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THE **FIRST** OF **EVERYTHING**

A Compendium of
Important, Eventful, and Just-Plain-Fun Facts
About All Kinds of Firsts

DENNIS SANDERS

Research coordinated by
LEONARD LOVALLO

DELACORTE PRESS/NEW YORK

SINGING IN THE SHOWER: Firsts Found in the Smallest Room of Your House



Acetylsalicylic acid was produced for the first time in 1899 by German chemists Felix Hoffman and Hermann Dreser, who manufactured the pain killer and fever reducer from coal tar. In 1905, aspirin was marketed for the first time by Bayer Aspirin, and soon became the largest selling over-the-counter, nonprescription drug in the world.

KLEENEX

The Kimberly-Clark Company manufactured the world's first disposable handkerchief in 1924 under the name Celluwipes. The product was later renamed Kleenex 'Kerchiefs, and eventually shortened to Kleenex.

THE FLUSH TOILET

English poet John Harrington invented a practical flushing water closet in 1595, but the device made no inroads against the common chamber pot. In 1775 Alexander Cummings, an English inventor, received the first patent for a flush toilet, and in 1778 Joseph Brahma, age thirty, invented the valve and syphon-type flushing

EVERYDAY FIRSTS

mechanism which became the model for all future toilets. However, the chamber pot remained firmly entrenched until the end of the nineteenth century, when the rich began discovering the joys of indoor bathroom plumbing.

THE TOOTHBRUSH

The toothbrush is said to have been invented in China in 1498, though they didn't become commonplace in Europe until the seventeenth century. The first nylon bristle brush was marketed in the United States in 1938 as Dr. West's Miracle Tuft Toothbrush. The bristles were made of Du Pont nylon. Squibb manufactured the first electric toothbrush in 1961.

BAND-AIDS

Johnson & Johnson of New Brunswick, New Jersey, introduced the Band-Aid—essentially unchanged today—in 1920.

ALKA-SELTZER

In 1931 Miles Laboratories of Elkhart, Indiana, introduced a tablet (containing sodium bicarbonate, monocalcium phosphate, aspirin, and citric acid), which fizzled in water. The product, Alka-Seltzer, would sell in excess of 2.5 billion tablets a year by the 1970's.

MERTHIOLATE

Eli Lilly Company introduced tincture of Merthiolate for cuts and scratches in 1930, though the product was not successful until Lilly added dye to make it stain the skin and alcohol to make it sting.

THE SAFETY RAZOR

King Camp Gillette patented the safety razor in 1901, and started his Gillette Safety Razor Company in Boston the same year. The new

DENNIS SANDERS

razors went on sale in 1903, when a grand total of 51 razors and 168 blades were sold.

MOUTHWASH

The Lambert Pharmaceutical Company of St. Louis introduced Listerine (named after Dr. Joseph Lister, discoverer of antiseptic surgical procedures) in 1880. However, the "it-kills-germs-by-the-millions-on-contact" slogan wouldn't make Listerine a household word until a massive marketing and advertising campaign was started in 1922.

KOTEX

During World War I, German-American chemist Ernst Mahler, thirty-one, developed a wood-cellulose substitute for cotton, called cellucotton, which helped alleviate a critical shortage of bandages when introduced in 1918. The Kimberly-Clark Company of Neenah, Wisconsin, which manufactured cellucotton bandages, learned that Red Cross nurses at military hospitals were using the bandages as sanitary napkins, and decided they were onto a good thing. In 1921 they introduced their modified cellucotton bandage as the world's first commercial sanitary napkin under the name "Kotex."

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WHAT'S COOKING?

Kitcheny Firsts

GAS STOVE

James Sharp, a gas company executive in Northampton, England, designed and built the first practical gas stove for his own kitchen in 1826, and started manufacturing the stoves commercially in 1836.

ELECTRIC OVEN

The first known electric oven was installed by an unknown inventor in a Swiss hotel in 1889, and by 1891 the Carpenter Electric Heating Manufacturing Company of St. Paul, Minnesota, offered the first electric ovens for sale. However, during the "gaslight" era, electricity was an expensive power source, and electric ovens and stoves did not become popular with the public until the cheap electricity era of the 1930's.

POP-UP TOASTER

Charles Strite, an American inventor, patented the first pop-up electric toaster in 1918; the famous Toastmaster was first marketed by the Elgin Illinois Company of McGraw Electric in 1930.

REFRIGERATOR

The first commercial home refrigerator was the Domelre, manufactured in Chicago in 1913, which retailed for a costly nine hundred dollars. The first Kelvinator was made in 1918, and the first Frigidaire in 1919. Early refrigeration was not a runaway success with homemakers, and annual sales didn't exceed ten thousand units until 1920. General Electric's famous "monitor" top refrigerator (the first with a hermetically sealed compressor) went on the market in 1927 and soon became the most successful model sold.

BLENDER

The blender was invented by Fred Waring, well-known band leader of the thirties and forties, in 1936, and revolutionized food preparation and bartending.

DISHWASHER

Invented by Mrs. W. A. Cochran, a Shelbyville, Indiana, housewife, 1879-89.

WASHING MACHINE

The Hurley Machine Company of Chicago introduced the "Thor"—the first self-contained electric clothes washer—in 1907.

MICROWAVE OVEN

Microwave cooking was accidentally discovered by Percy Le Baron Spencer of the Raytheon Company, who found that microwave signals melted a candy bar in his pocket; Raytheon developed Spencer's discovery into a commercial microwave oven which they marketed in 1947. The first compact microwave oven was introduced by Amana in 1967.

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EVERYDAY FIRSTS

ALUMINUM SAUCEPAN

Henry Avery of Cleveland produced the first aluminum saucepan in 1890, which Mrs. Avery used until 1933.

TEFLON

Roy J. Plunkett, a Du Pont chemist, discovered polytetrafluoroethylene, or Teflon, by accident in 1938, and the nonstick surface was soon being used for cooking utensils as well as industrial wiring.

TUPPERWARE

Earl W. Tupper, a former Du Pont chemist, started his own company to manufacture airtight plastic kitchen storage bowls and boxes in 1945.

TIN CANS

The tin can was patented in 1810 by Peter Duran of England, but the handmade cans were expensive (one tinsmith could cut, mold, and solder only about sixty cans a day); machine-stamped cans were introduced in 1847. In 1865 tins were made of thinner steel, allowing the first can opener to be made—prior to that, tin cans had been opened with a hammer and chisel.

ALUMINUM AND TAB-TOP CANS

American manufacturers introduced aluminum cans for soft drinks in 1960; the tab-top can, sponsored by Alcoa, was tested in Pittsburgh in 1962, and introduced on Schlitz beer nationally in February, 1963. By 1970, 90 percent of all beer was being sold in tab-top cans.

BETTER MOUSETRAPS:

Revolutionary Inventions and Discoveries

THE TELESCOPE

Man's concept of the universe was revolutionized in 1609 when Galileo Galilei (1564–1642), Italian astronomer, built the first refracting telescope, after having heard a description of a “magnifying tube” invented by a Dutch spectacle maker, Hans Lippershey, in 1608. The first reflecting telescope, which focuses the image on a mirror, rather than passing it through lenses directly to the viewer, was built in 1672 by Sir Isaac Newton (1642–1727).

THE MICROSCOPE

The man generally credited with inventing the microscope is Zacharias Janssen, a Dutch spectacle maker who discovered compound, or multiple lens magnification, ca. 1590.

Italian astronomer Galileo Galilei also claimed to have invented the microscope in 1610. *His* microscope was developed as an outgrowth of his telescope experiments (both instruments use compound lenses), and it's not known if the Italian knew of Janssen's invention. However, there may have been an indirect connection with Janssen's and Galileo's microscopes by way of the “magnifying tube” built in 1608 by Dutchman Hans Lippershey. Galileo did know of the Lippershey tube, and Lippershey and Janssen, being

countrymen, contemporaries, and spectacle makers, may well have been aware of each other's work.

THE LOOM

The simplest loom is not much more than a frame used to hold threads while being woven together, and it's been in use since about 4400 B.C. The automatic fly shuttle, which greatly speeded up the weaving process, was invented in 1733 by John Kay of England, and in 1785 Edmund Cartwright patented the first practical power loom. The first Jacquard loom was perfected in 1804; the Jacquard process, which makes use of punched paper patterns which are "read" by the loom to automatically weave complicated designs, had far-reaching implications for the eventual development of the computer punch card.

THE COTTON GIN

Eli Whitney (1765-1825), a twenty-seven-year-old Yale graduate, invented the cotton gin in 1792 while visiting Mulberry Grove Plantation on the Savannah River, Georgia. Whitney had noticed the difficulty with which seeds were separated from short-staple cotton bolls, and built a simple turning cylinder device with saw teeth made from bird cage wire which caught the seeds as the cotton fibers were pulled through by the rotating teeth. The Whitney device enabled one slave laborer to clean as much as fifty pounds of cotton a day, as opposed to the one pound which had been average with manual cleaning. In the decade after Whitney's gin was invented the agricultural economy of the United States had radically changed, with the 140,000 pounds of cotton produced in 1792 increasing to a staggering 35 million pounds by 1800.

THE STEAM ENGINE

The first crude steam engine was invented in 1698 by Thomas Savery, an English engineer. Called the "miner's friend," it was used to pump water from coal mines. In 1705 Thomas Newcomen, an English blacksmith, built the first steam engine with a piston driven by

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INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

condensed steam. James Watt of Scotland, usually credited with the "invention" of the steam engine, built his famous machine in 1765. Watt's steam engine greatly improved the efficiency of the Newcomen model by adding a condenser chamber.

THE SEWING MACHINE

The first sewing machine was built in 1829 by Barthelemy Thimmonier, a tailor in the town of Amplepuis in the Rhone district of France. Though built for his own use, Thimmonier received an order for eighty of his machines from a Paris uniform factory two years later, and the inventor himself was hired by the company. Unfortunately, the other employees felt their livelihood was threatened by the mechanization of hand sewing, and an "anti-sewing-machine mob" destroyed all but one of the machines, which was saved by Thimmonier. In 1845 the ill-starred Thimmonier got backing from a businessman, went into production, and once again had his sewing machines destroyed by an angry mob. The French sewing-machine business somehow never seemed to get off the ground.

The first sewing machine built for home use was the famous Singer model, invented by Isaac Singer in 1850 and patented and manufactured in 1851 at a Boston factory. Later Singer had to pay royalties to Elias Howe of Spencer, Massachusetts, who had patented his own machine in 1846, which was used by tailors in the United States and Britain. But the Singer model went on to become the first common labor-saving machine in the average American household.

THE ELEVATOR

Pulley-and-weight mechanisms have been in use for a long time for lifting freight and sometimes people (Louis XV had a "lift" to carry him upstairs from his suite at Versailles to that of his mistress, in 1743). But the revolution in the urban landscape wrought by the elevator began in 1852 in Yonkers, New York, where Elisha Graves Otis, then aged forty-one, invented the safety elevator, which had teeth and ratchets to prevent the platform from falling should the rope break. Otis himself dramatically demonstrated this in 1853 at the Crystal Palace exhibition when, before a dubious crowd, he had himself hoisted above the floor, then deliberately cut the ropes. The

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audience gasped and screamed, but Otis's gears held, and the proud inventor stepped safely to the ground, taking a bow.

The Otis elevator was soon in production. The first to be installed in a hotel went to the Fifth Avenue Hotel, New York, in 1859; the first in a commercial business went into the famous cast iron Hagwout Department Store at Broadway and Broome Street (still standing) in 1857. The Hagwout elevator was the first to have a completely enclosed passenger car.

BESSEMER STEEL CONVERTER

In 1856 Henry Bessemer, a British engineer, patented his converter, which made the production of high quality, low-cost steel possible by decarbonizing pig iron with a blast of cold air. The Bessemer process would make steel widely available for construction; cheap steel, when combined with the Otis elevator, would father the modern skyscraper.

THE PHOTO CAMERA

In the eighteenth century scientists discovered that silver salts darkened under light; in 1802 Thomas Wedgwood, the physician son of the famous potter, Josiah, took the world's first photograph when he spread moist silver nitrate on a piece of paper, then projected an image onto the sheet. The image "took," but Wedgwood had no way to fix the "image" and it soon faded. The first permanent photo was made in 1822, when J. N. Niepce and his seventeen-year-old cousin, Claude, discovered a method of producing fixed images on glass treated with bitumen.

Though cameras had been commercially available since 1839 when the french firm of Alphonse Giroux offered a large box camera for sale for four hundred francs, photography remained largely in the hands of professionals until 1895 when the first pocket camera developed by George Eastman was introduced by the Eastman Kodak Company of Rochester, New York. The even more successful Brownie camera was introduced in 1900, at a price of one dollar, putting photography in the grasp of amateurs for the first time.

The first color photograph was made in 1861 by Scotch physicist James Maxwell, who developed a technique of taking black-and-

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INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

white photos through three color filters, then projecting them on a screen through the same filters (red, blue, and green) to give a color image. This early experiment in the three-color process didn't give a final color print—only a "slide projection." In 1868, however, Louis Ducos de Hauron of France made the first true color photographic print—of his home village of Agen—by taking the three-color separation process of Maxwell and devising a method of transferring the three screens to one print in three dye steps.

Color photography remained complicated and difficult (though some of the early images that have survived are quite beautiful), and it wasn't until 1935 with the development of the Kodachrome process that color photography became readily available to the public.

THE OIL WELL

Man has been using petroleum for thousands of years for coating boat hulls, cementing bricks, occasionally as a flaming weapon, or, as by the American Indians, for body paint. But the oil age was born in 1859 when an unemployed forty-year-old railroad conductor named Edwin L. Drake successfully drilled the world's first oil well at what is now Titusville, Pennsylvania. The seventy-foot well hit oil-bearing shale using salt-well drilling equipment on August 28, and was soon producing two thousand barrels a day. The oil was used mainly in the production of kerosene for lamps. The first commercial oil refinery was opened in June, 1860, at Oil Creek valley in Pennsylvania, where only kerosene was extracted from the crude oil. (Kerosene was first extracted from oil in 1855 by Abraham Gesner of Newtown Creek, now part of Queens, New York, who named the liquid "Keros," after the Greek word for wax, and promoted it as a patented medicine!) At the Oil Creek valley refinery the by-products of the kerosene refining, including gasoline, had no use and were dumped into Oil Creek, creating the first environmental pollution by the oil industry.

THE ELECTRIC LIGHT

The first practical incandescent light bulb was demonstrated for the first time on December 20, 1879, by Thomas Alva Edison, who had constructed the bulb with a carbonized cotton filament after thirteen

months of experiments at his Menlo Park, New Jersey, laboratories; the cotton filament bulb was first built by Edison on October 21 of that year. A year earlier, however, British inventor and chemist Joseph Swan had demonstrated *his* carbon filament bulb to the Newcastle-on-Tyne Chemical Society (December 18, 1878). But the Swan bulb was not completely successful, and though he later perfected the bulb and went into production in 1881, the slightly "younger" but workable Edison bulb overtook the Swan design, and the modern electric industry developed from the Edison Company.

THE NUCLEAR REACTOR

The world's first controlled, self-sustaining nuclear reaction was achieved on December 2, 1942, at Stagg Field, University of Chicago, by a team headed by Enrico Fermi, Edward Teller, and Leo Szilard; their work led directly to the Manhattan Project in Los Alamos, New Mexico, which produced the first atomic bomb. After World War II, the application of atomic reactions to produce something other than destructive energy led to the first reactor, built in 1951 by the Atomic Energy Commission. Peaceful atomic energy remained largely experimental until 1956, when the first full-scale atomic-powered electric turbine went into operation at Calder Hall in England (August 20) and began supplying power to the British electric system on October 17 of the same year.

The first commercial nuclear reactor (that is, privately built and operated for energy production) was opened in 1963 by New Jersey Power and Light at Oyster Creek, New Jersey; the first serious nuclear reactor accident occurred on March 28, 1979, when the Three Mile Island reactor in Pennsylvania suffered a series of systems breakdowns causing the contamination of the central core room, a shutdown of the plant, the release of radioactive gas into the atmosphere (intentionally, to lower radiation levels in the reactor room), and the evacuation of area residents.



RADAR

The first practical radar device was developed by Rudolph Kuhnold, Signals Research Chief of the German Navy, and demonstrated at

New Jersey, laboratories; Edison on October 21 of his inventor and chemist filament bulb to the New York Times (October 18, 1878). But the Swan lamp, which he later perfected the design, and the modern incandescent lamp.

The first nuclear reaction was achieved by Enrico Fermi and his team at the University of Chicago in 1942. Edward Teller, and Leo Szilard were part of the Manhattan Project in Los Alamos, New Mexico. After the war, the first atomic bomb was dropped on Nagasaki. The first reactor, built in 1942, was the Chicago Pile-1. Peaceful atomic energy was developed when the first full-scale operation at Calder Hall began in 1956, providing power to the British grid. The first privately built and operated nuclear power plant in the U.S. was in 1954 in Shippingport, Pennsylvania. The first serious effort to develop a series of systems for the central core room, a nuclear reactor (the active gas into the atmosphere in the reactor room), was the Savannah River Plant in 1954. The first commercial nuclear power plant was built in 1954 in Shippingport, Pennsylvania. The first serious effort to develop a series of systems for the central core room, a nuclear reactor (the active gas into the atmosphere in the reactor room), was the Savannah River Plant in 1954. The first commercial nuclear power plant was built in 1954 in Shippingport, Pennsylvania.

INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

Kiel Harbor on March 20, 1934. Kuhnold bounced signals from his seven-hundred-watt transmitter from a battleship anchored six hundred yards away; this and subsequent tests were so successful that the German Government appropriated money to develop the device, which has had a dramatic impact on warfare, auto traffic, and even geologic research and other scientific applications.

THE COMPUTER

The first known mechanical computing device—or computer—is none other than the abacus, which was in use in China as early as (and probably earlier than) the sixth century B.C., and in Greece and Rome of ancient days. This most basic computer is still in use in parts of the Orient.

The first complex, modern computer was conceived, designed, and partially built by Charles Babbage (1792–1871), a British mathematician, who began building his computer in 1822. The Babbage machine (which was never completed because the sheer complexity of its moving parts was beyond the technology of the day) utilized many features and principles of the modern computer, including the punch card, borrowed from the famous Jacquard loom punch cards of 1804. Babbage's first concept, the "analytical engine," was put forth in 1822; the second and more complex, the "difference engine," was designed in 1833 and, had it been finished with sufficient technical accuracy, would have worked as well as early digital computers of the twentieth century.

The first electronic computer (actually a tabulating machine) was built by Dr. Herman Hollerith for the U. S. Census Bureau in 1889 for the 1890 census. The Hollerith machine made use of punch cards with eighty columns, which became part of the IBM system, and the card today bears Hollerith's name.

The first digital computer was the Mark I, completed in 1944 by Professor Howard Aiken of Harvard. The Mark I used both electronic and mechanical parts for operation. The first electronic computer was the Electronic Numerical Integrator and Computer (ENIAC), completed in 1946 at the University of Pennsylvania. ENIAC, which contained some eighteen thousand vacuum tubes and diodes, weighed thirty tons, and was used by the U. S. Army to solve artillery problems.

The modern computer industry began in 1951 with the introduction of UNIVAC, the first mass-produced computer available to private enterprise.

THE LASER

The first laser was built in 1960 by Theodore Maiman of the Hughes Research Laboratory, Malibu, California, based on work patented by physicists Charles Townes and Arthur Schwarlow. The term *laser* (light amplification by stimulated emission of radiation) was first coined by R. Gordon Gould of Columbia University in 1957, but Gould's leftist political activities in the 1940's caused his work on lasers to be hampered by the Defense Department and research agencies.

The first laser used a ruby rod surrounded by a flash tube to agitate chromium atoms in the ruby's lattice crystal to an excited state, producing pulses of red light with coherent waves.

The laser, thought of by the public as a twenty-first-century tool, has found numerous applications in holography, surgery, physics, and even astronomy.

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CONCEPTUAL FIRSTS: Five Ideas That Revolutionized Thinking

THE HELIOCENTRIC SYSTEM

Aristarchus of Alexandria, in the middle of the third century B.C., theorized that the Earth moved around the Sun, but his idea was ignored until revived by Copernicus in 1530. Though Copernicus (1473–1543) made errors, like assuming that planets have circular orbits, his destruction of the concept that the Earth is the center of the universe had a profound effect on later scientists like Newton and Kepler, and deflated traditional theological theories about man's place in things.

EVOLUTION

In 1859 Charles Darwin published *Origin of Species*, the mammoth culmination of years of travel and research, which led to his formulation of his theory of organic evolution. His ideas, such as the slow development of new and varied species through an interaction of chance and environmental adaptation, was heresy to theologians, but radically changed man's understanding of how he came to be. Ironically, Alfred R. Wallace of England developed an almost identical theory of evolution independently, at the same time as Darwin, and they jointly published their preliminary papers in 1858.

PSYCHOLOGY

Heraclitus, the Greek philosopher, was the first to say that dreams are not supernatural encounters but journeys into a personal world, in the fifth century B.C. But this concept was not to come to fruition until Sigmund Freud developed his theories of dreams, the subconscious, and sexuality beginning with his papers *On the Psychical Mechanism of Hysterical Phenomena* and *Studies in Hysteria* (written with early colleague Joseph Breuer) in 1893 and 1895. By 1900 Freud had written his *Interpretation of Dreams*, and within a few years men, women, and children were talking in terms of their egos, repression, Oedipal conflicts, and the subconscious.

THE DIVISIBILITY OF THE ATOM

From the time of Democritus in 330 B.C., the atom had been considered the smallest particle of matter (the word is Greek for indivisible or indestructible) until 1897 when Joseph John Thompson, a British physicist, put forth a model of the atom with nucleus orbited by electrons. The discovery that the atom was itself made up of smaller, moving particles revolutionized scientific thinking about the nature of matter—it suddenly had positive, negative, and neutral charges—and physicists are still discovering more and more obscure and curious subatomic particles every decade.

RELATIVITY

Albert Einstein revolutionized physics in 1905 with the introduction of his special theory of relativity, which made time the fourth dimension. One of the many aspects of the theory is that mass and energy are equivalent, a basic concept leading to the development of nuclear fission and the atomic bomb. The bomb demonstrated most impressively the divisibility of the atom (see above). However, it may someday render the concepts of psychology, evolution, and the heliocentric system irrelevant, since there may be no one left to psychoanalyze, nothing to evolve, and nothing left to revolve around the sun but radioactive dust.

SPEAK UP:

Communications Milestones

DOT-DOT-DASH-DOT

On May 24, 1844, Samuel F. B. Morse, a successful painter-turned-inventor, transmitted the famous first message, "What hath God wrought" from the U. S. Capitol in Washington to his assistant, Alfred Vail, at the Mount Clare station of the B. & O. Railroad in Baltimore, the first long-distance telegraph message.

Morse had begun developing his apparatus in 1832, while a professor of art at New York University, and had given the first public demonstration in 1837, the year he took out a patent on the telegraph. The same year Vail devised the Morse code to replace the cumbersome numbered system he and Morse had used up to that time.

Prior to Morse, British inventor Francis Ronald had devised an electric telegraph in 1822, which failed to get off the ground due to lack of Government interest. And two other British inventors, Charles Wheatstone and William Fothergill Cooke, patented *their* telegraph in 1837, the same year Morse gave his first demonstration. In 1831 Joseph Henry demonstrated an electromagnetic telegraph in Albany, New York, but failed to patent or promote the device, thus losing out to Morse—who made a fortune from his telegraph. Wheatstone and Cooke were more fortunate—the British telegraph system grew out of their patented invention, which they sold for a whopping £168,000 in 1846.

INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

UNDER THE OCEAN AND THROUGH THE WOODS

Cable service from New York to Chicago began in 1848. The English Channel cable was completed in 1850; the transamerican cable from New York to San Francisco was completed (despite Indians' objections) in 1861, putting the Pony Express out of business; and a major communications first came in 1866 when Cyrus W. Field completed the first transatlantic cable, allowing instantaneous communication between two continents for the first time.

ELEMENTARY, MY DEAR WATSON

On March 10, 1876, Alexander Graham Bell spoke the first sentence to be transmitted over wire at 5 Exeter Place, Boston, when he said, "Mr. Watson, come here, I want you." The first practical telephone was an improved version of the machine built in 1875, when Bell discovered by accident that a telegraph transmitter using harmonic frequencies in matching receivers could transmit matching sounds (June 2, 1875). Bell was only twenty-nine at the time he called Thomas Watson, who was twenty-two.

THE NEXT BEST THING TO BEING THERE

The first long-distance phone call was placed in October, 1876, when Boston lawyer Gardiner Hubbard, future father-in-law of Bell and an early promoter of the phone, took two of young Bell's telephones, hooked them up to a telegraph wire running from Boston to the Cambridge Observatory across the Charles River, and spoke to Thomas Watson for over three hours.

HELLO, CENTRAL

The first telephone was sold by Bell in May, 1877, to the Cambridge Board of Waterworks. By August there were eight hundred in service. The first switchboard was installed in the offices of the Holmes Burglar Alarm Company of Boston, at 342 Washington Street, who used their existing burglar alarm lines from a client's premises as phone lines during the day and burglar alarms at night. Bell loaned

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twelve of his phones to Holmes, and Holmes in turn didn't charge clients for the phone service.

The first commercial phone exchange was opened in New Haven, Connecticut, by the District Telephone Company on January 28, 1878, with twenty-one customers subscribing to the service. The first telephone operator was George W. Coy, who answered calls with shouts of "Ahoy!"

SORRY, WRONG NUMBER

The first telephone in a private home was installed on April 4, 1877, in Somerville, Massachusetts, in the home of Charles Williams, Jr., at the corner of Arlington and William streets. Mr. Williams was also the first to manufacture Bell phones commercially. Since the first phone exchange had yet to be installed, Williams had to have a line run to his office in Boston so there would be someplace to call.

THAT WILL BE FIVE CENTS, PLEASE, FOR THE NEXT . . .

William Gray, an inventor from Hartford, Connecticut, installed the first coin pay phone in the Hartford Bank in 1889 and began widespread installation in 1891. The cost of a call was a nickel, making a pay call one of the most stationary prices of modern times.

DIAL "U" FOR UNDERTAKER

The first automatic telephone, the precursor of today's dials and touchtones, utilized three keys which were depressed to register the number through a mechanical, operatorless central switchboard. It was patented in March, 1889, and went into service at La Porte, Indiana, on November 3, 1892. The inventor was Almon Strowger, an undertaker in Kansas City, who was moved to create the device because he was convinced that one of Kansas City's operators, who happened to be the wife of one of his chief rivals in the funeral business, was diverting calls for undertakers to her husband's establishment.

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INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

THEY TOLD MARCONI WIRELESS WAS A PHONY

Wireless telegraphy was developed between 1894 and September, 1895, by Guglielmo Marconi at his family's country house, the Villa Grifone, at Pontecchio near Bologna. Marconi, whose mother was British, took his device to Britain, where he demonstrated how elec- tronic signals could be transmitted through the air, over hills, and around obstacles—privately in September, 1896, on Salisbury Plain and publicly on December 12 at Toynbee Hall in London.

Ironically, the wireless, which has made Marconi famous, was apparently demonstrated first by an American, Mahlon Loomis of Washington, in 1866. Unfortunately, Loomis was a bit ahead of his time, and that, in combination with financial setbacks, prevented his wireless from getting off the ground.

Marconi was more fortunate, and formed the Wireless Telegraph Company Limited in July, 1897, for the manufacture and sale of his equipment. Though wireless telegraphy would find many applica- tions (the *Titanic* used wireless to signal that she was going down in 1912), Marconi's invention would be even more important than the beginning of radio.

LOOK, MA, NO WIRES!

The first transatlantic wireless message was sent from Poldhu, Corn- wall, on December 12, 1901, and received in Newfoundland by Marconi, using a wired kite as a receiving antenna. The message received consisted of the letter S.

YOU SOUND LIKE YOU'RE JUST NEXT DOOR

Transcontinental phone service began January 25, 1915, when Alex- ander Graham Bell in New York called Thomas Watson in San Francisco and repeated their famous message of 1876. The call took twenty-three minutes to get through, and cost \$20.70. (Presumably Mr. Bell put it on his expense account at Bell Telephone, but that's what a paying customer would have forked out.)

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LET YOUR FINGERS DO THE WALKING

The first true dial phones were introduced November 8, 1919, in Norfolk, Virginia. Dial mechanisms had been available earlier, but A.T. & T. hadn't been interested until a potential operators' strike threatened to stop phone service.

PLEASE DEPOSIT SEVENTY-FIVE DOLLARS FOR THE FIRST THREE MINUTES

Intercontinental long-distance service began January 7, 1927, between New York and London.

AFGHANISTAN? I WAS TRYING TO DIAL ARKANSAS

The first direct-dial long-distance service began on October 10, 1951.

LONG, LONG DISTANCE

A.T. & T. launched Telstar, the first private communications satellite, on July 10, 1962, to relay television programs globally. On April 6, 1965, the Communications Satellite Corporation (Comsat) launched Early Bird, the first of a projected network of commercial satellites designed to provide almost unlimited global telephone and telegraph communications.

WAY

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OVERDRIVE: The Automobile from Pressure Cooker to Edsel

1690 • Denis Papin (1647–1712), French physicist and inventor of the pressure cooker (“steam digester”), proposed a road vehicle driven by piston engine.

1769 • Nicholas Joseph Cugnot (1725–1804) took the first ride in a self-propelled, steam-driven vehicle of his own invention. The vehicle, which attained a speed of about 2½ mph, also resulted in the first auto accident. Cugnot knocked down a wall in Paris, where the experiment took place.

1801 • Englishman Richard Trevithick (1771–1833) invented and built the first successful steam vehicle, which he test ran—at a speed somewhere between 4 and 9 mph—in Cambourne, Cornwall. When the first model went up in flames, a veritable auto-da-fé, Trevithick rebuilt his vehicle, which in 1803 made the first cross-city trip, from Leather Lane to Paddington, London, by way of Oxford Street.

1805 • Isaac de Rivaz built the first vehicle powered by an internal-combustion engine, which, unfortunately, only made it a few yards. Since this was the first internal-combustion auto, it was also the first to pollute the air with carbon monoxide.

1829 • Goldsworth Guernsey made the first long-distance auto journey, from London to Bath, in his eighteen-seater, six-wheeled steam

coach. The size of Guerny's vehicle should also qualify him as the first bus driver, and the trip as the first bus tour. The distance traveled was about eighty miles.

1831 · The world's first scheduled "bus" service operated for a few months between Gloucester and Cheltenham, England, using three Guerny steam carriages.

1860 · Belgian-born inventor Jean Joseph Étienne Lenoir (1822–1910) built the world's first successful internal-combustion-engine vehicle—a "gas carriage"—using an engine he first constructed the previous year. By 1863 a second Lenoir vehicle traveled from Paris to Vincennes, a distance of six miles, in three hours—giving an average speed of one-half mile per hour.

1864 · The first auto export in history: Lenoir sold one of his internal-combustion-powered carriages to Czar Alexander II of Russia.

1865 · Karl Benz of Germany (1844–1929) designed and built a three-wheeled gas-driven vehicle, the first to be designed and built as a motor vehicle, rather than converted from a carriage. The Benz had its first test runs in 1886.

1888 · John Dunlop (1840–1921) "invented" the pneumatic tire (or, rather, tyre), marking the beginning of the modern tire industry. Curiously, another Scotsman, R. W. Thomson, took out a patent on pneumatic tyres in 1845. But Dunlop got all the credit.

1891 · French inventor Ferdinand Forest built the first four-cylinder gas engine with mechanical valve operation; a few years later he built the first six-cylinder engine. Ironically, Forest's inventions—which became the standard for millions of automobiles—were first used in boats, and he failed to be recognized for his contribution when they were later used in automobiles.

1893 · Brothers Charles Edgar and James Frank Duryea (1861–1938, 1869–1967) built the first "motor buggy" in Springfield, Massachusetts. Other motor vehicles had been built in the United States before the Duryeas', but theirs is recognized as the first practicable automobile built in the United States.

INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

1894 • Henry G. Morris and Pedro Salom open the first automobile factory in the United States in Philadelphia. The product: the Electrobat.

1896 • Henry Ford (1863–1947), Ransom Eli Olds (1864–1950), C. B. King, and Alexander Winton—all major pioneers in the American auto industry—built and tested their first models. In France, Léon Bollée offered his *voiturette* (little car), the first with pneumatic tires a standard feature.

1899 • Ransom Eli Olds began production of the first Oldsmobiles.

1901 • Cannstatt-Daimler of Germany introduced the first Mercedes, named after the teen-aged daughter of Emil Jellinek, one of Daimler's first customers.

1902 • Dr. Lehwiss Panhard made the first attempt to drive around the world, but his auto caravan *Passe Partout* didn't get past Ninji, Novgorod, Russia.

1903 • Henry Ford founded the Ford Motor Company in Detroit, Michigan. The same year, H. M. Leland founded the Cadillac Motor Car Company in the same city.

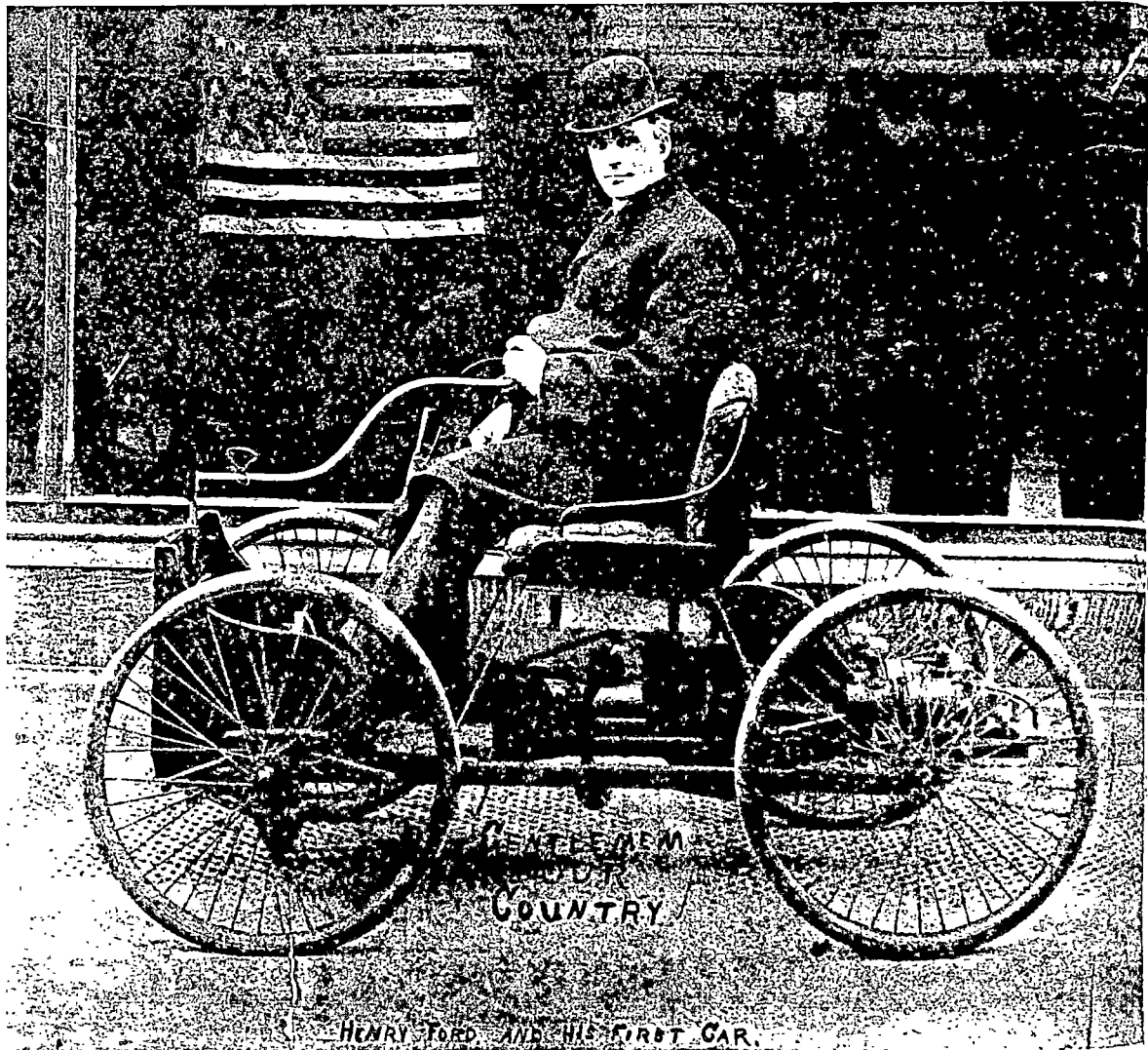
1906 • Sir (Frederick) Henry Royce (1863–1933) of England, who built his first Royce car in 1904, organized an auto manufacturing business with C. S. Rolls, and the first Rolls-Royce was born.

1908 • William C. Durant (1861–1947) founded General Motors Company, and Henry Ford produced the first Model T Ford, perhaps the most famous single model car ever built. The first year, eight thousand Model T's were built.

1909 • In France, De Dion Bouton produced the first important production-line auto with a V-8 engine.

1911 • Ford opened its first overseas factory at Trafford Park, Manchester, England. The same year Cadillac was the first manufacturer to feature electric lights and starters on their models.

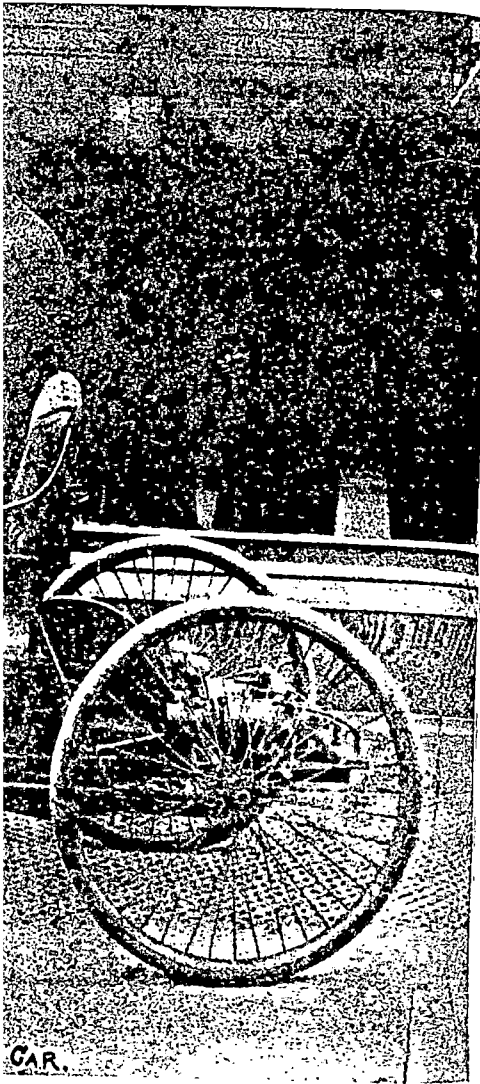
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For Ford and country: Sitting at the helm of his first car, complete with Stars and Stripes superimposed, this early public relations photograph of Henry Ford in retrospect makes a point about the impact of Detroit on the American Way of Life.

THE BETTMANN ARCHIVE, INC.

1913 • Henry Ford used conveyor belts in his assembly lines for the first time, but only for assembly of the magneto. In 1914 Ford



first car, complete with Stars
ons photograph of Henry Ford
Detroit on the American Way
THE BETTMANN ARCHIVE, INC.

his assembly lines for the
magneto. In 1914 Ford

INVENTIVE, EXPLOSIVE, AND DEADLY FIRSTS

produced the first cars completely assembled on conveyor belts, reducing the time required to build a car from twelve and one-half hours to one and one-half hours, revolutionizing American industry.

1915 • Because sales had surpassed annual target figures, Ford Motor Company offered the first rebate—fifty dollars—to anyone who purchased a Model T.

1918 • For the first time, car registrations in the United States exceeded 5 million.

1922 • In the United States, Trico introduced the electric windshield wiper.

1924 • Walter P. Chrysler (1875–1940) produced the first Chryslers.

1934 • The Chrysler Corporation produced the first Airflow cars—streamlined vehicles that were to have a revolutionary impact on auto design. Airflow also featured the first overdrive transmissions.

1936 • The Nazi Government financed the development and manufacture of the first Volkswagens, the design of which remained virtually unchanged to the 1970's.

1939 • The Lincoln division of Ford Motor Company produced the first Lincoln Continental and Mercury models.

1948 • Rover of Great Britain introduced the first four-wheel-drive Land-Rovers.

1950 • Rover pioneered the first gas-turbine engine car.

1956 • Ford Motor stock sold to the public for the first time since Henry Ford bought out all Ford shareholders in 1917. In the 1917 stock buy-back, Henry Ford paid 105 million dollars to buy out other shareholders, which gave a return of 12 million dollars on an investment of five thousand dollars in Ford stock made in 1908. From 1917 to 1956 the Ford family retained full control of the giant business.

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The Ford Foundation, which offered the stock for sale in 1956, netted some 643 million dollars from the transaction, 500 million dollars of which it gave away within the next eighteen months.

1957 • Ford produced the first Edsel—Detroit's first major flop.

FAR OUT: Astronomical Firsts

WHICH WAY TO POLARIS, JACK?

Hipparchus, a Greek astronomer, is credited with making the first star map in 134 B.C. after seeing a new star appear in the constellation Scorpio. He hoped his map would make it easier for future stargazers to spot new sky happenings.

LIGHTS OUT

The first recorded total solar eclipse occurred in China, October 22, 2137 B.C.: The two royal astronomers Hi and Ho were drunk and neglected to frighten away the dragon that had eaten the sun, for which negligence they were beheaded by Emperor Chung K'ang.

NOT WITHIN WALKING DISTANCE

Ancient astronomers had attempted to measure the distance of stars by using the trigonometric method of parallax, which had given them decent values for the distance of the sun, and for the diameter of the Earth. However, they had no concept of the immense vastness of space, and the minute measurements required for measuring the parallax of stars was wa-a-ay beyond their instruments.

In 1838, three astronomers, working independently, each mea-

FARAWAY FIRSTS

ured with reasonable accuracy the distance of a star. They were Friedrich Bessel of Königsberg Observatory, Germany, who gave a distance of less than 11 light-years for 61 Cygni. Thomas Henderson, Astronomer Royal of Scotland, gave a figure of 4.3 light-years for Alpha Centauri; in Russia, F.G.W. von Struve announced a figure of 27 light-years for Vega.

For the first time, man knew that space was very big, indeed.

SO BIG YET SO SMALL

In 1845 the third Earl of Rosse, an amateur astronomer of some means, built the world's largest telescope on his estate in Ireland. The earl's reflecting telescope had a seventy-two-inch metal mirror, and was suspended between two ivy-covered stone walls. The telescope revealed that what had appeared to be stars in other telescopes were actually glowing spiral objects. Ross did not realize, however, that these tiny spiral objects were galaxies, each as large as or larger than our own, each with hundreds of millions of stars.

FASTER THAN A SPEEDING BULLET

In 1675, Ole Roemer of Denmark noticed that satellites of Jupiter were eclipsed by the giant planet at irregular intervals—when Jupiter was closest to Earth the eclipses came too soon, and vice versa when Jupiter was at its farthest point. Roemer understood, of course, that the light was taking longer or shorter times to reach Earth, and by careful measurement and calculation he was able to estimate the actual speed of light. His answer was 186,000 miles per second—an amazingly accurate figure for 1675: The modern value is 186,282.397 m.p.s. The figure was so astonishingly high that Roemer didn't believe his own calculations.

FIRE IN THE SKY

In A.D. 1054 Chinese and Japanese astronomers recorded the sudden appearance of a new, remarkably bright star in the sky. We know today that it was a supernova—a star that, in a one-day explosion,

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can increase in brightness up to one million times. The remnants of the 1054 explosion are today's Crab Nebula.

GALILEO'S MANY FIRST SIGHTINGS

When Galileo turned his newly built telescope on the Italian sky in 1609 (see: "Better Mousetraps"), he saw more things for the first time than almost any astronomer since. To wit: the mountains of the moon; the rings of Saturn (which puzzled him); the "invisible" Pleiades (six stars of the constellation are visible to the naked eye, but Galileo saw forty in his telescope). In 1610 Galileo spotted three satellites of Jupiter, and in 1611 he observed for the first time sunspots and stars in the Milky Way.

COME AGAIN

In 1705, English astronomer Edmund Halley realized that the comets which were recorded in 1531, 1607, and 1682 were one and the same, and predicted that it would appear again in 1758. Halley died in 1742, but his prediction came true on Christmas Day of 1758, and the heavenly wanderer was duly named after him. Halley's comet last appeared in 1910, and it's due again in 1986.

VENICE ON MARS

In 1659 the Dutch astronomer-physicist Christian Huygens noticed that the planet Mars had markings on its surface. In 1877 Italian astronomer Giovanni Schiaparelli discovered narrow, regular lines crossing the Martian desert, and named the markings *canali*. The public—and some astronomers—soon came up with all sorts of fanciful ideas about the origins of these "structures," though Schiaparelli himself never suggested that they were anything other than natural features. We now know there are no canals on the red planet, and the "canals" are structural features of the planet's crust.

FARAWAY FIRSTS

SPACE ROCKS

The first sighting of an asteroid came when Sicilian astronomer Giuseppe Pazzi discovered a 623-mile-diameter asteroid, which was named Ceres, on January 1, 1801. There are now estimated to be forty thousand asteroids in the great belt between Mars and Jupiter.

THE FIRST PLANET TO BE "DISCOVERED"

Until 1781 the solar system consisted of six planets: Mercury, Venus, Earth, Mars, Saturn, and Jupiter. In that year William Herschel, a young musician who studied the heavens through a telescope in his spare time, was enjoying his nightly "review of the heavens" when he noticed a strange disc. Herschel thought it was a comet, but when he showed the disc to other astronomers, they realized the amateur had discovered the first new planet in man's history. The planet, 1.7 billion miles from Earth, was named Uranus. George III gave Herschel a pension as a reward, and he settled down to a lifetime of stargazing. Among other things, Herschel was also the first to show the arrangement of stars in the Milky Way.

IT'S GOT TO BE THERE SOMEWHERE

Once Uranus was discovered, it was studied closely, and astronomers noticed certain irregularities in its orbit. In 1834, the Reverend T. J. Hussey, an astronomer and the rector of Hayes, Kent, theorized that the presence of yet another planet was causing the irregularities. Astronomers then worked out theoretically where the distant, "invisible" planet should be, and on August 4, 1846, Professor James Challis picked up the planet through a telescope. The new planet was named Neptune.

WHITE DWARF—THE DARK COMPANION

In 1834 Bessel, one of the first to measure star distances with accuracy, noticed that Sirius, the Dog Star, had irregular motion which could only be accounted for by an unseen body. In the case of Sirius, a large star, the "dark companion" (as it became known) would have

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to be at least as massive as our own sun to exert such a strong gravitational force on Sirius.

In 1862 Alvan Clark, an American astronomer testing a new telescope, became the first to see Sirius's dim companion star. The new star, Sirius B, nicknamed the Pup, turned out to be the first in a series of unusual kinds of stars that astronomers were to discover in the next century. Sirius B is a very small, dim, but massive star. Only 24,000 miles in diameter (smaller than Jupiter, Saturn, or Uranus), it has as much mass as our sun—867,000 miles in diameter. A matchbox full of Sirius matter would weigh fifty tons on earth. This type of star, known as a white dwarf, results when a medium-size star, like our sun, evolves through a red giant stage, burning up its fuel, leaving a cold, dense, dying core.

FAST AND HEAVY

In 1939 J. Robert Oppenheimer (who also did important work on the first atom bomb) demonstrated mathematically how a star somewhat larger than our sun could, under certain conditions, implode, that is, suddenly collapse into a superdense body, smaller and denser than a white dwarf. Such a body would be only about ten miles across, and a cubic inch would weigh *10 billion tons*. The atoms in the body would be so compressed that most of the atomic matter would have been thrown off, leaving only neutrons tightly packed together.

In 1967 the first of these neutron stars was discovered at Cambridge University when Jocelyn Bell, a graduate student, detected weak but very precise radio signals coming from a spot in space. The signals were flicking on and off at intervals of 1.33730113 seconds. When Bell presented her discovery to Anthony Hewish, head of the team, it was at first thought that an intelligence might be sending the signals. However, the signals continued at the same precise intervals for months, and the astronomers realized that they had discovered a neutron star. The small, dense body, with an intense magnetic field, was rotating extremely fast (imagine a sphere ten miles in diameter rotating once every 1.3 seconds!), and with each rotation a radio signal created by the magnetic field was being thrown our way. These pulsing radio sources were dubbed pulsars, and others were soon found. The fastest known is the pulsar in the Crab Nebula, which signals thirty-three times a second. It is also the first (and so far,

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FARAWAY FIRSTS

only) visible pulsar, discovered by astronomers at Seward Observa-
tory in Arizona in 1969. The object, named NP0532, is the remnant
of the star which exploded creating the Crab Nebula, which was
visible on Earth as the supernova of A.D. 1054.

BLACK HOLES

In 1939, when Oppenheimer did his mathematical work on neutron
stars, he theorized an even more bizarre object, which would be
created if a very large star—one fifty times the size of the sun—
imploded. The mass of the star would be so great in an implosion that
its gravitational pull would collapse it, not into a neutron star, but
into a black hole. The black hole, which would be no more than forty
miles across, would exert such tremendous gravitational pull that not
even light could escape—hence its invisibility. Even more provoca-
tive, a black hole would literally pull matter into nothingness—a
concept new to astronomers—and it has been theorized that black
holes are actually holes in our universe where matter leaks into other
universes, which possibly run in reverse to ours.

The first black hole was detected in 1972 in the binary star X-ray
source, Cygnus X-1. The source is a massive, radiating star with a
black hole companion which has a mass about ten times that of the
sun, but a diameter of only 3.67 miles.

FARTHEST OUT: QUASARS

In 1963 Maarten Schmidt, a Dutch astronomer working at Mount
Palomar in California, was looking for a star in the Milky Way which
was believed to be a source of unusual radio signals. He found an
object in the sky, but it turned out not to be a star at all, but
something quite different. First of all, it was very far away—about
1 billion light-years, the most distant thing seen up to that time.
Second, it was very bright—as bright as two hundred Milky Way
galaxies put together (there are 100 billion stars in the Milky Way).
Third, it was moving away from us very fast—almost at the speed
of light.

Dubbed quasi-stellar radio source, or quasar 3C273, Schmidt's
finding was only the first of many. Astronomers have now found

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more than two hundred quasars, and they are the most distant (and therefore, the oldest observable) objects in space. The most distant quasar was discovered in 1974, and is receding from the center of the universe at 95.5 percent of the speed of light.

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GIANT LEAPS: Firsts from Blastoff to Man on the Moon

One of the most astonishing feats in man's history is the landing of man on the moon sixty-six years after the Wright brothers' first flight, and just forty-three years after the first fuel-propelled rocket flight. Here are some milestone firsts along the way.

BLASTOFF

Dr. Robert H. Goddard (1882–1945) of the United States developed and tested the first liquid fueled rocket. Goddard's work was done primarily without outside help, and with limited funding. (The Smithsonian Institution gave him a five-thousand dollar grant.) The first test of Goddard's rocket was made in November, 1923, when a liquid fuel missile was given a static test—that is, fired while attached to a holding platform. Though the static test was successful, Goddard spent three years modifying his apparatus before conducting the first rocket free-flight, on March 16, 1926, in a field near Auburn, Massachusetts. The three-foot rocket was ignited by Goddard himself, using a blowtorch attached to a long pole. The rocket attained a height of 184 feet and a speed of 60 m.p.h. Goddard, who was accompanied only by his wife Estha and two assistants at this historic moment, decided not to publish or announce his success since his earlier work on rockets had been ridiculed severely in many newspapers.

In less than half a century, Goddard's modest rocket had given

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birth to the giant Saturn V, over 100 times as high as the first model, and the five thousand dollar Smithsonian grant had grown to a 50-billion-dollar United States Government space program investment.

SOVIET SURPRISE

On September 4, 1957, the world was stunned by the announcement that Russia had launched *Sputnik 1*, the first artificial satellite to orbit the earth. *Sputnik*, weighing a modest 184.3 pounds and measuring only 22.8 inches in diameter, gave the USSR the world lead in space and rocketry technology until the mid-sixties.

A lagging United States managed to get its first satellite, *Explorer 1*, into orbit on January 31, 1958. *Explorer*, a featherweight 18.2 pounds, carried instruments designed by Dr. James Van Allen. The instruments detected for the first time the intense belts of radiation which surround the earth. They were named the Van Allen belts in the good doctor's honor.

BUT IS THERE LIFE ON MARS?

The precocious Russians chalked up another first on November 3, 1957, when they launched *Sputnik 2*, carrying a female dog named Laika. Laika was the first living thing from earth to be shot into space—except for a possible germ or two on *Sputnik 1*. Laika also became the first space-race victim when she died in her 1,100-pound capsule on the sixth day, due to a faulty temperature control mechanism. *Sputnik 2* continued to orbit the earth for 162 days; it burned up on reentering the Earth's atmosphere.

FREE AT LAST

A major first in the journey to the moon came on January 2, 1959, when Russia launched *Lunik 1*, the first object to break away from the gravitational pull of the Earth. *Lunik* passed within 4,000 miles of the moon before moving on to fall into orbit around the sun—making it the first artificial planet.

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FARAWAY FIRSTS

THE MAN IN THE MOON GETS A PIE IN THE FACE

Humankind's first contact with the moon was less than dignified. The Soviet's *Lunik 2*, the first man-made earthly object to touch another heavenly body, smashed into the moon's surface on September 13, 1959. Since the satellite's instruments were destroyed in the crash, no data were relayed back to Earth to record man's first physical contact with the moon.

THE DARK SIDE OF THE MOON

The first satellite to orbit the moon was *Luna 3*, launched by Russia on October 4, 1959. The satellite carried a single photographic camera (with self-contained film processing equipment), which transmitted photos back to Earth. A gyroscopic system kept the camera lens oriented continuously toward the moon. After a year of orbiting, *Luna* had sent enough pictures back to Earth to enable Russian scientists to publish an atlas of the heretofore unseen dark side of the moon.

STRELKA AND BELKA, COME HOME

A major step in the space race was taken with Russia's *Sputnik 5*, launched August 19, 1960: For the first time, a live payload—in this case consisting of two dogs named Strelka and Belka—was recovered after orbiting the Earth for twenty-four hours. The animals returned safely to Earth via an ejection mechanism which pulled them from the capsule as it reentered the atmosphere and lowered them by parachute to a soft landing on the ground. The Russians continued to pioneer dry-ground landings, while the United States concentrated on ocean landings.

SPACED OUT

On April 12, 1960, the Soviets launched *Vostok 1*, a 7½-foot, 10,416-pound spherical capsule which contained Yuri Gagarin, a twenty-seven-year-old cosmonaut, the first human being to enter space and to orbit the earth. The capsule orbited the earth one time, in 89.34

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seconds, and the total flight lasted only 108 minutes from takeoff at 9:07 A.M. in Tyura Tam, Kazakhstan, to touchdown at 10:55 A.M. near Smelkova, Saratov, USSR.

Gagarin became an overnight celebrity, but his fame was overshadowed by persistent rumors penetrating the cloud of secrecy around the Russian space program. The rumors were to the effect that Gagarin had not in fact been first man in space and that fellow cosmonaut Serge Ilyushin had made a three-orbit space flight three days earlier than Gagarin, but had been hospitalized immediately after landing. The rumors were never proven or disproven.

Gagarin died seven years later in a plane crash, at age thirty-four.

OUR BOYS IN SPACE

In 1958 NASA, or the National Space and Aeronautics Administration, selected seven men to be the United States' first space travelers. The chosen few—all married men—were picked from 508 volunteers and candidates from military and civilian test pilots. They were: M. Scott Carpenter; Leroy Gordon Cooper, Jr.; John H. Glenn, Jr.; Virgil I. "Gus" Grissom; Walter M. Schirra, Jr.; Alan B. Shepard, Jr.; and Donald K. Slayton.

UNCLE SAM KEEPS UP

The first American in space—a year after Gagarin—was Alan B. Shepard, Jr., who was launched from Cape Canaveral on May 5, 1961. Shepard's flight, which arched into space and back again without achieving orbit, reached an altitude of 114 miles and a speed of 5,181 mph.

THE QUEEN OF OUTER SPACE

On June 16, 1963, the Soviets launched their *Vostok 6* carrying Valentina Tereshkova, a former textile worker, in a forty-eight-orbit flight. The first woman in space later married fellow cosmonaut Andrian Nicolavev, making them the first spacemates.

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FARAWAY FIRSTS

THREE'S A CROWD, COMRADE

The Russians also took honors for being the first to put more than one man at a time into space. On October 12, 1964, they launched *Voskhod 1*, carrying three men: Vladimir Komarov; Boris Yegorov (an Air Force doctor); and Konstantin Feoktiskov, a civilian scientist. The last two were the first doctor and the first civilian in space, respectively. Their flight was also the first with a pressurized cabin, enabling the three men to forego pressurized space suits and helmets.

ON RYE WITH EXTRA MUSTARD

American astronaut John Young, who made the first multimanned U. S. flight with Gus Grissom starting March 23, 1965, was the first man to eat a corned beef sandwich in space. Young smuggled the sandwich on board to supplement the usual fare of dehydrated foods. However, stray crumbs posed a threat to the capsule's complex machinery, and Young was reprimanded by NASA officials for his celestial cravings.

SHOOTING THE MOON

On January 31, 1966, Russia launched *Lunik 9*, weighing 3,490 pounds, which approached within fifty miles of the lunar surface and released a spherical landing capsule. The capsule then made the first soft-landing on the moon.

On touchdown in the Ocean of Storms (February 9), the *Lunik 9* landing capsule opened four petal-like panels to expose a camera lens, which then took three panoramic photo views of the lunar surface and transmitted them back to Earth—man's first close look at his nearest neighbor in space.

RIVER OF NO RETURN

The first man to die in space was Russian cosmonaut Vladimir Komarov. His *Soyuz 2* satellite was launched from Tyura Tam, USSR, on April 23, 1967, on a scheduled twenty-five-hour, eighteen-orbit flight. Komarov died when the parachute straps lowering the

DENNIS SANDERS

capsule to earth "became twisted and the craft descended at a great speed." Western scientists have questioned the story, however, because Russian capsules have a device which ejects cosmonauts from their capsules as they reenter the atmosphere. Komarov did not eject possibly because of equipment failure, or because the capsule overheated on entering the atmosphere.

The first official statement after Komarov's flight was "Komarov . . . is in good health and feeling well." The death was not announced until twelve hours after the crash-landing.

The first American astronauts to die were Virgil Grissom, Roger Chaffee, and Ed White—on January 27, 1967, when their capsule was swept by fire during a routine on-the-ground test. The fire, thought to have originated from a faulty electrical cable, swept through the sealed capsule so quickly that the astronauts couldn't activate escape mechanisms. A subsequent investigation cited "113 significant engineering orders" that had been improperly carried out in the building of the capsule. The tragedy resulted in considerable redesign and reengineering work on the *Apollo* capsule.

GREEN CHEESE IT AIN'T

The first firsthand look at the moon came on the *Apollo 8* expedition, launched by the United States in December, 1968, with Frank Borman, James Lovell, Jr., and Bill Anders on board. Among the highlights of man's first orbit of the moon were the crew's reading of the opening verses of Genesis, "In the beginning, God created the Heavens and the Earth. . . .," and Borman's description of the moon's surface: "Looks just like plaster of Paris."

SO NEAR YET SO FAR

On the *Apollo 10* expedition Tom Stafford, John Young, and Eugene Cernan came within miles of immortality: It was their job to give the lunar landing module a dry run for the later moon landing. With the command module in orbit, Young and Cernan took the lunar lander to within eight miles of the lunar surface—the first close pass for the landing vehicle—and then returned to the command module for docking and flight back to Earth.

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EAT YOUR HEART OUT, JULES VERNE

Apollo 11, the U. S. mission destined to land on the moon, blasted off from Cape Kennedy at 9:32 A.M. Eastern Daylight Time, July 16, 1969. The Saturn V rocket stood 363 feet tall, weighed 6,000,000 pounds, and developed a 7,600,000-pound thrust. On board were Neil Armstrong, thirty-eight, commander of the expedition, Edwin E. "Buzz" Aldrin, the lunar module pilot, and Colonel Michael Collins of the U. S. Air Force. The expedition went without a hitch, and the lunar module with Armstrong and Aldrin touched down on the moon at 20.17 hours 42 seconds, G.M.T., July 20, 1969. Aldrin's first words after touchdown—the first by man from another body in the solar system—were, "Tranquility Base: the Eagle has landed."

NO PIE IN THE SKY

The first meal eaten on the moon—consumed by Armstrong and Aldrin before their historic moonwalk—consisted of four bacon squares, three sugar cookies, peaches, pineapple-grapefruit drink, and coffee.

PUT YOUR LITTLE FOOT

At 2:56 hours, 15 seconds, G.M.T., July 21, 1969, Neil Armstrong became the first human to set foot on another world when he descended from the lunar landing module. His words were "I'm at the foot of the ladder. The LM [lunar module] footpads are only depressed in the surface about two inches, though the surface appears to be very, very fine grained as you get close to it, like powder. Okay. I'm going to step off the LM now. (Pause) That's one small step for [a] man, one giant leap for mankind. The surface is fine and powdery. I can kick it loosely with my toe."

DO YOU MIND IF I TAKE THIS CALL?

President Richard M. Nixon placed the first phone call to the moon, on July 21, when he spoke to Armstrong and Aldrin in their lunar module parked on the moon's surface. Said Nixon, "Neil and Buzz,

DENNIS SANDERS



Do you mind if I tape this call? President Richard M. Nixon places the first phone call to the moon, July 21, 1969, when he spoke to Neil Armstrong and Buzz Aldrin, 240,000 miles away.

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I'm talking to you from the Oval Room of the White House, and this certainly has to be the most historic telephone call ever made."

Like most of Nixon's phone calls, this one was both tape recorded and widely disseminated among the public. However, it was one taped call he wasn't later to regret. Nixon summed up his feelings about the moon landing by saying, "This is the greatest work in the history of the world since its creation."

FROM ATOM TO ADAM:

The First 15 Billion Years of the Universe

THE COSMIC EGG: THE FIRST THING EVER

More than 15.5 billion years ago the universe as we know it did not exist. All matter, or so most astronomers believe, was compressed together into a superdense core at the center of an empty universe. This core is known as the Cosmic Egg. Science has yet to propose a Cosmic Chicken.

THE FIRST EVENT, EVER

And it was a big one. The Cosmic Egg exploded, hurling the compressed matter out into the emptiness of space. This "Big Bang" signaled the start of the universe as we know it, about 15.5 billion years ago.

A STAR IS BORN

About 12 billion years ago matter from the Big Bang began to condense into clusters of hundreds of billions of stars—the first galaxies. A galaxy is usually a flat spiral with dense concentrations of stars near the center of the spiral, thinning out along the arms. The whole thing rotates as it hurtles through space, and astronomers estimate there are hundreds of billions of them out there.

DENNIS SANDERS

Our own galaxy, the Milky Way, is 100,000 light-years across, 30,000 light-years thick at the center, and is moving at 170 miles per second.

TERRA FIRMA

About 10 billion years ago our sun had a star companion (or, some theories go, a nebula companion), which was finally pulled apart $5\frac{1}{2}$ or 6 billion years back by the tidal forces between the two objects. The remnants of this destroyed companion began collecting into the first planets about 5 billion years ago.

HOT ROCKS

When the earth was first formed it was about one thousand times larger and five hundred times heavier than the planet we know. The earth spent the first half billion years or so of its existence cooling down and settling in. The heavier elements (iron, nickel, cobalt) settled to the earth's core, while the lighter elements (hydrogen and helium) moved up into the atmosphere, with large amounts escaping the planet's gravity altogether. By 4.5 billion years ago the molten planet had cooled down enough for the first basaltic rocks to form, making a crust on the planet.

WATER, WATER, EVERYWHERE

The molten, volcanic conditions in the primordial earth created huge amounts of water vapor which, along with poisonous methane and ammonia, made up the atmosphere. When the crust cooled sufficiently about 4 billion years ago, the water vapor began condensing, forming the first oceans, which cover 71.43 percent of the surface.

OUT OF THE PRIMORDIAL OOZE

In 1979 a rock from Australia was found to have wavelike layers that are believed to be the fossils of threadlike bacteria that were alive 3.5 billion years ago in the ocean of the Precambrian era. The bacteria

FIRST THINGS LAST

represent a fairly complex state of evolution, and indicate that the formation of organic molecules by the interaction of the oceans and atmosphere, which evolved into the first life, began soon after oceans were formed.

THE FIRST LAND ANIMAL

The scorpion (like spiders, an arachnid, and part of the phylum Arthropoda, which includes true insects and crustaceans) evolved during the Silurian period, 405–425 million years ago; it was possibly the first animal to live on land and to take oxygen directly from the atmosphere. Amphibians had yet to evolve.

WHEN DINOSAURS RULED THE EARTH

During the Jurassic period, 150 million years ago, small animals evolved that gave birth to live young and nourished them with secretions from the female's skin. Reptiles, especially dinosaurs, dominated the animal world at the time, and these first mammals remained relatively inconspicuous for millions of years.

VERY HANDY

Fifty to sixty million years ago, the first primates—small lemurs and tarsiers—evolved. The arboreal, nocturnal mammals developed binocular stereoscopic vision and five-fingered hands to cope with their environment. Their great-great grandchild, *Homo sapiens*, would eventually rule the earth.

PLANET OF THE APES

Thirty million years ago the first apes began to evolve from their primate ancestor, the monkey. The apes, who would eventually evolve into the modern gibbon, orangutan, chimpanzee, gorilla, and man, developed brachiation—locomotion by overarm swinging, a high ratio of brain volume to spinal cord volume, and complex social and child-rearing behavior.

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Ancient Kos is mentioned in the *Iliad* as an ally of the Greeks. It was settled by Dorian Greeks from the northern Peloponnesus and became the birthplace of Ptolemy II (Ptolemy Philadelphus), the poet Theocritus, the painter Apelles, and the physician Hippocrates, who founded a school of medicine there. It was occupied by Alexander the Great in 336 B.C. and in the ensuing centuries was controlled by Persians, Greeks, Egyptians, and Romans. It was captured by the Ottoman Turks in 1523, occupied by Italy in 1912, and was ceded to Italy by the Treaty of Lausanne in 1924 and then to Greece by the treaty of peace with Italy in 1947. Population: (1971) of the island, 17,939; of the city, 7,828.

KOSCIUSKO, Mount, kos-ē-us'kō, a mountain in southeastern New South Wales, Australia. It is located in the Snowy Mountains of the Australian Alps and, with an altitude of 7,305 feet (2,228 meters), is Australia's highest peak. It is snow-covered from May to September and bears evidence of Ice Age glaciation. The Snowy, Murray, and other rivers that form important units in the Snowy Mountains Hydro-Electric Scheme are fed by its snows.

The mountain was named by Sir Paul Strzelcki in 1840 after the Polish patriot Tadeusz Kościuszko. It rises in Kosciuszko National Park, a preserve of about 2,070 square miles (5,370 sq km), and is a major ski resort during the winter.

KOŚCIUSZKO, kōsh-chōōsh'kō, **Tadeusz Andrzej Bonawentura** (1746–1817), Polish statesman and soldier, who fought in the American Revolution and led an uprising for national independence in his homeland.

Tadeusz (often written Thaddeus in English) Kościuszko was born in the Polish village of Merczowoszczyno on Feb. 4, 1746, to a family of noble origin. He began his military education at the Warsaw Corps of Cadets and then continued it in Germany, France, and Italy, specializing in fortification. He returned to Poland in 1774.

In 1776 he fled to France to escape the consequences of a love affair. He went on to America and joined the colonists in their war for independence from Britain. From 1778 to 1780 he supervised the fortification of West Point, and he later served under Gen. Nathanael Greene as an engineer and a cavalry officer. He ended the war as a brigadier general. Kościuszko's involvement in America's struggle for independence influenced his later life.

He returned to Polish service in 1784 and in 1792 led Polish troops against Russian forces that had invaded Poland to suppress the reformist constitution of May 3, 1791. When the Russians completed their occupation of Poland and forced Poland's King Stanislaw II to renounce the constitution, Kościuszko went into exile. An underground resistance movement was formed in Poland in 1793 and Kościuszko was asked to lead it. Before a tumultuous gathering in Kraków in 1794, he vowed to restore Poland's independence. In his role as political and military head of the Polish insurrection, he exercised virtually dictatorial power. To promote greater equality throughout Polish society he issued the *Polaniec* Proclamation on May 7, 1794, which declared the serfs free. In April 1794 he routed the Russians



General Kościuszko figured prominently in both the American and the Polish struggles for independence.

at Raclawice, leading an army that included peasants wielding pikes and scythes. But in October the Polish army was beaten at Maciejowice, where Kościuszko was wounded and taken prisoner. The insurrection collapsed and the final partition of Poland took place. Kościuszko was imprisoned in Russia until 1796.

In 1797 he traveled to the United States and established a lasting friendship with Thomas Jefferson. He hastened back to Europe in 1798 where the ferment caused by the rise of Napoleon encouraged him to believe he could advance Poland's cause. He discovered, however, that a restored democratic Poland did not suit the goals of any European power. His proposal to Czar Alexander I in 1814 to establish a large Polish state with a liberal social order was also ignored. After this rebuff Kościuszko retired to Solothurn, Switzerland, where he died on Oct. 15, 1817. He was buried in Kraków's cathedral alongside the Polish kings.

Kościuszko's life spanned the entire era of 18th century democratic revolutions, of which he remains an outstanding figure. It is an irony of history that his ideas were ahead of their time in his own homeland.

PETER CZAP, JR., *Amherst College*

Further Reading: Gardner, Monica M., *Kościuszko* (1920; rev. ed., Norton 1942); Haiman, Mieczyslaw, *Kościuszko in the American Revolution* (1943; reprint, Kościuszko Foundation 1975); id., *Kościuszko, Leader and Exile* (1946; reprint, Kościuszko Foundation 1977).

KOSHER, kō'shar, in Judaism, a term that designates whether foods individually or in combination, or their mode of preparation or processing, are in accordance with biblical and rabbinical rules. The term *kosher* (the Ashkenazic form of *Kasher*) means "clean" or "proper," and the system of dietary laws is known as *kashrut*. Orthodox and Conservative Jews are obliged by tradition to "keep kosher," whereas Reform Jews are not. See **DIETARY LAWS**.

Can Science Education Be Saved? Feb 15, 1991

Three ambitious but very different projects are testing a variety of ways to overhaul an education system that has been getting failing grades

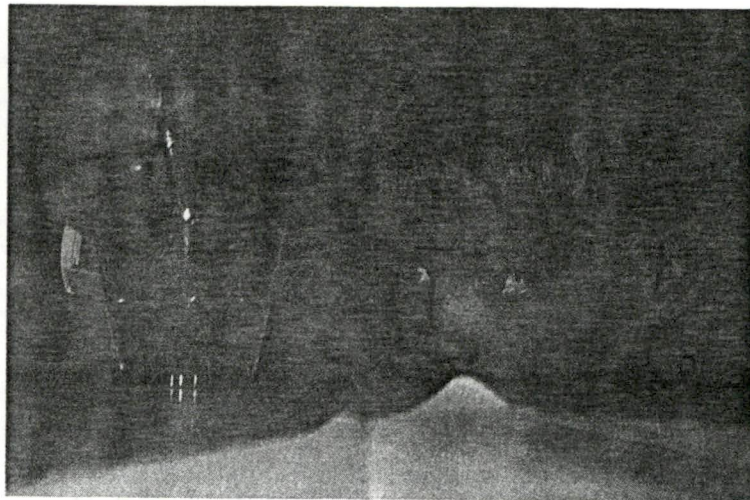
WISCONSIN 9TH GRADER Joel Marino has already decided at age 14 that science is bad news, but he's pretty content with the project his earth science teacher gave him last September: building a working, three-dimensional model of a mid-ocean ridge. To Joel, "This project is more recreational. It's not from the book, you don't have to memorize stuff, and you can work together. Also, it's not due tomorrow. It's not like real science."

Joel's dreary image of "real science"—sitting alone memorizing books—will

come as no surprise to anyone who has heard the litany of reports on the dismal state of U.S. science and math education. But the scope and ambition of current efforts to attack the problem may be surprising. After 7 years of gloomy warnings about the problem, legions of teachers and scientists are together launching a reform movement the likes of which hasn't been seen since Sputnik. And scientists are playing an increasingly important role in the revolution.

As individuals, scientists across the nation are trying to advise and cajole their local school boards and the teachers of their children to teach science in a more compelling manner. Some scientists have even taken on entire school systems—Nobel prize-winning physicist Leon Lederman is leading an effort to reform science curricula and teaching throughout the city of Chicago (*Science*, 31 August, p. 979). But if there is to be reform on a national scale it will likely require more than the heroic efforts of individuals.

During the past few months, *Science* has looked at three national reform programs, each dedicated to heeding Joel's message, but each pursuing a rather different route to the grail of getting kids intellectually involved in science. One is a long-range effort sponsored by the American Association for the Advancement of Science (AAAS is also the publisher of *Science*); the second, run by the National Science Teachers' Association, is concentrating on more immediate goals;



Hands on. Third graders in McFarland, Wisconsin, learn about dilution through direct experimentation with eyedropper and colored water.

and the third, a project of the National Council of Teachers of Mathematics, is trying to overhaul the content and style of math courses. Will these programs—or any others around the country—succeed? No one can answer that question today. But these efforts to use classrooms as laboratories for education experiments—to permit hands-on, creative, even noisy environments for "real science"—will receive their own grades in the coming years, as local districts decide whether to jump on the reform bandwagon or cling to the status quo.

To Joel, the folks who came up with his plate boundary project deserve—well, at least a B. While the specific project isn't part of a reform program, Joel's teacher, Joe Cabibbo, is a member of a revolutionary cadre of teachers and scientists involved in what is arguably the most ambitious of all the efforts: the AAAS's Project 2061. Named for the year Comet Halley returns to Earth, Project 2061's long-term goal is nothing less than the complete transformation of science, math, and social studies teaching from kindergarten through 12th grade. No part of the present system is considered sacred. Subjects, textbooks, grades—all are under scrutiny, and if this project somehow winds up flunking as a revolutionary movement, it will at least have earned an A for effort.

Project 2061 is developing its vision in three stages: First, decide what students

need to know; second, illustrate how they can learn it; third, spread the revolution around. In stage one, teams of prominent scientists delineated what every high school graduate should know about science in a 100-page exposition published in 1989 titled "Science for All Americans." The book emphasizes concepts over data and considerably lightens the burden of facts students must know. Oxidation and isotopes are in; the periodic table is out.

Not every reviewer loved the book. "Still No Beef," complained an editorial in

The Washington Post, saying Project 2061's "lofty theorists" had put off the work of developing a curriculum. Of scientists' reactions to their colleagues' work, Project 2061 director F. James Rutherford sighs, "They always want more of their own discipline in there."

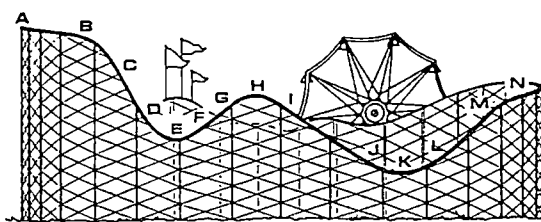
But many educators and scientists have endorsed both the book and the entire project as a vision of what education could become. "For the first time we have a total representation of what should constitute science education," says Luther Williams, head of education and human resources at the National Science Foundation. NSF has provided more than praise; it chipped in over \$2 million for the project's \$8.5-million second phase. IBM, the Department of Education, AAAS itself, two private foundations, and state and local governments made substantial contributions.

The *Post*'s criticisms are being answered—slowly—by this crucial second phase, now under way at six sites around the country: Philadelphia; McFarland, Wisconsin; rural Georgia; San Antonio; San Francisco; and San Diego. This time, it's the teachers who are in charge. Their mission: to design a new type of curriculum that carefully builds an accurate picture of the way the world works. With support from scientists, they're translating the concepts in "Science for All Americans" backward into simple ideas children can understand, reorganizing the

book's knowledge into a framework for curricula. For example, a high school understanding of organ systems might begin with the simple statement: "Things go on inside my body that I can't see." That seems obvious, but kids need to thoroughly comprehend it before they attempt to understand body processes, 2061 teachers say.

This type of work, more conceptual than concrete, draws critics such as the director of a smaller science education program, who extended the *Post's* complaint to stage two and told *Science* that 2061 was too idealistic and slow. But the project was never intended to make change quickly, responds Rutherford. This is to be a thorough and therefore slow revolution. If the models are any good, AAAS expects the rest of the nation to join the revolution, district by district, throughout the decade and later. But Rutherford himself concedes that 1993 will be the watershed year for the project. That's when the curriculum models will be unveiled and a few vanguard districts are expected to start putting the 2061 philosophy into practice. And that's when critics will finally have something tangible to endorse or reject.

Here is a picture of a roller-coaster track:
Sketch a graph to show the speed of the roller coaster versus its position on the track.



But even if 2061 were to get the seal of approval from the scientific and education communities in 1993, the project's Achilles' heel may be the decades required by stage three. AAAS knows the risk, and took it, because it felt that every quick fix previously tried in the U.S. educational system had eventually fallen before the multi-headed monster that has parceled out authority across 50 states and 80,000 schools. Reformers might change any one piece of the system—say, by training teachers differently—but the other pieces, such as textbooks, standardized tests and school boards, will drag teachers back to the status quo. So, for good or ill, AAAS opted to try to change the entire

Graphic example. A sample problem from the new math standard (Source: "Reshaping School Mathematics: A New Philosophy and Framework for Curriculum," National Academy Press, 1990.)

system. As Rutherford puts it, "We can't overwhelm that system; we've got to out think it."

But schools can't wait years to improve. While members of Project 2061 dream of the possibilities,

other science teachers, through the National Science Teachers Association (NSTA), have spearheaded another massive project called Scope, Sequence, and Coordination (SSC). NSF coughed up an even larger amount for this teacher-based program—\$8.6 million—and the Department of Education awarded an additional \$2.5 million (*Science*, 31 August, p. 978). Focusing on grades 7 through 12, the project is already in classrooms in three sites—California, Iowa, and Houston—and planning is under way in two more, Puerto Rico and North Carolina.

It works something like this: Seventh graders in Houston don't study the life and physical sciences separately, but instead learn

The Reform Agenda: Emerging Consensus

It may be a time of experimentation for science education, but many trials are testing the same hypotheses. Some common themes are emerging from the patchwork of programs:

■ **Less is more.** It's time for kids to stop memorizing the difference between a type I and type II lever and the names of all the molecules involved in photosynthesis. One study estimated that students encounter more new words in a high school biology book than in 2 years of instruction in a foreign language.

"We still live with the Victorian view of school, with minds trained like dogs to memorize things," says Timothy Goldsmith, chair of the committee that wrote a recent report on biology education for the National Research Council. New programs have kids doing more projects and less memorizing.

■ **Teacher power.** Post-Sputnik reforms sometimes took the tone of academic highbrows telling teachers what to do, and teachers have taken much of the blame for education's ills. But the new goal is to boost teachers, not bash them, giving them time to learn science themselves, rather than berating them for their backgrounds.

■ **Science without walls.** Sixth graders in rural Elbert County Georgia don't take science, math, social studies, or reading. Instead, they take one big course—200 minutes run by four teachers—that incorporates all four subjects. A trial balloon floated by members of Project 2061, the course illustrates the push for integrating subjects. Real life problems rarely come labeled as "chemistry" or "math," educators say. How far should such course integration go? Each program seems to have a different answer. Meanwhile, Georgia teachers are still seeking a good moniker for their mega-course.

■ **Do it yourself.** At the end of the school day in inner-city Philadelphia, teachers gather to learn how to separate salt from pepper using static electricity. They're being trained to use an elementary science kit, doing all the experiments their students will do. A staple of the 1960s reforms, hands-on activities are back and better, with a new emphasis on quality—"minds-on" as well as hands-on. Teachers are to be trained more carefully and given the logistic support they need.

■ **Two-way traffic.** Kids haven't understood much of what we've been telling them, in part because we haven't listened to the ideas they already have. For example, research shows that many youngsters don't understand the concept of temperature. They think putting on a sweater keeps you warm because sweaters always exist at a higher temperature. Listening to kids can give teachers clues on how to change such ideas.

■ **Science for everyone.** It's vital to widen the science career pipeline, especially to include more women and minorities. Reformers now also recognize a second goal: producing scientifically literate citizens. Even students who will never become scientists need to understand more about how the world works. New programs are aimed at all students, not just the gifted.

■ **Matchmaker, matchmaker.** Scientists and teachers come from very different worlds. Elementary teachers often opted out of science as soon as they could, but they know their business—kids. Meanwhile many scientists would like to help with science education, but don't know how to do it. "We're like a long-term marriage broker," says F. James Rutherford of Project 2061. "Our job is finding useful work and structures where both sides can interact."

■ E.C.

experiment. A second concern is that SSC teachers are being asked to do too much. NSF's Williams, though clearly an overall booster of SSC, nevertheless warns, "In my view, the greatest potential liability of the program is the preparation of the teachers." Indeed, several Houston life science teachers hadn't had chemistry since high school and never took physics, but are now required to teach both. NSTA officials say they've built in teacher supports, such as summer workshops and detailed training sessions. Aldridge himself gave a workshop on "Floating and Sinking" to the Houston teachers. "Most of them hadn't had any physics, and they didn't have any trouble with it," he says.

Ironically, while Project 2061 is criticized for being too slow, SSC gets accused of moving too fast to make real change. Several education experts, including one involved

zations, after a period of initial jostling over their respective roles the two programs have endorsed each other, with Project 2061 staking out the long-term vision and SSC moving ahead now. But no matter how cordial science educators seem, they've a long way to go before reaching the solidarity of the math community, which is sponsoring a third great challenge to the educational status quo in the United States.

While science educators experiment with course integration and current events, and argue about what to toss out of the curriculum, they watch with envy as the math community calmly describes what to teach and how to teach it. Mathematicians have already wrestled with the tough curricular questions and are moving swiftly toward implementing reform. Last year, math curriculum standards for all grade levels were issued in the form of a 250-page book that was almost universally endorsed. The sequel comes next spring, when another book on professional standards will explain how teachers can reach the curriculum goals.

Part of the smooth progress in math seems to come from the cozy relations between mathematicians and math teachers. The National Council of Teachers of Mathematics (NCTM) developed the standards, but works closely with representatives from the math community on the Mathematical Sciences Education Board (MSEB), an arm of the National Research Council. "The degree to which people agree is amazing," says Iris Carl, who happens to be both president of the teachers' group and vice-chair of the education board.

Mathematicians have an easier time reaching consensus because their field doesn't encompass sub-disciplines as diverse as those in science, Carl says. Also, almost everyone, including parents, believes kids should learn math starting on the first day of school. Of course, most parents think math = multiplication tables, and popular opinions can be a burden as well as a blessing, says MSEB executive director Kenneth Hoffman. "Math came to replace Latin in the minds of some people. It's one of those things you do because it's good for you, to teach you neatness, discipline, and order."

Lovers of discipline are in for a bit of a surprise. The draft version of the professional standards describes a different style of classroom. Youngsters work and talk in groups, explaining problems to each other. Calculators and computers are everywhere and thinking skills and reasoning are emphasized. Kids are to spend less time laboriously plotting points and more time understanding graphs—after a computer does the plotting. It sounds great, but what if the 12-year-olds resist engaging in "mathematical



Human development. Philadelphia high school student giving presentation in class taught by a Project 2061 team member.

with SSC itself, told *Science* they worried that at some sites the project could become a cosmetic reshuffling of the old curriculum. Aldridge counters that on his advice the NSF funds are conditional on an annual show of progress. If a center doesn't seem to be doing the job, NSF can simply yank it off the project—and perhaps substitute a willing newcomer from a growing pool of states eager to join the program. Also, NSTA officials say they expect change to snowball, as other parts of the system accommodate the project. In conjunction with SSC, California has already begun to use new hands-on tests so unusual that some 6th graders asked to take them again, says Tom Sachse, coordinator of the California site.

While SSC and 2061 compete for funds and are sponsored by very different organi-

discourse" and chatter about rap music instead? Be patient, counsel the math wizards.

"I tell people over and over: Don't expect it to happen overnight," says Shirley Hill, former chair of MSEB and professor of math and education at the University of Missouri. "Kids are conditioned otherwise and they're not going to expect math to be fun or relevant all of a sudden. It's a process." The best math teachers already run classrooms like those in the standards, says Carl.

For reform to spread, educators say it's important that all these projects—and many smaller ones not mentioned here—work together, or at least pull in the same direction. "No one will succeed in isolation," says Williams. But while there's much agreement on what teachers should strive for, each program has a slightly different vision of the future. It's not exactly clear, for example, how the new math standards fit with "Science for All Americans," which includes math, but less of it.

And new programs are coming. The Na-

tional Academy of Sciences, for example, is expected to decide upon a much-expanded role for itself in science education in late December. A few educators who work for existing programs fear the academy will repeat or compete with their efforts, although executive officer Philip Smith insists the institution won't invade any turf. Academy officials are still plotting their strategy and Smith defers any detailed revelations until later this month. But he says they're considering a two-pronged approach, to provide immediate relief as well as long-term vision. And he hints that the academy may tackle undergraduate instruction, an arena where other educators say they'd especially welcome the academy's clout.

For the moment, all sides tend to downplay whatever differences may exist. "It doesn't hurt at all to have different experiments going on simultaneously," says Susan Snyder of NSF's division of teacher preparation and enhancement. "We'll probably never have one single answer."

Snyder and other educators would prefer to focus instead on the momentum for change. The president and National Governors' Association, they boast, have announced the goal of having U.S. students first in math and science by 2000. Privately, though, almost no one thinks that can be done. At least, those involved plaintively conclude, the goal is on the national agenda. The unspoken question: How long will our easily distracted society keep it there? Back in Wisconsin, Joel Marino had the perseverance to complete his model of a mid-ocean ridge with chicken wire, blue plastic, kitty litter, and a mysterious red substance that quickly developed fruit flies. If the education experts succeed equally well with their own models, then Joel—or at least his younger siblings—may one day admit that science and recreation can sometimes be the same thing. ■ ELIZABETH CULOTTA

Elizabeth Culotta is a science writer for the Milwaukee Journal.

Computer Security: NAS Sounds the Alarm

Electronic vandals, viruses, and other malignancies of the computer world are likely to grow more virulent soon, according to a new report from the National Research Council. Indeed, a panel of computer security experts chaired by David Clark of the Massachusetts Institute of Technology warns that unless preventive action is taken, the economy could suffer. In a study titled "Computers at Risk," the panel calls for the establishment of an Information Security Foundation, a private nonprofit body that would set standards, promote research, and review the "trustworthiness" of computer software and hardware. It would require federal support to get started, says one panel member, and after that, it could support itself with membership dues.

"To date, we have been remarkably lucky," the report begins. Money has been stolen by computer—perhaps millions of dollars from credit card companies alone—and "lives have been lost because of computer software errors." But no intruder has been able to "subvert" a critical system. Yet the report warns that "there is reason to believe that our luck will soon run out."

The reason: Little is being done outside the government to reduce the vulnerability of computer networks, even though the nation's reliance on them is growing. For example, no concerted effort has been made to plug the many faults of personal computers, which are difficult to make secure because of the way they were designed. As network linkages grow, more PCs will be connected, and the weak points in systems will increase. "There's no doubt that things get considerably more dangerous when you get unprofessionally administered machines on networks," says panel member M. Douglas McIlroy of AT&T Bell Laboratories.

Most computer and software manufacturers have failed to take the risks of attack seriously, responding to problems as they occur in an "episodic and fragmented" fashion, says the report. And within government, computer security work is concentrated in the National Security Agency, which has been constrained by its secrecy and its national defense mission.

However, McIlroy points out that between 1983 and 1990, the NSA ran an advisory body "outside the perimeter" of secrecy called the National Computer Security Center. It set public standards and served as a clearinghouse for research. This was a valuable service for the handful of companies—like his own AT&T—that wanted to develop better defenses. But this year, the NCSC went back "behind the wire" of secrecy, McIlroy says, and it's not clear that any other office will step in to serve the public. The National Institute of Standards and Technology (NIST) might fit the bill, but the report comments that NIST "has limited technical expertise and funds" to do the work. Congress gave it only \$2.5 million for computer security programs in 1990; when NIST attempted to double this budget for 1991, the increase was axed by Congress.

Meanwhile, companies are reluctant to advertise security problems. Their customers often aren't convinced that they're real. Unless they have been stung themselves, says McIlroy, they may not want to bear the costs of improving systems. Many computer users try to get around the problem in a superficial way, using security gimmicks of one kind or another. As a result, hundreds of products are offered for sale, but there's no objective means of judging their quality. The Clark report recommends several actions, in addition to creating a new foundation:

- Establish guidelines for "trustworthy systems" that reflect the consensus of security experts.
 - Take a series of immediate short-term actions such as creating emergency response teams and asking vendors to ship products with security systems automatically turned "on."
 - Create a system to monitor security breaks and to collect data on them for research.
 - Clarify a confusing jumble of export controls and consider relaxing limits on the use of the U.S. Data Encryption Standard.
 - Develop and fund a comprehensive program of research on computer security issues.
- ELIOT MARSHALL

EDWARD F. DENISON



Trends in American Economic Growth, 1929-1982



per Steve Olson, OSTP, x 5860 :
(Feb. 13, '91; 3pm)

$\frac{1}{2}$ of ec. growth per employed person
-OR-

$\frac{1}{3}$ of ec. growth



THE BROOKINGS INSTITUTION
Washington, D.C.

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*Advances in Knowledge and Miscellaneous Determinants*⁵¹

Advancing knowledge of ways to produce at low cost is the biggest and most basic reason for the persistent long-term growth of output per unit of input. The term "advances in knowledge" covers both technological knowledge and managerial and organizational knowledge. It includes knowledge originating in this country and abroad, and knowledge obtained in any way: by organized research, by individual research workers, and by simple observation and experience.

The term must, however, be limited in a study of the sources of growth of any output series to those advances in knowledge that allow the same amount of *measured* output to be obtained with less input. This limitation automatically excludes knowledge applied outside the business sector. It also excludes new knowledge that leads to "unmeasured" quality change in the final products of the business sector. The introduction of new and improved products for final sale from the business sector to consumers and government provides the buyer with a greater range of choice or enables him to meet his needs better with the same use of resources, but it does not in general contribute to growth as measured; rather, it results in unmeasured quality change. Hence advances in knowledge that permit business to supply households and government with final products that are different from those previously available are excluded.

Organized R&D conducted in the United States of the type covered by the National Science Foundation series for R&D expenditures contributed an estimated 0.2 percentage points, or, at most, 0.3 points to the growth rate of measured output in nonresidential business during the postwar period.⁵²

51. Besides the tables indicated in footnote 34, data relating to this determinant appear in table 4-4.

52. For a discussion of these estimates see *Slower Growth*, pp. 123-26; Zvi Griliches, "R&D and the Productivity Slowdown," and Edward F. Denison, "Comment," both in *American Economic Review*, vol. 70 (May 1980, *Papers and Proceedings*, 1979), pp. 343-48, 354-55; Barry P. Bosworth, *Tax Incentives and Economic Growth* (Brookings, 1984), pp. 32-33; and citations in these sources. As I explain later (in chapter 3), a higher estimate by John W. Kendrick is not comparable, nor pertinent to an explanation of changes in any existing output series, because Kendrick is really estimating what R&D would have contributed to an imaginary output series that would be obtained if the rise in output could somehow capture the welfare benefits from new and improved final products. Kendrick has implicitly recognized this situation by noting that the part of R&D "that results in cost reduction increases productivity and the part that results in new and improved consumer goods increases satisfaction. However, . . . real product and productivity estimates are generally considered to understate growth to the extent that there have been net

To obtain such estimates, the dollar value of the contribution of R&D to yearly growth is calculated by multiplying the annual cost of R&D expenditures of types that, if successful, will raise measured output per unit of input by a social rate of return on such R&D expenditures (estimated to be extremely high) that is based on sample studies (mainly, the admirable work of Edwin Mansfield and his collaborators). Sometimes a deduction is made for estimated obsolescence on knowledge acquired from previous R&D.⁵³ Unfortunately, there is no way to estimate directly the contribution of advances in knowledge derived from any other source, or all other sources, to the growth rate of output per unit of input in nonresidential business.

The combined contribution of changes in all determinants of output that were not directly measured on an annual basis, including advances in knowledge and a group of miscellaneous determinants, is obtained by removing from the growth rate of output the effects of changes in all determinants that were so measured. Table 5-1, column 12, shows an index constructed in this way. From 1948 to 1973 it grew at an annual rate of 1.38 percent (table 5-3).

improvements in the quality of goods and services." See John W. Kendrick, *The Formation and Stocks of Total Capital* (New York: National Bureau of Economic Research, 1976), pp. 9-10. To obtain the contribution of R&D to growth of measured output, either R&D that does not contribute to measured productivity must be excluded or, if such R&D is counted, the rate of return must be lowered by including it with a zero rate of return.

53. The estimates assume, I believe correctly, that but little knowledge that raises measured output results from the spinoff of findings of military research to commercial applications. Richard R. Nelson finds that whatever spinoff may once have occurred, it dwindled away decades ago as military hardware became more specialized and distinct from its civilian counterparts (as in the case of the airplane) or became concentrated in areas without civilian counterparts. See Richard R. Nelson, "Policies in Support of High Technology Industries," Working Paper 1011 (Institution for Social and Policy Studies, Yale University, July 1984). David M. Levy and Nestor E. Terleckyj infer from correlation analysis that federally financed R&D has an effect on commercial output but that it does so by stimulating government contractors to increase their private expenditures on R&D in order to adapt their findings to commercial products. See David M. Levy and Nestor E. Terleckyj, "Effects of Government R&D on Private R&D Investment and Productivity: A Macroeconomic Analysis," paper presented to the Southern Economic Association, Atlanta, November 11, 1982. Edwin Mansfield reached a similar conclusion based on a questionnaire survey ("Engineering Employment, Federal Funding, and Company-financed R&D Expenditures," paper presented to the American Economic Association, New York, December 1982) while Frank R. Lichtenberg reached the opposite conclusion ("The Relationship Between Federal Contract R&D and Company R&D," *American Economic Review*, vol. 74 [May 1984, *Papers and Proceedings*, 1983] pp. 73-78). Because all private expenditures are counted, when appropriate, in computing the estimate of the contribution of R&D to the growth rate that is cited in the text, the estimate includes any positive or negative effect of government expenditures on private R&D.

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In the past I have interpreted the movement of this index from 1948 to 1973 (but not thereafter) as an acceptable approximation of the contribution made to growth by the incorporation of new knowledge into the process of production. Because the effects of so many determinants were measured, this series is far more refined than the indexes of output per hour worked and unit of capital that have often been identified as measures of "technical progress."⁵⁴ However, my interpretation was based on more than improvement upon precedent. It was supported by the following considerations.

First, and most important, the index displayed the stable growth that an index measuring the contribution of advances in knowledge would be expected to show in the world's most advanced, largest, and most diversified economy. From 1948 to 1973 it rose every year. Moreover, it did so at a rather steady rate. In the three shorter periods in this time span its growth rates were 1.33 percent, 1.34 percent, and 1.46 percent. Irregularities in the size of the annual increases were scarcely greater than one might have expected from calendar differences alone, even though the series picks up the effect of errors in the output measure as well as certain errors in the indexes for other output determinants.

A second consideration was that similar residual estimates for other countries revealed a pattern that appeared reasonable for the contribution of knowledge.⁵⁴ In brief, despite large differences in the growth rates of output, the residuals were fairly similar in the United States and other advanced Western countries and moderately higher in Japan—a pattern that conformed to the accepted belief that in Japan technology was moving up toward the much higher levels prevailing in the West. The fact that the growth rate of the index had increased from earlier periods in the United States itself was also in accord with usual beliefs about the pace of new knowledge.

Finally, although I had not attempted annual estimates for the miscellaneous determinants that may affect the residual index, I had attempted to quantify the contribution of some of them over longer periods and to judge the possible magnitude of others.⁵⁵ My conclusion was that the effects of the miscellaneous determinants probably were small and

offsetting. Confidence in this conclusion, as applied to 1948–73, is weakened by experience after 1973, when miscellaneous determinants apparently exerted a large negative effect on growth. Although there are reasons why miscellaneous determinants should have changed more after 1973 than before, it is not clear why their effect was so large. Despite this later experience, I still consider that the 1.38 percent growth rate of the residual provides a reasonable estimate of the contribution of advances in knowledge in 1948–73.

The growth rate of the residual is also, I believe, an acceptable estimate of the contribution of advances in knowledge in 1941–48. It was 1.11 percent. Interpretation of the 0.34 percent growth rate in 1929–41 is more dubious. In a previous examination of the period I concluded that restrictive practices introduced during the Depression that affected the miscellaneous determinants restrained the growth of output per unit of input, but probably were not responsible for much more than one-tenth of a percentage point of the difference between the 1929–41 and 1948–69 growth rates.⁵⁶ Advances in knowledge evidently contributed much less to growth in 1929–41 than in 1948–73.

The behavior of the residual series since 1973 has been altogether different from anything that has gone before (tables 5-1 and 5-3). Its growth rate dropped by 1 full percentage point, or 72 percent, from 1948–73 to 1973–78, and by an additional full percentage point from 1973–78 to 1978–82. In 1973–78 the growth rate was about as low as it had been in 1929–41, and thereafter it was actually negative by a substantial amount, –0.66 percent, in 1978–82 and was probably little different in 1978–83. The peak in the index to date was reached in 1978. The decline in the growth rate after 1973 was abrupt, with no hint of slackening through 1973 and a sudden decline thereafter. Moreover, since 1973 the index has behaved erratically, rising in four years and falling in five.

It is not plausible that an index measuring the contribution of advances in knowledge would have behaved this way. I can only conclude that some of the miscellaneous determinants of output were responsible for the collapse in the growth rate of the residual and its erratic movement. I offer this opinion

54. Edward F. Denison, "A Cross-Country View of the Contribution of Knowledge to Economic Growth," published in Russian translation in T. S. Khachaturov, ed., *The Soviet-American Symposium of Economics* (Moscow, 1978), pp. 39–46.

55. Examples of such estimates are scattered throughout my writings. See Denison, *Sources of Growth*, chaps. 15–20; *Why Growth Rates Differ*, chaps. 3, 9, 17 (part 3), 18, parts of chaps.

12, 20, 21, and appendixes M, N; *Accounting for Growth*, pp. 76–79; *Slower Growth*, pp. 81–83 and chap. 9; and "Accounting for Slower Economic Growth: An Update," pp. 21–37.

56. *Accounting for Growth*, pp. 81–82. An alternative way of measuring real output—using current price weights for each decade instead of the same weights for all periods—would also narrow the differences between periods.

even though, as the next chapter indicates, the evidence is insufficient to establish conclusively which of the many developments suspected of being the culprits responsible for the collapse were really to blame.

This conclusion leaves no way to measure what actually happened to the contribution of advances in knowledge after 1973. It is not unlikely that the contribution was reduced. The period from World War II to 1973 was one in which, it appears, progress in all types of knowledge was exceptionally fast by historical standards. A gradual falling back to longer term rates would not have been surprising. However, there is no certainty that such a decline occurred.

In the following section I summarize estimates of the sources of growth of output over the 1929–82 period as a whole. Solely for this purpose I assume (reasonably) that the residual series measures the contribution of advances in knowledge from 1941 to 1973; and (as guesses) that the 0.34 percent growth rate of the residual from 1929 to 1941 consisted of a 0.45 percent rate for advances in knowledge and a –0.11 percent rate for miscellaneous determinants, while the –0.07 percent growth rate of the residual from 1973 to 1982 consisted of a 1.00 percent growth rate for advances in knowledge and a –1.07 percent growth rate for miscellaneous determinants. This procedure results in an estimate that advances in knowledge contributed 1.07 percentage points to the 1929–82 growth rate of total potential national income in nonresidential business, while miscella-

neous determinants subtracted 0.21 points. Neither source affects growth of measured output in the other sectors, and so these sources contributed smaller amounts to the growth rate of potential national income in the whole economy: advances in knowledge, 0.84 percentage points, and miscellaneous determinants, –0.16 points. Reasonable variations in the numbers used for 1929–41 and 1973–82 would not greatly change these results.

Sources of Long-Term Growth

Detailed estimates of the contributions that the output determinants made to the growth rates of various output series during each of the eleven standard periods are shown in tables 7-1 to 7-4 and 8-1 to 8-4. These sources-of-growth tables are provided for four measures of total national income and four of national income per person employed, as well as for output per unit of input, a subtotal given in the tables. The tables show the number of percentage points contributed to the growth rate.

The tabulation below condenses growth sources into ten groups and shows the percentage of the growth rate of each of the eight output series contributed by each group of determinants over the fifty-three years from 1929 to 1982. This tabulation identifies the sources of growth in the United States over the longest period presently possible. However, these distributions should not be regarded as “normal” or “typical” patterns. The data in this study

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Contributions to 1929–82 growth rates

	<i>Potential national income</i>				<i>Actual national income</i>			
	<i>Total</i>		<i>Per person employed</i>		<i>Total</i>		<i>Per person employed</i>	
	<i>Whole economy</i>	<i>Nonresidential business</i>	<i>Whole economy</i>	<i>Nonresidential business</i>	<i>Whole economy</i>	<i>Nonresidential business</i>	<i>Whole economy</i>	<i>Nonresidential business</i>
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Growth rate	3.2	3.1	1.6	1.7	2.9	2.8	1.5	1.6
Percent of growth rate								
All sources	100	100	100	100	100	100	100	100
Labor input except education	34	25	–13	–23	32	20	–12	–25
Education per worker	13	16	26	30	14	19	27	34
Capital	17	12	15	10	19	14	20	13
Advances in knowledge	26	34	54	64	28	39	55	68
Improved resource allocation	8	11	16	19	8	11	16	18
Economies of scale	8	11	17	20	9	12	18	22
Changes in legal and human environment	–1	–2	–3	–4	–1	–2	–3	–4
Land	0	0	–3	–4	0	0	–3	–3
Irregular factors	0	0	0	0	–3	–5	–7	–8
Other determinants	–5	–7	–10	–13	–5	–8	–10	–13

show that patterns have changed from period to period, and other studies show that they have differed widely among countries.⁵⁷

The greatest interest attaches to the estimates for potential output shown in the first four columns. The first column of the tabulation analyzes the growth of potential national income in the whole economy. By the classification adopted, six groups of sources made positive contributions to this growth rate. The largest contribution, 34 percent of the growth rate, is identified in the table as coming from the increase in "labor input except education." It represents the increase in the amount of work done in our economy, when account is taken of the number, working hours, and characteristics of workers (except their education) and of the effect of changes in the hours of work upon the work done in an hour. Second largest, at 26 percent, is the incorporation into the productive process of advances in knowledge of how to produce at low cost. Third, at 17 percent, is the increase in the services provided by four types of capital. Fourth, at 13 percent, is the increase in the level of education of persons employed in the nonresidential business sector. (If the two components of labor input are combined, they account for nearly half—47 percent—of the growth rate.) Fifth and sixth, at 8 percent each, are gains from economies of scale and the reduction in the overallocation of labor to farming and to nonfarm self-employment. Land and irregular factors neither added to nor subtracted from this growth rate. Three changes in the legal and human environment subtracted an amount equal to 1 percent, and other determinants an amount equal to 5 percent, of the growth rate. The latter consists of the amount allocated to miscellaneous determinants in the preceding section, with a slight offset from the inclusion of the dwellings occupancy ratio.

The second column analyzes the growth of potential output in the nonresidential business sector alone. When the other three sectors are eliminated, the contributions of labor input and of capital are reduced and the contributions (positive or negative) of the other sources are increased. The reason is that all growth in the government, households, and institutions sector is ascribable to labor input except education, and practically all growth in the services of dwellings and international assets sectors is ascribable to capital. Advances in knowledge were much the largest source of growth in nonresidential business, followed by labor input except education.

The third column of the tabulation analyzes the growth of potential output per person potentially employed in the whole economy. To an important extent this growth rate was the net result of offsetting positive and negative influences. Five of the ten groups of determinants contributed an amount equal to 128 percent of the growth rate, one (irregular factors) did not affect it, and four subtracted an amount equal to 28 percent.⁵⁸ When expressed in percentage points, the contributions of education per worker, advances in knowledge, improved resource allocation, economies of scale, changes in legal and human environment, irregular factors, and "other determinants" are all practically the same as their contributions to the growth rate of total potential output in the whole economy, but when expressed as percentages of the growth rate, they are about twice as large. The contribution of advances in knowledge equaled 54 percent of this growth rate. On a per person employed basis, labor input except education declined and made a negative contribution equal to 13 percent of the growth rate because of declining average hours (including the effect of an increase in part-time employment) and the change in the demographic composition of hours worked. Land per person potentially employed also declined and subtracted an amount equal to 3 percent of the growth rate.

The fourth column refers to potential national income per person potentially employed in nonresidential business. The contribution of capital was a smaller percentage of the growth rate than in the whole economy, where it includes dwellings and international assets, but the positive or negative contributions of all other determinants were larger and the importance of offsets correspondingly greater. Advances in knowledge alone contributed an amount equal to 64 percent of the growth rate, education per worker 30 percent. In all, five groups contributed an amount equal to 143 percent of this growth rate, while four subtracted an amount equal to 43 percent.

Columns 5 through 8 of the informal tabulation provide estimates for the actual output series that are the counterparts of the potential output series just reviewed. The contributions of many determinants are the same on an actual as on a potential basis when expressed in percentage points, but differ when expressed as percentages of the growth rate because the growth rates are different. When contributions expressed in percentage points differ, the

57. See Denison and Chung, *How Japan's Economy Grew So Fast*, pp. 39-45.

58. There were also offsetting pluses and minuses within the "labor input except education" group and also, no doubt, among the "other determinants."

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only reason is that the positions of 1929 and 1982 with respect to the business cycle and productivity cycle were different. Irregular factors make a negative contribution to growth rates on an actual basis because the index for the effect on output per unit of input in nonresidential business of changes in the intensity of utilization of employed resources resulting from fluctuations in intensity of demand was 7 percent lower in 1982 than in 1929.

Contributions to the series computed on a potential basis are not affected by the cyclical positions of end years, but even they may be somewhat affected by the cyclical pattern—and international events—of the past. However, the effect is rarely known. For example, would the sizes of the capital stock and potential employment in 1982 have been bigger if the

Depression and World War II had not cut net capital formation and birth rates in 1930–46? Or were capital formation and population growth in the postwar years larger than they would otherwise have been so that the deficiency was eliminated? The reader may suppose that the percentage of growth contributed by capital is reduced by inclusion of the period's last three years, 1980–82, in which business activity was weak, but in fact all the percentages for capital in the informal tabulation were the same or lower in 1929–79 than in 1929–82.

The following chapter examines changes in the sources of growth after 1973. Readers are encouraged to look at the estimates for other periods shown in the tables, which have been discussed in my previous books.

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HORACE FREELAND JUDSON

The Search for Solutions

ABRIDGED EDITION
(text complete, pictures and captions omitted)

Introduction by Lewis Thomas, M.D.

1987

The Johns Hopkins University Press

BALTIMORE

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the builder of bridges: ~~the professional's pride in skill, the swelling gratification that comes with recognition accorded by colleagues and peers, perhaps the competitor's fierce appetite, perhaps ambition for a kind of fame more durable than most.~~ At the beginning is curiosity, and with curiosity the delight in mastery—the joy of figuring it out that is the birthright of every child. I once asked Murray Gell-Mann, a theoretical physicist, how he got started in science. His answer was to point to the summer sky: "When I was a boy, I used to ask all sorts of simple questions—like, 'What holds the clouds up?' " Rosalind Franklin, the crystallographer whose early death deprived her of a share in the Nobel Prize that was given for the discovery of the structure of DNA (the stuff that genes are made of), one day was helping a young collaborator draft an application for research money, when she looked up at him and said, "~~What we can't tell them is that it's so much fun!~~" He still remembers her glint of mischief. ~~The play of the mind, in an almost childlike innocence, is a pleasure that appears again and again in scientists' reflections on their work.~~ The geneticist Barbara McClintock, as a woman in American science in the 1930s, had no chance at the academic posts open to her male colleagues, but that hardly mattered to her. "I did it because it was *fun!*" she said forty years later. "I couldn't wait to get up in the morning! I never thought of it as 'science.'"

The exuberant innocence can be poignant. François Jacob, who won his share of a Nobel Prize as one of the small group of molecular biologists in the fifties who brought sense and order into the interactions by which bacteria regulate their life processes, recently read an account I had written of that work, and said to me with surprise and an evident pang of regret, "We were like children playing!" He meant the fun of it—but also the simplicity of the problems they had encountered

and the inner them. Two although Jacob parallel—Isa death, said:

I do not know to myself playing or now and the prettier she of truth lay

For some, the world to Sheldon Glau at Harvard, simple questions learning about and the moon said. "And I the Man in us"—that the same face to 'Why is the us?' She was was hard. As in college-level learns the art difference is, moon and w interesting'—can't let go."

Curiosity by far, a word for creation, arts. Medawar to young scientists exploratory in incomprehensible other side of problem work and months