Charles Goodyear (1800–1860), American Inventor, on the Bicentennial of His Birth

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Abstract: Goodyear was neither a chemist nor scientist and, like Thomas Edison, used trial-and-error methods. He recognized rubber's valuable properties—elasticity, plasticity, strength, durability, electrical nonconductance, and resistance to water, and he became preoccupied with this elastomer. His vulcanization process, accidentally discovered in 1839 after five years of countless experiments, transformed rubber from a smelly, virtually useless substance that became sticky in summer, hardened and cracked in winter, and was attacked by various solvents into a stable, versatile commercial product with literally hundreds of uses. He devoted the last quarter-century of his life to experimenting with ways to improve, promote, and exhibit it to the great detriment of his own and his family's finances and health.

Ironically, the recent unprecedented Bridgestone–Firestone recall of millions of 15-inch truck tires used in the production of Ford sport utility vehicles and pickup trucks is occurring in the year marking the bicentennial of Charles Goodyear's birth. Without this American inventor's vulcanization process, tires or any of the myriad other rubber products that we take for granted today would be impossible.

Rubber, a Museum Curiosity

Rubber, obtained from the tree, *Hevea braziliensis* (order, *Euphorbiales*; family, *Euphorbiaceae*—the spurge family), is one of nature's unique materials (Figures 1 and 2). Pictures and carvings by the ancient Egyptians, Ethiopians, and other African and Asian peoples depicted games with bouncing rubber balls, and Amazon Basin Indians were familiar with the properties and uses of this peculiar natural substance long before Columbus's explorations brought knowledge of rubber to Europe (Figure 3) [1, 2]. Spanish navigator and historian Gonzalo Fernández de Oviedo y Valdes (1478–1557) first described the rubber balls used by the Indians, as did Antonio de Herrera y Tordesillas (1559–1625), Philip II of Spain's historian [3, 4]. In 1735 rubber was brought to Europe from the Amazon by French mathematical geographer, Charles Marie de La Condamine (1701–1774) [5].

Rubber, however, remained a mere museum curiosity. Although it found limited use for waterproofing boots, shoes, and garments (called "mackintoshes" after Scottish chemist–inventor Charles Macintosh (1766–1843)), it hardened and cracked when cold and became sticky or melted when warm [1]. It was known to the Maina Indians as "caoutchouc" (from *caa,* wood, and *o-chu*, to weep) until 1770 when English chemist and clergyman Joseph Priestley (1733–1804), the discoverer of oxygen, suggested the name "rubber" because by rubbing on paper it could be used to erase pencil marks [6–8].

* Series Editor contribution.

Goodyear's Early Life

Charles Goodyear (Figures 5 and 6), the son of Amasa Goodyear, an inventor and manufacturer of hardware and farm implements, and his wife Cynthia (née Bateman), was born on December 29, 1800, in New Haven, Connecticut [1, 9–20]. The family produced seven inventors in four generations. Goodyear attended school at Naugatuck, Connecticut until 1817 when he was apprenticed to a hardware manufacturer in Philadelphia, Pennsylvania, where he remained until 1821. He returned to New Haven to enter his father's business. On August 24, 1824, he married Clarissa Beecher, daughter of a Naugatuck innkeeper. The couple had nine children.

In 1826 in Philadelphia Goodyear and his father founded the first retail domestic hardware store in the United States, but by 1830 the business had gone bankrupt. From that time on Charles was usually poor and often in debtors' prisons where he carried out many of his experiments on rubber. He often sold household items and furniture for food for his growing family. Becoming an inventor, during the period 1830–1834, he was awarded six patents for mechanical inventions. Early in his career, he became intrigued with rubber, which he had unsuccessfully tried to use in some of his other inventions.

Goodyear's Preoccupation with Rubber

The modern rubber industry began in 1820 with the founding of the world's first rubber factory by English coachmaker and inventor Thomas Hancock (1786–1865), who later pirated Goodyear's discovery of vulcanization because Goodyear was denied an English patent. In 1832 the India Rubber Company of Roxbury, Massachusetts began manufacturing rubber bottles, mackintoshes, and overshoes, but these goods became hard in winter and soft in summer. During the summer of 1834, Goodyear visited the company's New York salesroom where he became acquainted with the problems afflicting the new rubber industry. He recognized rubber's valuable properties of elasticity, plasticity, strength, durability, nonconductance of electricity, and resistance to water, and he became preoccupied with rubber and devoted the remaining quarter-century of his life to experimenting with

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Figure 1. A few copies of Goodyear's book were printed on an India rubber tissue and bound in rubber covers. Of these, the only one extant is in the Smithsonian Institution, Washington, DC. The carved hard rubber cover depicts South American natives tapping rubber trees, collecting the latex, and smoking it over a fire (from ref 13, Wolf, R. F. *India Rubber Man: The Story of Charles Goodyear;* Caxton: Caldwell, ID, 1940). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Figure 2. A tapper at Goodyear's Dolok Merangir plantation on the Indonesian island of Sumatra cuts a rubber tree for latex for use in tires and other rubber products. Dolok Merangir, site of Goodyear's first rubber plantation, was carved out of the jungle in 1916; (from reference 32, O'Reilly, M. *The Goodyear Story;* Benjamin: Elmsford, NY, 1983, p 122).(Reprinted with permission from Goodyear Tire and Rubber Co.)

Figure 3. Native Americans playing with a rubber ball (from ref 19, Moynihan, J. Goodyear and the Gum Tree. *Today's Chemist* **October 1989**, *2*(5), 14). (Reprinted with permission from John Heinly.)

Figure 4. Before Goodyear's discovery of vulcanization, rubber goods became sticky in warm weather (from ref 19, Moynihan, J. Goodyear and the Gum Tree. *Today's Chemist* **October 1989**, *2*(5), 18). (Reprinted with permission from John Heinly.)

Figure 5. Charles Goodyear (1800–1860), from a portrait on hard rubber by G. P. A. Healy, Paris, 1855 (from ref 13, Wolf, R. F. *India Rubber Man: The Story of Charles Goodyear;* Caxton: Caldwell, ID, 1940). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Figure 6. A statue of Goodyear that welcomes visitors to the World of Rubber museum in Akron, Ohio (from ref 32, O'Reilly, M. *The Goodyear Story;* Benjamin: Elmsford, NY, 1983). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Figure 7. "He was constantly ridiculed and called crazy." A contemporary artist's engraving showing Goodyear walking down the street (from ref 10, McCabe, J. D. *Great Fortunes and How They Were Made;* E. Hannaford: Cincinnati, OH, 1870).

Figure 8. An artist's conception of Goodyear's discovery of vulcanization (from ref 29, Allen, H. *The House of Goodyear: Fifty Years of Men and Industry;* Corday & Gross: Cleveland, OH, 1949). (Reprinted with permission from Goodyear Tire and Rubber Co.)

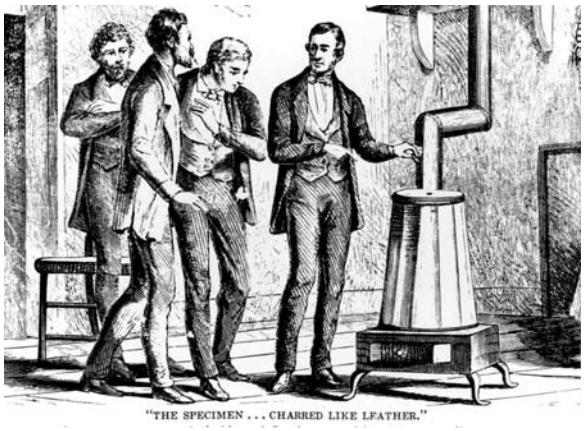

Figure 9. "The specimen …charred like leather." A contemporary artist's idea of Goodyear making his discovery (from ref 10, McCabe, J. D. *Great Fortunes and How They Were Made;* E. Hannaford: Cincinnati, OH, 1870).

ways to improve, promote, and exhibit it, to the great detriment of his own and his family's finances and health.

Goodyear was neither a chemist nor scientist and, like Thomas Alva Edison after him, he used trial-and-error methods. His first successful improvement was the development of rubber sheeting, for which he received a silver medal from the Mechanics Institute of New York in 1835. It did not age well, however, and it became soft and sticky in warm weather.

In 1838 Goodyear bought the Eagle India Rubber Company of Woburn, Massachusetts from Nathaniel M. Hayward, whom he hired to work for him. Hayward added small amounts of sulfur to some of his rubber compounds. Hayward occasionally dusted sulfur over the surface of his rubber fabrics and exposed them to the sun. He patented this process, which he called "solarization," and sold his rights to Goodyear. Hayward possessed all the essentials of vulcanization—rubber, sulfur, and heat—and if he had substituted a higher degree of heat for sunlight, he, rather than Goodyear, might have discovered the long sought "key to the riddle of rubber." Like all rubber manufacturers, however, he avoided heat, which caused rubber to melt.

The Discovery of Vulcanization

Goodyear spent more than five years in countless but unsuccessfull experimetns (Figure 7). Finally, in January 1839 he accidentally placed a rubber sample that had been mixed with sulfur and litharge (PbO, lead oxide) on a hot stove in Woburn, Massachusetts (Figures 8 and 9) [9–21]. This still poorly understood chemical reaction of rubber with sulfur at a high temperature transformed it from a smelly, almost useless substance that became sticky in summer, hardened and cracked in winter, and was attacked by various solvents into a stable, versatile commercial product with hundreds of uses. Hancock's friend William Brockedon, a friend of Goodyear's, proposed the name "vulcanization" for the process after Vulcan, the Roman god of fire and metalworking. This term became popular, and Goodyear reluctantly but repeatedly used the words "vulcanization" and "vulcanized" in his treatise of 1853 [22].

Many scholars consider Goodyear's discovery of vulcanization to be a case of serendipity. However, the term, coined and first used by Horace Walpole, fourth Earl of Orford (1717–1797), in a letter to British diplomat Horace Mann [23], required that the discovery be not only accidental but *unsought*. Inasmuch as Goodyear's accidental discovery occurred after five years of constant attempts to convert rubber into a commercially useful product, the term serendipity really does not apply in this case [21]. To accommodate such discoveries Roberts proposed the term "pseudoserendipity" to describe "accidental discoveries of ways to achieve an end sought for" [24].

Despite periods of extreme poverty, ill health, and time spent in debtors' prison, Goodyear quickly applied the new process to the manufacture of various articles (Figure 10). He was manufacturing rubber sheet goods by 1841 and other items by 1843 when he again went to debtors' prison and went bankrupt. U.S. patent No. 3633 was granted to him on June 14, 1844 for his vulcanization process. Profits from manufactured goods and license fees allowed him to pay his creditors.

Figure 10. Horseman wearing a waterproof cloak, taken from Goodyear's notebook (from ref 13, Wolf, R. F. *India Rubber Man: The Story of Charles Goodyear;* Caxton: Caldwell, ID, 1940; p 217). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Figure 11. Goodyear's Vulcanite Court at the Great Exhibition in London, 1851 (from ref 13, Wolf, R. F. *India Rubber Man: The Story of Charles Goodyear;* Caxton: Caldwell, ID, 1940). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Figure 12. Manufacturing a large rubber tire (from ref 29, Allen, H. *The House of Goodyear: Fifty Years of Men and Industry;* Corday & Gross: Cleveland, OH, 1949). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Litigation over Rubber

Goodyear's discovery converted the fledgling rubber industry into a multimillion dollar enterprise. Later discoveries have modified his original procedure to some extent, but today it remains essentially the same process that it was more than a century and a half ago. However, his vulcanization process was so simple that many persons used it without paying royalties, and he spent most of his time contesting about sixty infringements of his patent.

The most famous of these suits, known as "The Great India Rubber Case," was filed in Goodyear's name in 1851 by his licensee, The Shoe Associates, against Horace H. Day, who was probably the most flagrant of the many infringers. The trial, considered the greatest American business lawsuit of the nineteenth century, received widespread press coverage largely because Goodyear's chief attorney was Daniel Webster (1782–1852), who was then U.S. Secretary of State. On September 28, 1852, Goodyear's claim was upheld, but he still spent time in debtors' prisons in the United States, England, and France because he used all his available funds on experiments, inventions, and exhibitions.

A Missionary in Europe

Goodyear considered himself a missionary for vulcanized rubber and spent six years in Europe extolling its virtues and applications (Figure 11). On April 16, 1844, six weeks before Hancock's English patent of May 30, 1844, Goodyear had been granted a French patent for vulcanization, the first publication in any country to describe the process. Yet he was deprived of all rights under this patent for a trivial reason; he had sent several American-made rubber shoes to France before taking out his French patent. For his large exhibit at the Exposition Universelle in Paris in 1855, Emperor Napoleon III awarded him the Grand Medal of Honor and the Cross of the Legion of Honor. Ironically, Goodyear was in Clichy, the debtors' prison of Paris, at the time of the second award.

Goodyear's Last Years

In March 1853 Goodyear's wife Clarissa, who had shared his dreams, tribulations, and poverty for three decades, died. His single-minded preoccupation with rubber had prevented him from making many friends, and now, lonely and unaccustomed to caring for himself, he remarried on May 30, 1854, in London. His second wife, an Englishwoman, Fanny Wardell, bore him three children, only one of whom survived its father.

Goodyear returned to New Haven in 1858, reputedly pawning his wife's jewelry to pay for their passage. In 1859 he moved to Washington, DC. He died on July 1, 1860 in New York City, where illness had forced him to stop while en route to the funeral of Cynthia, his third daughter from his first marriage. The estimates of the debts that he left behind range from $200,000 to $600,000.

Rubber Today

Since Goodyear's day, rubber technology has advanced in leaps and bounds [25, 26]. Some 60 to 70 percent of rubber is now used in the manufacture of tires—a use unforeseen by

Figure 13. Passengers on the Goodyear blimp Europa get a bird's-eye view of the Coliseum in Rome. Since 1972 the airship's mission has been to build recognition and goodwill for Goodyear throughout Europe as its sister ships have done so successfully throughout the United States, (from reference 32, O'Reilly, M. *The Goodyear Story;* Benjamin: Elmsford, NY, 1983, p 176). (Reprinted with permission from Goodyear Tire and Rubber Co.)

Goodyear (Figure 12). Whereas over half of this rubber is synthetic [27, 28], the first tires were made of natural rubber. Today, rubber companies are among the world's largest corporations [29–32], and the recent recall of rubber tires has been front page news in newspapers around the world. Goodyear's name lives on in Goodyear tires and the Goodyear blimp overhead (Figure 13). Paradoxically, neither Goodyear nor any of his family members or descendants were connected with the Goodyear Tire and Rubber Company, whose founder, Frank A. Seiberling, named it to honor one of the United States's most famous inventors and the founder of an industry that is indispensable in modern life [29, 32, 33].

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References and Notes

1. Kauffman, G. B. Rolling On and On. *The World & I* **1989** (May), *3*(5), 294–299.
2. Kauffman, G. B.; Seymour, R. B. Elastomers, I. Natural Rubber. *J. Chem. Educ.* **1990,** *67,* 422–425.
3. Buehr, W. *Rubber: Natural and Synthetic*; Morrow: New York, NY, 1964; p 7.
4. de Herrera y Todesillas, A.; Stevens, J., Transl. *The General History of the Vast Continent and Islands of America…;* J. Batley: London, 1725.
5. de La Condamine, C. M. *A Succinct Abridgement of a Voyage Made Within the Inland Parts of South America; from the Coasts of the South-Sea to the Coasts of Brazil and Guiana, down the River of the Amazon*; Withers: London, 1747.
6. Priestley, J. *A Familiar Introduction to the Theory and Practise of Perspective*; Johnson & Payne: London, 1770.
7. Oesper, R. E. *The Human Side of Scientists;* University of Cincinnati Press: Cincinnati, OH, 1975; p 159.
8. Miller, F. A. Joseph Priestley, Preeminent Amateur Chemist. *J. Chem. Educ*. **1987,** *64,* 745–747.
9. Dutton, S. W. S. *A Discourse, Commemorative of the Life of Charles Goodyear, the Inventor, Preached in the North Church, July 8, 1860*; T. J. Stafford: New Haven, CT, 1860.
10. McCabe, J. D. *Great Fortunes and How They Were Made;* E. Hannaford: Cincinnati, OH, 1870.
11. Hubert Jr., P. G. *Inventors;* Charles Scribner's Sons: New York, NY, 1893.
12. Iles, G. *Leading American Inventors;* Henry Holt & Co.: New York, NY, 1912.
13. Wolf, R. F. *India Rubber Man: The Story of Charles Goodyear*; Caxton: Caldwell, ID, 1940.
14. Barker, P. W. *Charles Goodyear: Connecticut Yankee and Rubber Pioneer*; Godfrey L. Cabot: Boston, MA, 1940.
15. Batten, M. *Discovery by Chance;* Funk & Wagnalls: New York, NY, 1968; pp 137–156.
16. Stempel, G. H. Charles Goodyear 1800–1860. In *American Chemists and Chemical Engineers;* Miles, W. D., Ed.; American Chemical Society: Washington, DC, 1976; pp 179–181.
17. Asimov, I. *Asimov's Biographical Encyclopedia of Science & Technology,* new rev. ed.; Doubleday: Garden City, NY, 1978; pp 430–431.
18. Kauffman, G. B. Charles Goodyear—Inventor of Vulcanisation. *Education in Chemistry* **1989,** *26,* 167–170.
19. Moynihan, J. Goodyear and the Gum Tree. *Today's Chemist* **1989** (October), *2*(5), 14–15, 17–18, 34.
20. Kauffman, G. B. Charles Goodyear. In *American National Biography*; Garraty, J. A.; Carnes, M. C., Eds.; Oxford University Press: New York and Oxford, 1999; pp 275–277.
21. Kauffman, G. B. Oops...Eureka!: Serendipity and Scientific Discovery. In *1991 Yearbook of Science and the Future*; Encyclopædia Britannica: Chicago, IL, 1990; pp 224–240; p 228.
22. Goodyear, C. *Gum-Elastic and Its Variety, with a Detailed Account of Its Applications and Uses, and of the Discovery of Vulcanization*, Vol. I; Published for the author: New Haven, CT, 1855; and *The Applications and Uses of Vulcanized Gum-Elastic; with Descriptions and Directions for Manufacturing Purposes*, Vol. II; Published for the author: New Haven, CT, 1853. Both these volumes, together with Hancock, T. *Personal Narrative of the Origin and Progress of the Caoutchouc or India-Rubber Manufacture in England*; Longman, Brown, Green, Longmans & Roberts: London, 1857, were reprinted in facsimile as a single volume, *A Centennial Volume of the Writings of Charles Goodyear and Thomas Hancock*; American Chemical Society: Washington, DC, 1939.
23. Walpole, H., letter to H. Mann, January 28, 1754.
24. Roberts, R. M. *Serendipity: Accidental Discoveries in Science;* John Wiley & Sons: New York, NY, 1989.
25. Le Bras, J.; Goundry, J. H., Transl. *Introduction to Rubber*, rev. ed.; Maclaren & Sons: London, 1968.
26. Blow, C. M.; Hepburn, C. *Rubber Technology and Manufacture*, 2nd ed.; Butterworth Scientific: London, 1981.
27. Allen, P. W. *Natural Rubber and the Synthetics;* John Wiley & Sons: New York, NY, 1972.
28. Kauffman, G. B.; Seymour, R. B. Elastomers, II. Synthetic Rubbers. *J. Chem. Educ.* **1991,** *68,* 217–220.
29. Allen, H. *The House of Goodyear: Fifty Years of Men and Industry*; Corday & Gross: Cleveland, OH, 1949.
30. Lief, A. *The Firestone Story: A History of the Firestone Tire and Rubber Company*; McGraw-Hill Book Co.: New York, NY, 1951.
31. Babcock, G. D. *History of the United States Rubber Company: A Case Study in Corporation Management;* Bureau of Business Research, Indiana University: Bloomington, IN, 1966.
32. O'Reilly, M. *The Goodyear Story;* Benjamin: Elmsford, NY, 1983.
33. Kirkman, G. G. *Genealogy of the Goodyear Family;* Cubery & Co.: San Francisco, CA, 1899.