; 11: (top) Library of Congress, (bottom) jaroslava V/Shutterstock; 12: (left) Mondadori Portfolio via Getty Images, (right) Science Source; 13: Stefano Bianchetti/Corbis via Getty Images; 14: science photo/Shutterstock; 15: AP Photo; 16: (top) IBM, (bottom) Juergen Faelchle/Shutterstock; 17: Library of Congress; 18: Pavel L Photo and Video/Shutterstock; 19: CSU Archives/Courtesy Everett Collection; 20: AP Photo/The News Journal, Jennifer Corbett; 21: (top) Jim West/Alamy Stock Photo, (bottom) Lee Balterman/The LIFE Picture Collection/Getty Images; 22: 3D Systems Inc.; 23: Bilgin S. Sasmaz/Anadolu Agency/Getty Images; 24–25: Andrey Armyagov/Shutterstock; 26: Library of Congress; 27: (left) Library of Congress, (right top) robynt/Dollar Photo Club, (lower) Library of Congress; 28: (top) Granger, NYC, (bottom) SSPL/Getty Images; 29: Keystone-France/Gamma-Keystone via Getty Images; 30: (top) simonekesh/Dollar Photo Club, (bottom) Juulijs/Dollar Photo Club; 31: (left) Granger, NYC, (right) Everett Historical/Shutterstock; 32: (top) Granger, NYC, (bottom) Granger, NYC; 33: Fox Photos/Getty Images; 34: Everett Collection Historical/Alamy Stock Photo; 35: Denison University; 36: (left) Stars and Stripes, (right) Pcbang/Shutterstock; 37: (top) Stephanie Cartier/NWS&T magazine, (bottom) AndreyTTL/istockphotos.com; 38: AP Photo/Steven Senne; 39: (top) Lionel Alvergnas/Shutterstock, (bottom) Wikipedia; 40: Ed Uthman/Wikipedia; 41: AP Photo/Atlanta Journal & Constitution, William Berry; 42: Corbis/Getty; 43: Gregg Segal; 43: http://stv.re/oculus-street-view-vr-js; 44–45: H. Armstrong Roberts/ClassicStock/Getty Images; 46: Hulton Archive/Getty Images; 47: GraphicaArtis/Getty Images; 48: (top) Collection of the New-York Historical Society, USA Bridgeman Images, (bottom) Alex WongGetty Images; 49: (left) H. Armstrong Roberts/Retrofile/Getty Images, (right) Granger, NYC, (left) Wikiwand; 50: (right) Universal History Archive/UIG via Getty Images; 51: (left) Prismatic Pictures/Bridgeman Images, (middle) chrisboy2004/istockphoto, (bottom)

Northwind Picture Archives; 52: Bettmann/Getty Images; 53: (top) The John Deakin Archive/Getty Images, (bottom) AP Photo/Bob Wands; 54: (left) Lloyd Copeman.com, (right) Lynden Pioneer Museum/Alamy Stock Photo; 55: http://www.reminisce.com/1930s/waring-blender-mixes-up-75-years-of-memories; 56: Bettmann/Getty Images; 57: Andrew Pini/Getty images; 58: (top) Michael Ochs Archives/Getty Images, (bottom) johnnyraff/Shutterstock; 59: Evelyn Floret/The LIFE Images Collection/Getty Images; 60: Edward Lowe Foundation; 61: (top) Karsten Lemm/picture-alliance/dpa/AP Images, (bottom) Stephen Krow/istockphoto; 62–63: Apic/Getty Images; 64: (top) ullstein bild/ullstein bild via Getty Images, (lower left) Time Life Pictures/Mansell/The LIFE Picture Collection/Getty Images, (lower right) Bettmann/Getty Images; 65: (left) Granger, NYC, (right) Science Source; 66: Science Source; 67: (top) BSIP SA/Alamy Stock Photo, (bottom) AP Photo; 68: Bettmann/Getty Images; 69: Archive Photos/Getty Images; 70: AP Photo/Vincent Michel; 71: (top) Bettmann/Getty Images, (bottom) sfam_photo/Shutterstock; 72: areeya_ann/Shutterstock; 73: (top left) Jim West/Alamy Stock Photo, (middle) AP Photo, (right) Keystone-France/Gamma-Keystone via Getty Images; 74: University of Chicago; 75: (top) VA.gov, (bottom) Will & Deni McIntyre/Science Source; 76: (left) wenht/istockphoto, (right) Neville Elder/Corbis via Getty Images; 77: (left) Courtesy of Conrad Wong, (right) AP Photo/Damian Dovarganes; 78–79: Bridgeman Images; 80: (left) Library of Congress, (right) Tarker/Bridgeman Images; 81: Wikipedia; 82: (left) Library of Congress, (right) The Advertising Archives; 83: Goodyear; 84: (top) Library of Congress, (bottom) Library of Congress; 85: Brooklyn Museum of Art, New York, USA/Bridgeman Images; 86: (left) Granger, NYC, (right) Library of Congress; 87: Bettmann/Getty Images; 88: (top) Bettmann/Getty Images, (bottom) Popperfoto/Getty Images); 89: Philipp Kester/ullstein bild via Getty Images; 90: (top left) Science Source, (top right) Library of Congress, (bottom) jules/Dollar Photo Club; 91: (top) USPTO (bottom) https://eldoradojones.wordpress.com/; 92: Library of Congress; 93: (top) http://afflictor.com/wp-content/uploads/2014/12/ctd55-e1419371605268.png, (inset) Graphic Compressor/Shutterstock; 94: (left) SpaceX, (right) Hadrian/Shutterstock, 95: Ben Cooper/Getty Images; 96, AP Photo;

Publisher Margot Schupf
Associate Publisher Allison Devlin **Vice President, Finance** Terri Lombardi **Vice President, Marketing** Jeremy Biloon **Executive Director, Marketing Services** Carol Pittard **Director, Brand Marketing** Jean Kennedy **Finance Director** Kevin Harrington **Sales Director** Christi Crowley
Assistant General Counsel Andrew Goldberg **Assistant Director, Production** Susan Chodakiewicz **Senior Manager, Category Marketing** Bryan Christian **Brand Manager** Katherine Barnet
Associate Prepress Manager Alex Voznesenskiy **Assistant Project Manager & Production** Lauren Moriarty **Editorial Director** Kostya Kennedy **Creative Director** Gary Stewart
Director of Photography Christina Lieberman **Editorial Operations Director** Jamie Roth Major **Senior Editor** Alyssa Smith
Project Editor Eileen Daspin
Assistant Art Director Anne-Michelle Gallero **Copy Chief** Rina Bander
Assistant Managing Editor Gina Scauzillo **Assistant Editor** Courtney Mifsud
Special thanks: Brad Beatson, Nicole Fisher, Kristina Jutzi, Seniqua Koger, Kate Roncinske

Published by Time Inc. Books

225 Liberty Street

New York, NY 10281

eISBN: 978-1-68330-294-0

We welcome your comments and suggestions about Time Inc. Books. Please write to us at: Time Inc. Books, Attention: Book Editors, P.O. Box 62310, Tampa, FL 33662-2310

If you would like to order any of our hardcover Collector's Edition books, please call us

at 800-327-6388, Monday through Friday, 7 a.m.—9 p.m. Central Time.

Produced by Print Matters, Inc.
Project Director Richard Rothschild **Project Editorial Director** David Andrews
Writers Brian Boone, Michael Centore, Michael Cramer, Katharine Greider, Don Rauf **Photo Researcher** Jane Martin, The Photo Editor, Inc.
Designer Matthew Riley Cokeley, MRCokeley Design, LLC.
Copy Editor Laura Daly
Expert Reviewer Stephen M. Tomecek, Science Plus, Inc.