The Undiscovered World of Thomas Edison

by KATHLEEN McAULIFFE

Historians, sorting through a treasure trove of Edison's papers, are discovering revealing details that enrich our portrait of one of America's most accomplished inventors

WHEN an associate asked Thomas Alva Edison about the secret to his talent for invention, the plainspoken Edison retorted, "Genius is hard work, stick-to-itiveness, and common sense."

"There's still more!" his colleague said imploringly. "Although [the rest of us] know quite a lot . . . and worked hard, we couldn't invent . . . as you did."

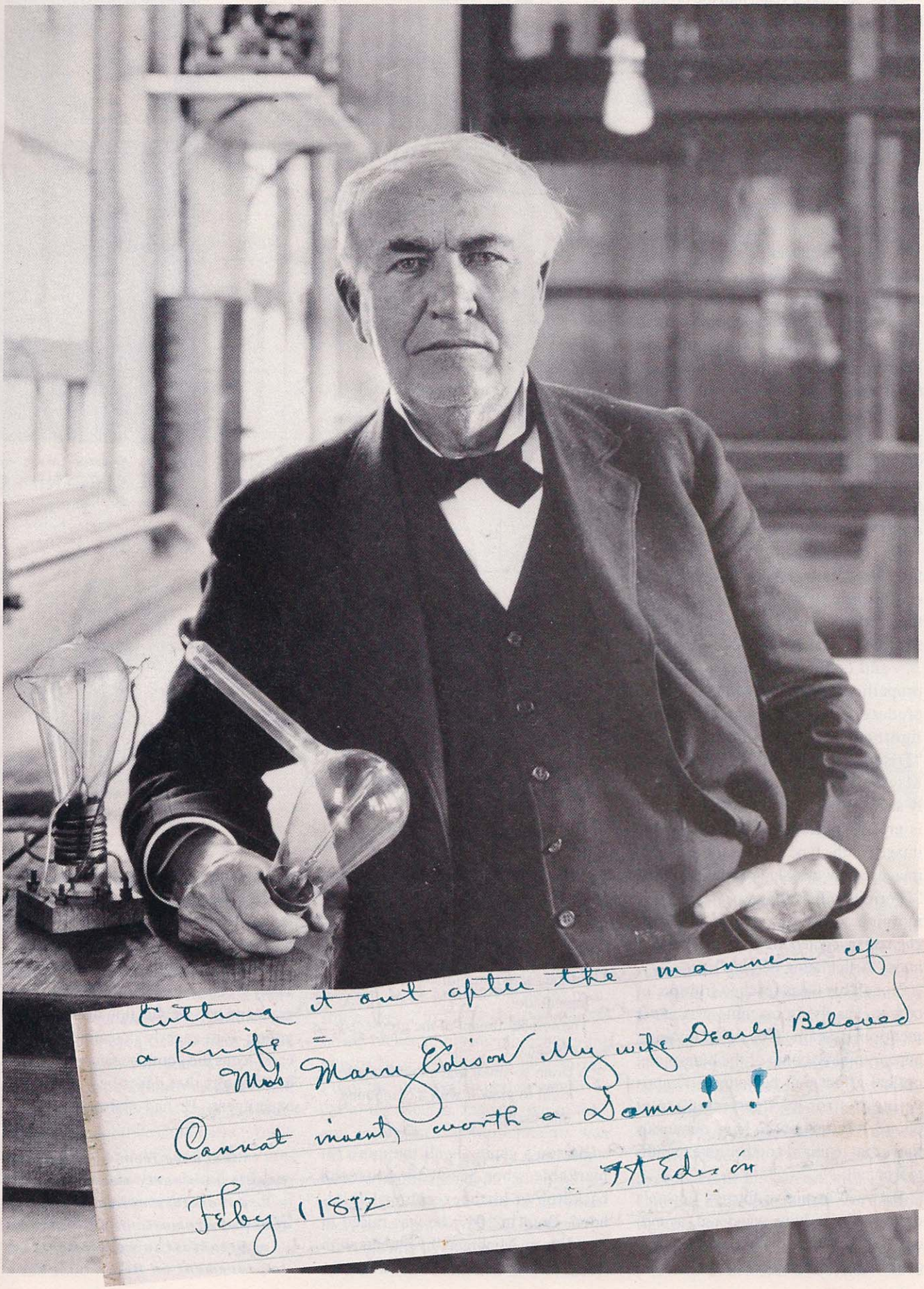
What Edison never seemed to grasp was that his "common sense" was exceedingly uncommon—freakish, really. More patents were issued to him than have been issued to any other single person in U.S. history: 1,093. But Edison's towering status reflects more than his extraordinary productivity. He created things that transformed our world—among them the phonograph, the motion-picture camera, and the incandescent light bulb. And he made substantial contributions to numerous technologies, including telegraphy, telephone communications, and several business procedures.

Yet, in the six decades since the inventor's death, little serious writing has been done about Edison's remarkable genius for invention. In the words of the historian Keith Nier, "He is actually one of the least well known of all famous people, and much of what everybody thinks they know about him is no more reliable than a fairy tale."

Nier is one of eight historians at Rutgers University and at the Edison National Historic Site, in West Orange, New Jersey, who are now trying to set the record straight. The team, headed by Robert Rosenberg, is in the process of editing and publishing selected documents from the inventor's life's work. The scale of their endeavor is virtually unprecedented in the history of technology and science. What is now known as the Edison Papers Project started in 1978, when archivists estimated that the inventor's estate included just over a million pages of documents. Having been told that the contents had been "loosely organized" by previous archivists, the Edison Papers staff expected to have chosen the documents for a highly selective microfilm edition within a decade, after which a still more selective book edition would be completed.

Alas, organization, like beauty, turns out to be in the eye of the beholder. "It was a big mess," recalls the associate director of the project, Thomas Jeffrey, remembering his dismay at seeing for the first time the documents housed at the extensive industrial complex that makes up the Edison National Historic Site. Dusty stacks of papers—many seemingly untouched since Edison's death—sprouted as haphazardly as weeds across the space. Jeffrey, who had been hired to make the initial selection for the microfilm edition, instead found himself leading a scouting expedition. "We went from building to building, room to room, drawer to drawer," he recalls. "It took us more than a year just to get to the end of the paper trail, and when we added up the numbers in our inventory, we were shocked."

The collection turned out to include at least four million pages, and quite possibly as many as five million. According to Jeffrey's most recent estimate, publishing a representative sample of the inventor's work in both a microfilm edition and a printed edition of fifteen to twenty volumes could take until 2015. (To date the team has published more than 250,000 pages of documents on microfilm and three enormous printed volumes, and has begun preparing for electronic publication.)



THE GRANGER COLLECTION

Now, seventeen years into the project, the historians have become so intimately acquainted with their subject that, as Rosenberg half guiltily admits, "we've become spies inside his mind." All are acutely aware of their unique privilege. In many instances they are the first people since the inventor's death to gaze on laboratory records, early drafts of patent applications, letters, photos of models, and other telling memorabilia.

Luckily for posterity, the process by which Edison invented is documented in exquisite detail in a series of 3,500 notebooks. The researchers unabashedly compare his fecundity of ideas to Leonardo da Vinci's. The notebooks are filled with fascinating observations and insights—many pertaining to unrelated projects, in a seeming free flow of associations. Consecutive sketches—some rough and crude, others executed with the exactitude of a draftsman—traverse a vast spectrum of technologies.

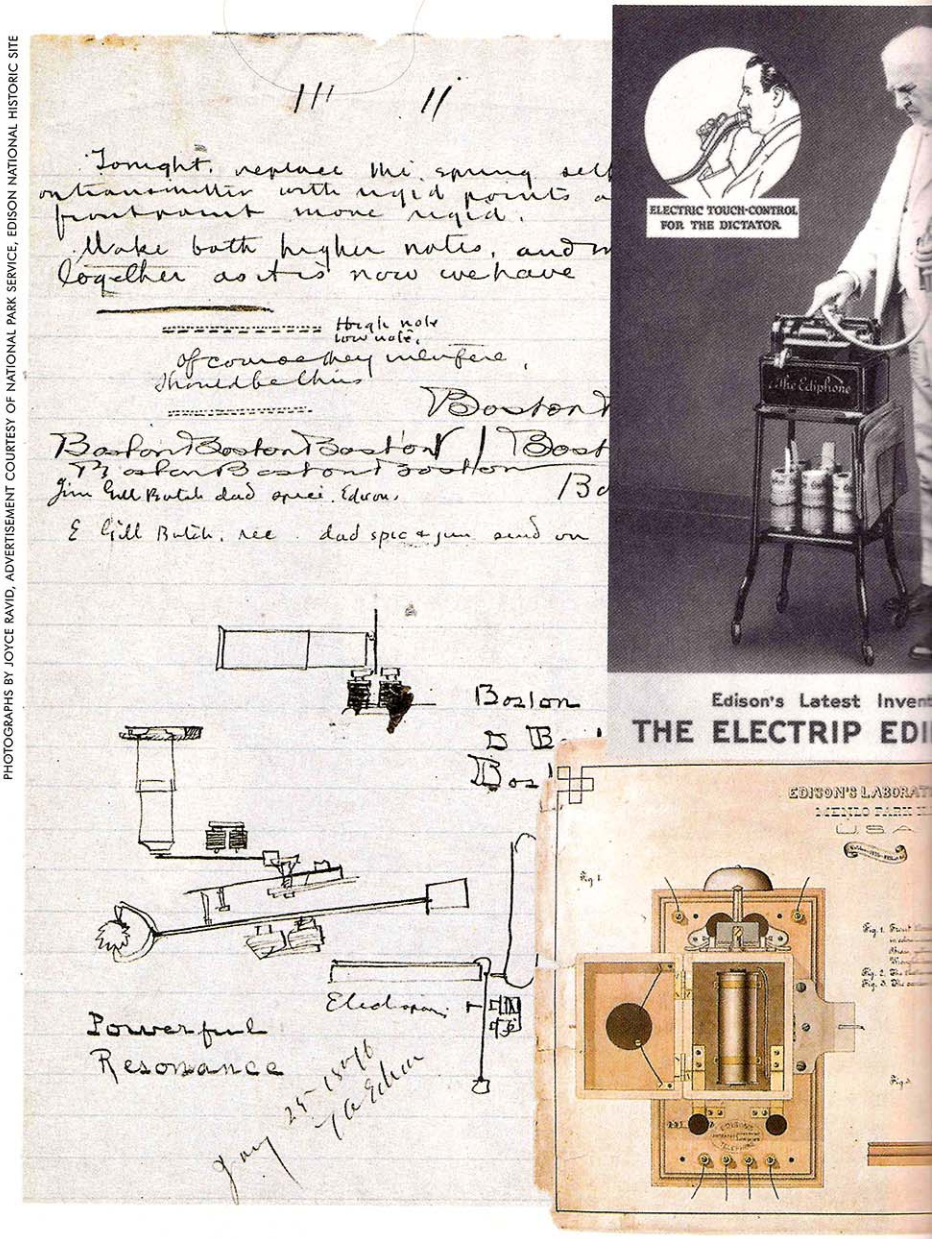
On New Year's Day, 1871, more than three decades before the Wright brothers' historic flight, Edison speculated that "a Paines engine can be so constructed of steel & with hollow magnets . . . and combined with suitable air propelling apparatus wings . . . as to produce a flying machine of extreme lightness and tremendous power." "Discovery," begins an entry dated May 26, 1877. "If you look very closely at any printed matter so that the print is greatly blurred and you see double images of the type . . . one of the double images is always blue or ultra violet=" "Glorious= Telephone perfected this morning 5 AM," he confidently proclaimed in a notebook entry two months later. "Articulation perfect."

Not all his ideas reached fruition, of course. His flying machine was never mentioned again. Nor does anything appear to have come of the blue-violet optical effect that he found so captivating. As for his "perfected" telephone, it turned out to have numerous flaws that required another nine months to iron out.

Between inventive flurries Edison's mind seems to have wandered, as evidenced by pages decorated in half a dozen florid styles of calligraphy. Occasionally he even jotted down a poem. Here is a notebook sample from the mid-1870s:

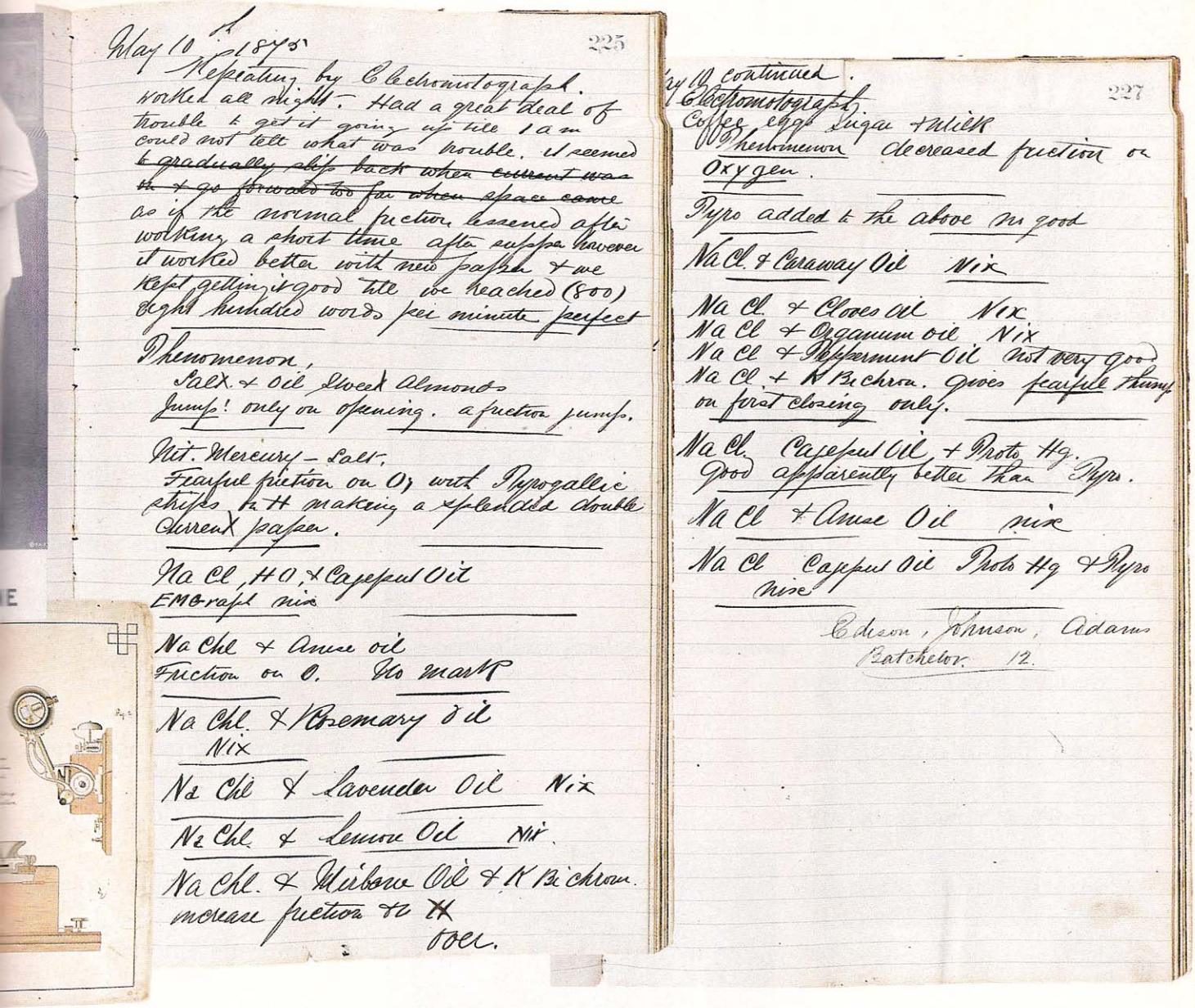
> A yellow oasis in hell=
> premeditated stupidity= A phrenological idol.
> The somber dream of the grey-eyed Corsican
> A Brain so small that an animalcule went to view it with a compound microscope. . . .

Edison's genius is all the more remarkable when viewed against the backdrop of his unexceptional childhood. Born in 1847, he was raised in Port Huron, Michigan, by parents with no special mechanical bent. His mother, a former schoolteacher, provided him with a few years of instruction at home. His father, a jack-of-all-trades who tried his hand at everything from real-estate speculation to running a small grocery store, was also highly literate and had a collection of books that young Tom eagerly consumed. In his early teens the youth began reading science books that described chemistry experiments. He had a job selling news-



PHOTOGRAPHS BY JOYCE RAVID, ADVERTISEMENT COURTESY OF NATIONAL PARK SERVICE, EDISON NATIONAL HISTORIC SITE

Clockwise from left: journal doodles; an early advertisement; laboratory notes describing a) use of aromatic oils and b) use of breakfast in experiment; an improvement on Bell's telephone



papers and candy to passengers on the Grand Trunk Railway between Port Huron and Detroit, and during breaks from work he tried out some of these experiments in a baggage car.

Later in his teens he received a more thorough grounding in the rudiments of what would soon be his trade while hanging around railroad yards, newspaper offices, and machine shops, and working in a jeweler's shop and various telegraph offices. On these jobs he was exposed to lathes and various precision tools, clockwork and printing equipment, and a wide assortment of telegraphy instruments, which he studied and experimented with during his spare time.

By his early twenties Edison, moonlighting as an inventor, had totted up enough successes to win lucrative research contracts from Western Union and other prominent firms, giving him the confidence to strike out on his own. But he never fit the popular stereotype of the reclusive nineteenth-century inventor, struggling alone in a garret. From the start collaboration was critical to his success. Indeed, one of Edison's greatest accomplishments was the invention of an entirely new institution—the independent industrial-research laboratory, or what he affectionately called his "invention factory."

At his first large independent laboratory, in Menlo Park, and later at facilities in West Orange, Edison kept a well-stocked chemistry lab and a machine shop under one roof—a considerable novelty for that period. He also surrounded himself with a core group of half a dozen or more assistants. A few were university-educated men specially chosen because of their expertise in fields in which Edison felt himself to be deficient (mathematics was one). His intimate working relationships with the mechanic and experimenter Charles Batchelor, who assisted him over much of his career; with Francis Upton, a major collaborator on electric lighting; and with the electrical engineer Arthur Kennelly—to mention only a few of his closest associates—have

long been appreciated by scholars. But the new research into Edison's papers shows that Edison's talent for motivating people extended well beyond this elite inner circle—a finding that may contain an important lesson for the entrepreneurial research-and-development firms that are the modern-day incarnations of Edison's vision.

Everyone—from his closest lieutenants to the cadre of skilled workers who operated his facilities—was encouraged to jot down diagrams and ideas. Particularly good ideas would be initialed by the experimenter in charge of the project and then developed further by the group, making it impossible to assign the credit for an invention to any one creator. "One of Edison's greatest overlooked talents," the historian Greg Field argues, "was his ability to assemble teams and set up an organizational structure that fostered many people's creativity."

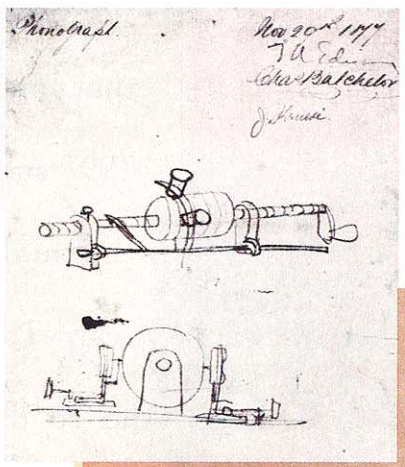
This is not to imply that Edison's opinion carried no more weight than that of any other collaborator. A large, burly figure with piercing eyes and a bristling intolerance for laziness, he was very much the commander leading the charge for innovation. Typically he would surge forth on his own course of research, dashing off ideas and conducting experiments seemingly as fast as they came to mind. Once the groundwork for an invention had been laid, he would leave the details to others. The frequent notes of assistants duly recorded the master's advice: "Mr Edison says the temp is to[o] high." "Edison says this is good brick."

In addition to tapping the creative juices of his staff, Edison was knowledgeable about the research of competitors. Contrary to public perception, he almost never worked on any invention that wasn't already being pursued by several other people. What set him apart from his peers was his knack for transforming those ideas into practical results.

Every Failure a Success

THE Edison Papers team has been able to find little evidence to support the view that inspiration again and again struck Edison like lightning bolts out of the blue. Take Edison's widely repeated account of a carbon-filament light bulb that burned forty hours straight as his associates watched, transfixed by the miracle. That episode, dramatized in a Hollywood film starring Spencer Tracy as the great inventor, never really happened. Scrutinizing the notebooks from that period, the scholars discovered that the bulb burned only fifteen and a half hours. According to Paul Israel, a historian preparing a biography of Edison based on the archival endeavor, the team's version of that exciting event became inflated after subsequent tests of other carbon-filament materials confirmed the general approach. "The whole 'Eureka!' story arose afterward, probably because they needed a date for the anniversary of the electric light," Israel theorizes. "So they cast their minds back, and suddenly a fifteen-hour bulb became a forty-hour bulb."

A casual reading of Edison's notebooks leaves one with the impression that Eureka! moments were frequent in the laboratory. That's because Edison tended to become wildly enthusiastic about virtually any quirky or unaccountable phenomenon—from the unexpected deflection of a galvanometer needle during an electrical experiment to his discovery on his daily walk around the lab grounds of a bug emitting an unusual odor (this so fascinated the inventor that he wrote to Charles Darwin about it). Yet the project team can identify only a few Eureka! moments that actually had valuable results over Edison's long and illustrious career, and only one—the discovery of the principles behind the phonograph—that deserves the mythic importance with which the public invests such events.



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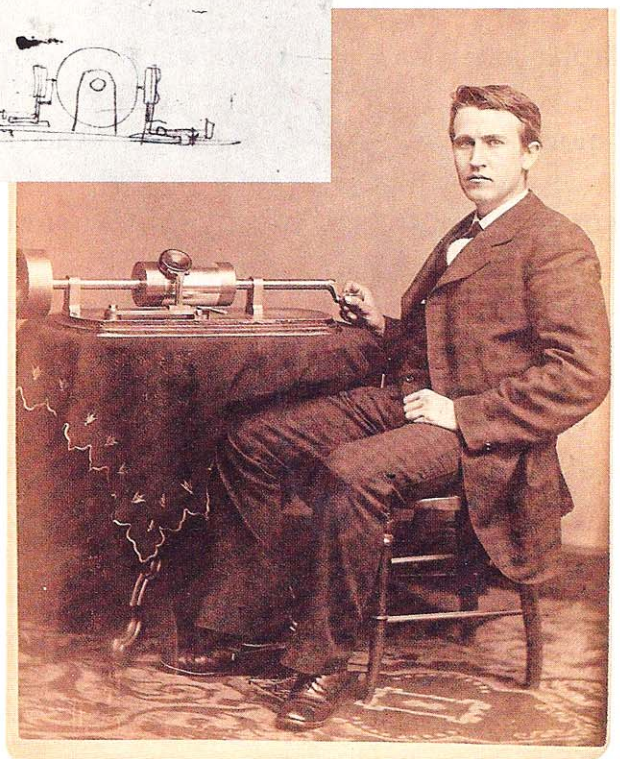

THE GRANGER COLLECTION

Sketch for first phonograph, 1877, and 1878 photograph of Edison with finished product

A classic spinoff, the phonograph emerged unbeckoned from work on telegraphs and telephones. In the interest of efficiency, the American mode of telegraphy used receiving instruments that produced a series of clicks, which operators mentally translated into letters. The clicks themselves left no lasting trace. In 1876 Edison and his associates developed a telegraph recorder that would emboss a message on paper, so that it could be transmitted repeatedly at high speed and a receiving operator could re-

run it more slowly for transcription. One July day in 1877 Edison considered using a very similar technique for recording telephone messages. The next day he realized that he could dispense with the electrical message, directly emboss the vibrations of the original sounds, and replay them for a simulacrum of the speaker's voice. This flash of insight paved the way for the modern recording industry.

Why, given that major inventions seldom emerge as revelations, was Edison so effective? The Edison Papers Project scholars can point to attitudes, work habits, and methods of reasoning that clearly contributed to his prolific output.

In Israel's view, perseverance was a cornerstone of Edison's strength. This idea is captured in his famous proclamation, "Invention is ninety-nine percent perspiration, and one percent inspiration." In Victorian-era America, of course, hard work and determination were commonly invoked to explain the self-made man. But the recent scholarship casts doubt on the inventor's clever but ultimately facile account of his own genius, addressing such fundamental issues as what enabled him to push ahead in the face of numerous setbacks and how exactly he learned from failure.

Edison could not conceive of any experiment as a flop. As Israel puts it, "He saw every failure as a success, because it channeled his thinking in a more fruitful direction." Israel thinks that Edison may have learned this attitude from his enterprising father, who was not afraid to take risks and never became undone when a business venture crumbled. Sam Edison would simply brush himself off and embark on a new moneymaking scheme, usually managing to shield the family from financial hardship. Israel says, "This sent a very positive message to his son—that it's okay to fail—and may explain why he rarely got discouraged if an experiment didn't work out." In addition to teaching him what wouldn't work, Israel says, failed experiments taught him the much more valuable lesson of what *would* work—albeit in a different context.

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Very few challenges failed to yield to Edison's brute intelligence, but one that did ultimately defeat him was the undersea telegraph. To help his experiments, Edison designed a laboratory model of a transatlantic cable, in which cheap powdered carbon was used to simulate the electrical resistance of thousands of miles of wires. Alas, the rumble of traffic outdoors, clattering in the machine shop, or even the scientists' footsteps shook the equipment enough to change the pressure of the connecting wires on the carbon, thus altering its resistance. Since the accuracy of the model depended upon constant resistance in the carbon, Edison finally abandoned this approach. But later, when confronted with the problem of how to improve the transmission of voices over the telephone, he used a funnel-shaped mouthpiece to focus sound waves on a carbon button. The pressure of those vibrations altered the resistance in the circuit in synchrony with the speaker's voice. In other words, what ruined Edison's underwater-telegraphy experiments is exactly what made his telephone transmitter such a triumph. Indeed, this innovative transmitter rendered Alexander Graham Bell's telephone practical—so much so that it remained the industry standard for a century.

Edison viewed even disasters as an opportunity for learning. On one occasion his lab stove went out in the dead of winter, causing an assortment of expensive chemicals to freeze. On another occasion unprotected chemicals were damaged by sunlight. Instead of bemoaning the losses, Edison put aside all other projects to catalogue changes in the properties of the bottled substances. Keith Nier observes, "He knew how to turn lemons into lemonade."

In his memoirs, and certainly before the press, Edison projected the image of a no-nonsense workaholic. In various respects he lived up to this reputation, often working as many as 112 hours a week. His second wife, Mina, had a cot set up in a corner of his library so that he could take catnaps in a more dignified manner than stretching out on the laboratory bench, as had been his habit. Yet this hard-driving man also had a childlike sense of curiosity and a fun-loving streak that could not always be contained in his rush to meet deadlines and achieve goals.

Perhaps the most delightful document yet unearthed by the project editors is one that captures a giddy moment in the lab during a marathon work spell, when Edison and his colleagues behaved with the goofy abandon of high school kids set loose in chemistry class. Searching for a liquid with specific properties for

The inventor taking a characteristic nap on a workbench

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Edison's West Orange, New Jersey, chemistry lab in 1910

an electrochemical device, they tried caraway oil, clove oil, oregano oil, nitrogen chromate, and peppermint oil. But as night stretched on into the wee hours of the morning, they adopted a more freewheeling approach. The next notebook entry records that they tested coffee, eggs, sugar, and milk.

Breakfast was scarcely the most exotic material to be harnessed during the course of experimentation. Whale baleen, a tortoise shell, elephant hide, and the hair of a native Amazonian are just a few of the items collected by Edison in his obsessive quest for compounds with unique properties. One of his colleagues joked that his lab storeroom held everything, including "the eyeballs of a US senator." Although most of these substances had no practical applications, a few did. Rain-forest nuts were compressed into bricks from which Edison made phonograph needles. Japanese bamboo was fashioned into a filament for his commercial light. As for the Amazonian's hair, it came in handy as a wig for the first talking doll, in whose chest was concealed a tiny phonograph speaker.

Concepts Mixed and Matched

JUST as the inventor played with materials, he played with ideas, suspending his critical faculties during the earliest stages of invention. In an era before photocopying machines he developed an electric "pen" —really a puncturing device that rapidly punched holes in a sheet of waxed paper, which then served as a stencil for generating more copies. To make the point of the pen vibrate up and down, Robert Rosenberg, the project director, reports, Edison came up with concepts

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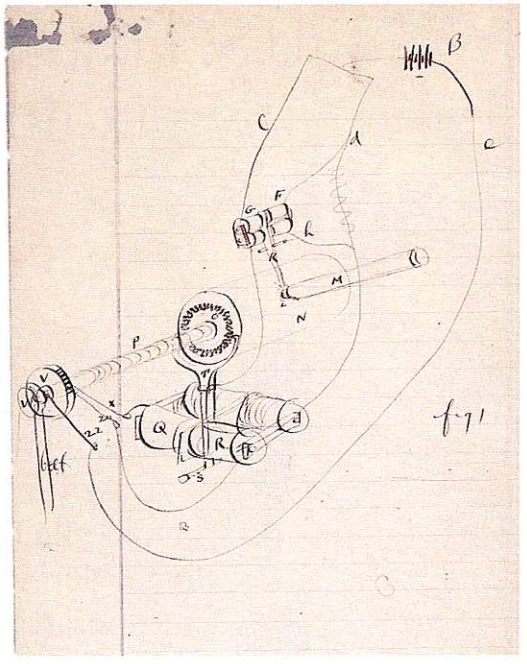

that "ranged from the practical to the absurd." Rosenberg reviewed a series of drawings showing how the point might be set in motion by a treadle mechanism reminiscent of an early Singer sewing machine, by little waterwheels attached to the end of the shaft, by air pumps, or by an electric motor tethered to the operator's wrist.

Part of the impetus for Edison's dogged search for alternative solutions to problems was his wish to cover himself with as broad a patent as possible. But the project historians emphasize that Edison also simply exulted in the challenge of inventing. It was a test of his ingenuity—almost a matter of pride—to see how many possibilities he could come up with.

Although he cast a wide net initially, Edison would gradually become more focused in his thinking. As his understanding of a problem grew, he typically devised theories, tested them, and then narrowed the range of potential solutions. Still, his inventive process at no stage resembled the linear, step-by-step progression that the scientific method is supposed to be. Just when he appeared to be putting the finishing touches on an invention, Edison would often go back and review his earlier sketches to see if, in the light of the new knowledge he had acquired, abandoned ideas could be resurrected.

A single page from Edison's notebooks beautifully captures his remarkable facility for mixing and matching concepts. It shows three different designs for recording sound, from the time Edison first displayed his phonograph. Those pictures foretell the main directions the recording industry would take throughout the first half of the twentieth century.

One sketch, illustrating the design Edison went on to market commercially, shows a stylus pressed against a cylinder resembling a rolling pin. The so-called "cylinder phonograph" derived directly from a cylinder version of his recording telegraph. A second drawing features a grooved disc not unlike an LP record; it sprang from the basic version of his telegraph recorder, the device that led to the discovery that sound could be captured on paper or foil. The third drawing foreshadows the tape recorder, with paper tape running under a stylus. The project scholars be-

Edison's kinetoscope produced the first "movie": **The Sneeze**

lieve that Edison got this idea from his work on earlier printing and chemical telegraph systems, which had similar configurations.

A closely related observation of the scholars—one with exciting implications for school-based programs aimed at cultivating innovative minds—is that Edison employed similar problem-solving strategies across numerous technologies. Notably, he reasoned by analogy, with a distinctive repertoire of forms, models, and design solutions that he applied to invention after invention. Reese Jenkins, who assembled and until last year headed the Edison Papers Project staff, calls these repeating motifs in Edison's work "theme and variations."

To illustrate Edison's brand of logic, Jenkins holds up one of his first drawings of the kinetoscope, a prototype motion-picture camera. "Notice any similarity to his wax-cylinder phonograph?" he asks.

The resemblance is obvious. Both phonograph and kinetoscope consist of an axle supporting a cylinder that has information (either a sound recording or a sequence of still photos) wound along its length. Each device also has a long thin instrument (a stylus in the case of the phonograph and a viewing apparatus in the case of the kinetoscope) held perpendicular to the surface of the cylinder.

Not surprisingly, these forms had a common origin. While Edison was working on an improved model of the phonograph in 1888, Jenkins reports, he was paid a visit by the photographer Eadweard Muybridge, who brought with him some of his famous still photos of animals in motion. Inspired by these images, Edison began to think about developing a moving picture in tandem with his other project. Jenkins finds evidence of a conceptual link between the two inventions in a patent caveat Edison drafted later that year, in which he announced, "I am experimenting upon an instrument which does for the eye what the phonograph does for the ear." He went on to describe the parallel between the spiral of images that make up what we now call film and the spiral grooves on the phonograph record.

The motion-picture camera that evolved from Edison's kinetoscope ultimately abandoned the cylinder in favor of reels of film, thus concealing from generations of scholars its close kinship to the phonograph. "If we hadn't looked at his notebooks and draft caveats," Jenkins points out, "we'd never know what the original impetus for the idea was."

The Private Man

THE Edison papers have brought to light another dimension of the inventor's success: the brilliant scientist was also a clever businessman, and capable of engineering literally dazzling public-relations stunts. In a bid to get New York City to allow its streets to be torn up for the laying of electrical cables, Edison invited the entire city council out to Menlo Park at dusk. He directed the aldermen up a narrow staircase in the dark, and as they grumbled and fumbled their way, he clapped his hands. On came a flood of lights, illuminating a lavishly set dining hall complete with a sumptuous feast catered by Delmonico's, then New York's premier restaurant.

Edison knew how to use the rumor mill to enhance his professional image. He portrayed his younger self as having been a guileless rube who didn't know what to do with a check for $40,000 that he received shortly after arriving in New York. The story—originally told by Edison—is that after cashing the check, he stuffed the bills into the lining of his coat. Edison loved to tell this fabricated tale, possibly because it fit nicely with that era's image of the wild, enterprising Yankee.

Edison the private man is not nearly as scintillating as Edison the inventor and self-promoter. "He had few of the endearing eccentricities commonly associated with genius," Greg Field says, expressing an opinion also held by his colleagues. Edison was in many respects a typical Victorian man, with solid midwestern tastes. Like many of his contemporaries, he was sheltered from women in his youth, and he seems to have been genuinely chagrined to discover that his partner in marriage would not be his partner at the laboratory bench. Just over a month after marrying Mary Stilwell, the twenty-four-year-old Edison despaired in a notebook, "My wife Dearly Beloved Cannot invent worth a Damn!!" He also shared with Americans of his background stereotypical prejudices against Jews, Poles, Irishmen, and other newly arriving immigrant groups (though ethnic biases apparently never stopped him from hiring anyone he deemed talented).

As he advanced in years, he became increasingly protective of his discoveries. Lisa Gitelman, a project historian, recently uncovered an irate letter (circa 1916) from Edison to his manufacturing department. It had been prompted by the news that teenagers were turning up the speed of his cylinder phonograph to make the music faster. Instead of capitalizing on this trend, Edison complained, "This change of speed is far worse than any loss due to having dance records too slow. . . . They are absolutely right time but young folks of the family want this fast time & like stunts & I dont want it & wont have it." To make sure his will was obeyed, he ordered his machinists to make a governor for the motor.

Of course, next to Edison's accomplishments, his shortcomings seem puny. Even among other hallowed figures in the pantheon of inventors, Edison is Bunyanesque. What Henry Ford is to the automobile, George Eastman to photography, and Charles Goodyear to rubber, Edison is to not one but several of today's essential technologies.

Is the Edison Papers Project helping to demystify his genius? "His ability to reason by analogy and to learn from failure are certainly examples of traits that should be useful to people of all sorts of talents and occupations," Paul Israel says. "Nonetheless, when you see his mind at play in his notebooks, the sheer multitude and richness of his ideas makes you recognize that there is something that can't be understood easily—that we may never be able to understand."