overview of Borlaug's career, describing the impact of the Dust Bowl and Depression on his agricultural views, commitment to high-yield agriculture, and responses to criticisms of biotechnology.

Hesser, Leon F. *The Man Who Fed the World: Nobel Prize Laureate Norman Borlaug and His Battle to End World Hunger*. Foreword by Jimmy Carter, Durban, 2006. Laudatory biography penned by a US government agriculturist and friend who worked worldwide with Borlaug, who authorized this account.

Mann, Charles C. *The Wizard and the Prophet: Two Remarkable Scientists and Their Dueling Visions to Shape Tomorrow's World*. Vintage, 2019. Compares and contrasts the views of Borlaug and fellow twentieth-century scientist William Vogt.

Pence, Gregory E. "Norman Borlaug: He Fed a Billion People but You Don't Know His Name." *Brave New Bioethics*, Rowman, 2002, pp. 159-62. Discusses Borlaug's monumental but little-known work feeding the world's hungry.

Pence, Gregory E., editor. *The Ethics of Food: A Reader for the Twenty-First Century*. Rowman, 2002. A collection of writings on the ethics of food, food production, agriculture, genetically modified foods, and other related topics, with the essay "Are We Going Mad?" by Norman Borlaug.

Shiva, Vandana. *The Violence of the Green Revolution: Third World Agriculture, Ecology, and Politics*. Zed, 2002. Offers a critique of the Green Revolution's impact in India and other developing countries.

Max Born

German mathematician and physicist

Max Born's work in quantum mechanics earned him the Nobel Prize in Physics in 1954. He taught numerous other physicists who eventually won the Nobel Prize, many of whom were instrumental in the development of atomic fission. Like his close friend Albert Einstein and other Jewish scientists, he fled from Germany's Nazi regime in the early 1930s.

Born: December 11, 1882; Breslau, Germany (now Wrocław, Poland)
Died: January 5, 1970; Göttingen, Germany
Primary field: Physics
Specialty: Quantum mechanics

EARLY LIFE

Max Born was born on December 11, 1882, in Breslau, Germany (now Wrocław, Poland). His father, Gustav, was a physician, and his grandfather was a professor of embryology at the University of Breslau. His mother, Margarete Kaufmann, was the daughter of a wealthy industrialist and was known for her musical talent. Max had one sister, Käthe, who was born in 1884. His mother died in 1886, after which his father remarried.

The family's wealth gave Born access to a good education. As a teenager, he attended Kaiser Wilhelm Gymnasium. As in most senior secondary schools intended to prepare students for college, the principal emphasis of the curriculum was Latin and other an-

Max Born, c. 1934. Photo via Wikimedia Commons. [Public domain.]

C

Melvin Calvin

American chemist

American biochemist Melvin Calvin was among the first modern scientists to use a truly interdisciplinary approach in his research, blending techniques from the fields of chemistry and biology. In 1961, he won the Nobel Prize in Chemistry for his research concerning the chemical reactions that take place during photosynthesis.

Born: April 8, 1911; St. Paul, Minnesota
Died: January 8, 1997; Berkeley, California
Primary field: Chemistry
Specialties: Biochemistry; organic chemistry; molecular biology

EARLY LIFE

Melvin Calvin was born on April 8, 1911, in St. Paul, Minnesota, to Elias and Rose Hervitz Calvin. His father had immigrated to the United States from Kalvaria in Lithuania and his mother from the province of Georgia in Russia. Calvin's early years were spent in a middle-class area of St. Paul that was home to some of his Lithuanian American relatives. His father worked as a cigar maker, and his mother was a full-time homemaker. About the time Calvin was ready to enter high school, the family moved to Detroit, Michigan, where his father worked as an auto mechanic. Calvin attended public high school and knew at an early age that he wanted to be a scientist. His physics teacher, however, predicted that Calvin could never achieve that goal because he was too eager to reach conclusions.

Calvin began college at the City College of Detroit, which would later become Wayne State. Then, he won a full scholarship to the Michigan College of Mining and Technology (MCMT) at Houghton; the college later became known as Michigan Technological University. Calvin was able to take a wide range of science courses as part of the new chemistry program at MCMT, and he later credited this experience with forming his interdisciplinary approach to science. Calvin graduated from MCMT in 1931 with a degree in chemistry.

Pursuing graduate studies at the University of Minnesota, Calvin studied under chemist George Glocker. Again, Calvin's interests encompassed wide-ranging re-

Calvin, circa 1960s. Photo via Wikimedia Commons. [Public domain.]

balloon, and discusses hydrogen's potential as a future fuel of choice.
Pickover, Clifford A. *The Physics Book: From the Big Bang to Quantum Resurrection, 250 Milestones in the History of Physics*. Sterling, 2011. Illustrated survey of some of the most significant discoveries in the field of physics. Includes Charles's Law governing the behavior of gases.
Rousseau, George Sebastian, and Roy Porter, editors. *The Ferment of Knowledge: Studies in the Historiography of Eighteenth-Century Science*. Cambridge UP, 2008. A collection of scholarly essays that explore the state of scientific fields during the period in which Jacques Charles worked, when experimentation and empirical evidence became the norm.

Martha Chase

American biologist

A new college graduate working at Cold Spring Harbor, Martha Chase aided geneticist Alfred Hershey in discovering that viruses replicate through DNA (deoxyribonucleic acid). The work led to Watson and Crick's helix model of DNA less than a year later.

Born: November 30, 1927; Cleveland Heights, Ohio
Died: August 8, 2003; Lorain, Ohio
Also known as: Martha Chase Epstein; Martha Cowles Chase
Primary field: Biology
Specialty: Genetics

EARLY LIFE

Martha Cowles Chase was born on November 30, 1927, in a suburb of Cleveland, Ohio. At the College of Wooster (Ohio), she earned a bachelor's degree in biology in 1950.

LIFE'S WORK

Following her commencement, Chase worked as a lab assistant to bacteriologist and genetics expert Alfred Day Hershey at the Carnegie Institution Department of Genetics (now Cold Spring Harbor Laboratory) in Cold Spring Harbor, New York. In 1952, she assisted Hershey in what has become known as the Hershey-Chase blender experiment. By using the centrifugal force created by a common kitchen blender, the pair was able to demonstrate that viruses used DNA, not proteins, to replicate and to synthesize protein. This experiment confirmed that DNA was the chemical responsible for genetic inheritance. By one account, Chase was not at the time fully aware of the significance of the experiment.

Chase later worked at the Oak Ridge National Laboratory with biologist A. H. Doermann. While at Oak Ridge, she was one of only a few women who attended the 1953 Cold Spring Harbor Symposium on Quantitative Biology, which focused on viruses and during which molecular biologist James Watson be-

Martha Chase. Photo via Wikimedia Commons. [Public domain.]

Key to Pronunciation

Many of the names of personages covered in *Great Lives from History: Scientists and Science* may be unfamiliar to students and general readers. For difficult-to-pronounce names, guidelines to pronunciation have been provided upon first mention of the name in each essay. These guidelines do not purport to achieve the subleties of all languages but will offer readers a rough equivalent of how English speakers may approximate the proper pronunciation.

Vowel Sounds

Symbol	**Spelled (Pronounced)**
a	answer (AN-suhr), laugh (laf), sample (SAM-puhl), that (that)
ah	father (FAH-thur), hospital (HAHS-pih-tuhl)
aw	awful (AW-fuhl), caught (kawt)
ay	blaze (blayz), fade (fayd), waiter (WAYT-ur), weigh (way)
ee	believe (bee-LEEV), cedar (SEE-dur), leader (LEED-ur), liter (LEE-tur)
eh	bed (behd), head (hehd), said (sehd)
ew	boot (bewt), lose (lewz)
i	buy (bi), height (hit), lie (li), surprise (sur-PRIZ)
ih	bitter (BIH-tur), pill (pihl)
o	cotton (KO-tuhn), hot (hot)
oh	below (bee-LOH), coat (koht), note (noht), wholesome (HOHL-suhm)
oo	good (good), look (look)
ow	couch (kowch), how (how)
oy	boy (boy), coin (koyn)
uh	about (uh-BOWT), butter (BUH-tuhr), enough (ee-NUHF), other (UH-thur)

Consonant Sounds

Symbol	**Spelled (Pronounced)**
ch	beach (beech), chimp (chihmp)
g	beg (behg), disguise (dihs-GIZ), get (geht)
j	digit (DIH-juht), edge (ehj), jet (jeht)
k	cat (kat), kitten (KIH-tuhn), hex (hehks)
s	cellar (SEHL-ur), save (sayv), scent (sehnt)
sh	champagne (sham-PAYN), issue (IH-shew), shop (shop)
ur	birth (burth), disturb (dihs-TURB), earth (urth), letter (LEH-tur)
y	useful (YEWS-fuhl), young (yuhng)
z	business (BIHZ-nehs), zest (zehst)
zh	vision (VIH-zhuhn)

ten used the same basic concepts as devices that detect radiation today. As nuclear and particle physics increasingly dominate contemporary science, Hess's ideas and methodologies remain the significant and invaluable first steps on which all else is based.

—Thomas Fleischmann

Further Reading

Basu, Shantanu, and Pranav Sharma. *Essential Astrophysics: Interstellar Medium to Stellar Remnants*. CRC, 2022. An introduction to the concepts of astrophysics. Touches on Hess's work on cosmic rays.

Dahl, Per F. *Heavy Water and the Wartime Race for Nuclear Energy*. Institute of Physics, 1999. An illustrated account of the scientific push to discover nuclear energy during World War II, including Hess's contribution and ideas.

Schlickeiser, Reinhard. *Cosmic Ray Astrophysics*. Springer, 2010. An explanation of cosmic rays, with notes on the history of their discovery and an emphasis on implications and research in twenty-first-century physics. Illustrations, bibliography, index.

Tully, Christopher G. *Elementary Particle Physics in a Nutshell*. Princeton UP, 2011. A basic overview of particle physics, demonstrating the modern understanding of ideas first researched following Hess's early experiments. Illustrations, bibliography, index.

Elisabeth Hevelius

Polish astronomer

One of the first modern female astronomers, Elisabeth Hevelius capped a lifetime of celestial observations with the publication of her and her late husband's work in 1690, consisting of a comprehensive star catalogue and star atlas.

Born: January 17, 1647; Danzig (now Gdansk), Poland

Died: December 22, 1693; Danzig (now Gdansk), Poland

Also known as: Catharina Elisabetha Koopman; Elzbieta Heweliusz (in Polish)

Primary field: Astronomy

Specialty: Observational astronomy

EARLY LIFE

Catharina Elisabetha Koopman Hevelius was born in Danzig (now Gdansk), Poland, on January 17, 1647. Her parents, Nicholas Kooperman and Joanna Mennings Kooperman, were Dutch Lutherans who had emigrated from their native Amsterdam to Danzig, where they had become a rich, landholding merchant family.

Elisabetha Hevelius observing the sky with a brass octant. Detail from an engraving from Johannes Hevelius's "Machinae Coelestis: Pars Prior", (1673), fig. O, facing p. 254. Image via Wikimedia Commons. [Public domain.]

become the basis for the internet. Kleinrock described his theories first in a paper titled "Information Flow in Large Communication Nets" (1961), which he developed further in his 1963 PhD thesis and then published in his book *Communication Nets* (1964).

At UCLA, Kleinrock first began to put his theories to practical use. He was inspired by the desire to allow students to make better use of the university's computers by teaching them to process data more efficiently, and he established the Network Measurement Center, where he and a group of graduate students worked researching digital networks.

LIFE'S WORK

In 1957, the Soviet Union launched Sputnik 1, the world's first artificial satellite, which prompted US president Dwight D. Eisenhower to establish the Advanced Research Projects Agency (ARPA). ARPA developed the first successful US satellite eighteen months later, and within a few years, ARPA began to focus on computer networking and technology. In 1962, ARPA created the Information Processing Techniques Office (IPTO), which commissioned computer scientists from around the country to perform research. ARPA was soon interested in data networking, and Kleinrock was called in to help prepare the specifications for a government-supported data network.

In 1969, Kleinrock and his colleagues used Kleinrock's packet-switching formula and queuing theory to effectively design the first router. The machine, which was called the Interface Message Processor (IMP), was the size of a large refrigerator. It was hooked up to UCLA's main host computer, a Scientific Data Systems Sigma 7, with Kleinrock in attendance. Once the IMP began communicating with the Sigma 7, the first computer network was born.

The next month another IMP was installed at Stanford Research Institute, and the two schools attempted to connect to each other through their separate host computers. Kleinrock and his colleague Charlie Klein sent the first message between two distant computers. The intended message from UCLA was "LOG," to which the Stanford computer was to reply "IN." However, UCLA's computer crashed after only transmitting the letters L and O, making "LO" the first message sent over the primordial internet.

Kleinrock's Queuing Theory

Queuing theory is the mathematical modeling of waiting in lines. In data processing, it means ordering information by whatever method is needed: chronologically, by priority, or by size. The internet, which is essentially a giant amount of data processing, would not work without queuing theory.

Leonard Kleinrock's PhD thesis, published in 1963, established the mathematical theory behind queuing. Imagine a line of people at the airport, all going to different destinations around the globe. Before they can get to their plane, they need to have someone look at their tickets and direct them to the proper gate. To understand Kleinrock's related packet theory, imagine a large family trying to get through at the same time, and each person is processed individually instead of all at once. In digital communication terms, this works much more efficiently than at airports. Each person is one packet, and each packet is small enough to be processed without overloading the system. There are no dead spaces and no overloads when the packets are forced to wait their turn before they are sent along the network.

Kleinrock's bedrock work on the subject, *Queuing Systems Volume 1: Theory*, was published in 1975. It is one of the most cited works on queuing theory in the world.

After returning from a conference on computer communications in 1973, Kleinrock realized he had left his electric razor back in Brighton, England. For demonstration purposes during the conference, a satellite link had been established between Brighton and Los Angeles. Kleinrock assumed that his friend Larry Roberts was still awake and online in England, so he logged on and initiated a primitive version of internet chat. Kleinrock asked his friend to find his razor and send it back to Los Angeles with one of the conference attendees.

Taton, Reni, and Curtis Wilson, editors. *Planetary Astronomy from the Renaissance to the Rise of Astrophysics: Part A, Tycho Brahe to Newton*. Cambridge UP, 2003. Multivolume project that covers the entire scope of investigation of the solar system from earliest times to the present, with emphasis on individuals like Ole Rømer who helped advance the science of astronomy.

Wilhelm Conrad Röntgen

German physicist

Wilhelm Conrad Röntgen made important contributions to several areas of physics but is best known for his revolutionary discovery of X-rays and his investigations of their properties.

Born: March 27, 1845; Lennep, Prussia (now Remscheid, Germany)
Died: February 10, 1923; Munich, Germany
Also known as: Wilhelm Conrad Roentgen
Primary field: Physics
Specialty: Atomic and molecular physics

EARLY LIFE

Wilhelm Conrad Röntgen was the only child of Friedrich Conrad Röntgen, a German textile manufacturer and merchant, and Charlotte Constanza Frowein, who came from a Dutch merchant family. When he was three, his family moved to Apeldoorn, his mother's hometown in Holland. There, he attended primary public school and later became a student at Kostschool, a private boarding school. In 1862, Röntgen went to Utrecht, where he entered a secondary technical school, from which he was later expelled for refusing to inform on a fellow student who had drawn an unflattering caricature of a teacher. Although he attended some classes at the University of Utrecht, he was unable to become a formal student because he lacked a secondary school diploma. He resolved his academic problems by passing the difficult entrance examination of the recently established Federal Institute of Technology (or Polytechnic) in Zurich, Switzerland.

In November 1865, Röntgen began his education as a mechanical engineer. Over the next three years, he studied various technical courses but found his greatest fulfillment in a physics course taught by Rudolf Clausius, a distinguished scientist who helped found modern thermodynamics. Röntgen eventually passed his final examinations with excellent grades and received his diploma on August 6, 1869.

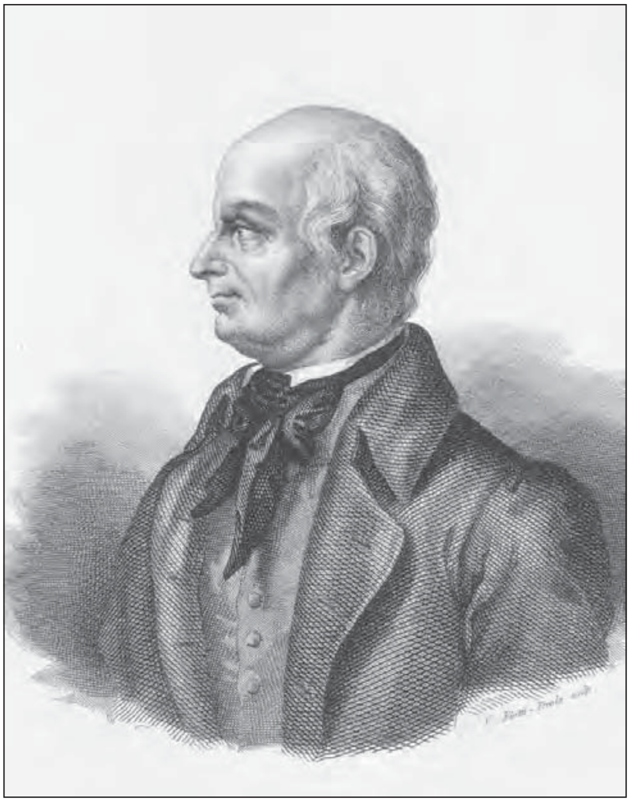
Röntgen remained in Zurich after graduation to work in the laboratory of August Kundt, a Polytechnic physics professor who had befriended him. Röntgen studied different gases to see if they

Wilhelm Conrad Röntgen in 1900. Photo via Wikimedia Commons. [Public domain.]

A mother of twelve and one of the first women to become a professor in Europe, Bassi instilled in young Spallanzani a love of science. She likely influenced Spallanzani's spirit of skeptical and critical inquiry as well. Bassi was an early proponent of the physics of English scientist Sir Isaac Newton, who envisioned nature as subservient to natural laws, not divine whim. As Bassi's embrace of Newton's controversial ideas defied conventional wisdom, Spallanzani would follow suit with his own bold rejection of the theory of spontaneous generation.

With Bassi's behind-the-scenes support, Spallanzani earned his father's blessing to pursue a doctorate in philosophy. In 1754 or 1755, Spallanzani, then in his mid-twenties, secured his first university appointment as a professor of logic, metaphysics, and Greek. Academic work would dominate the rest of his professional life, even after he was ordained as a priest a few years later. Spallanzani fielded offers from several universities before accepting a chair at the University of Modena in the early 1760s.

During the six years he spent in Modena, Spallanzani's reputation grew. He turned down a number of offers before being personally persuaded by the Habsburg empress Maria Teresa to accept, in 1769, the chair of natural history and curatorship of the museum of natural history at the University of Pavia. He retained both positions for the next thirty years.



Lazzaro Spallanzani. Image via Wikimedia Commons. [Public domain.]

LIFE'S WORK

The theory of abiogenesis, or spontaneous generation, had prevailed from ancient times until 1668, when Italian physician Francesco Redi proved, in a series of controlled experiments, that the presence of maggots on rotting meat was the product of fly eggs and not the meat itself. Yet belief in the capacity of life-forms to generate spontaneously—encouraged by the invention of the microscope, which unveiled a teeming world of microorganisms that seemed to originate out of nowhere—remained strong in Spallanzani's day.

In 1761, Spallanzani encountered the work of two of the leading proponents of abiogenesis, Georges-Louis Leclerc, Comte de Buffon, and the English priest John Tuberville Needham. It was common knowledge that, with time, water in which organic matter was left to decay would be swarming with microscopic life, and that boiling the water would kill off these life-forms. In a series of experiments, Needham boiled his solutions before transferring them to sealed containers. When microscopic examination revealed the eventual presence of cellular life despite boiling and sealing, Needham claimed to have produced definitive proof that microscopic life-forms can arise spontaneously.

Spallanzani, however, remained skeptical and set out to duplicate Needham's experiments. Unhave the same impact as his efforts in science, many of his ideas, including the encouragement of employee buyouts and payment of double wages for overtime work, became important to labor relations activities in the twentieth century.

—*Laurence W. Mazzeno*

Further Reading

Fichman, Martin. *An Elusive Victorian: The Evolution of Alfred Russel Wallace*. U of Chicago P, 2010. Examines Wallace's major intellectual and cultural views and activities. Explains how Wallace's pursuit of scientific knowledge coalesced with his social, political, ethical, and theological interests.

Raby, Peter. *Alfred Russel Wallace: A Life*. Princeton UP, 2001. Detailed biography providing extensive discussion of Wallace's travels and analysis of his contributions to science and social policy.

Shermer, Michael. *In Darwin's Shadow: The Life and Science of Alfred Russel Wallace*. Oxford UP, 2011. Psychological study of Wallace, stressing his iconoclasm and providing insight into the methodologies that led him to embrace scientific study, social activism, and spiritualism with equal vigor.

Slotten, Ross. *The Heretic in Darwin's Court: A Life of Alfred Russel Wallace*. Columbia UP, 2004. Presents a comprehensive biography of Wallace, including a discussion of his involvement in various social and political causes and his lifelong interest in spiritualism.

Smith, Charles H., and George Beccaloni, editors. *Natural Selection and Beyond: The Intellectual Legacy of Alfred Russel Wallace*. Oxford UP, 2008. Presents twenty essays by leading scientists exploring aspects of Wallace's career and contributions to evolutionary biology.

Smith, Charles H., James T. Costa, and David Collard. *An Alfred Russel Wallace Companion*. U of Chicago P, 2019. Collects chapters on Wallace's life and varied works.

Warren M. Washington

American atmospheric scientist

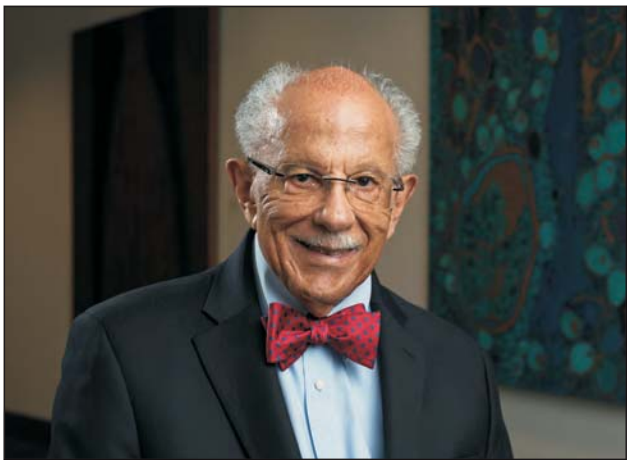
A senior scientist for Boulder, Colorado's National Center for Atmospheric Research, Warren M. Washington became known as one of the world's foremost climate researchers. His 1975 computer model of Earth's climate—one of the first ever developed—was an early predictor of global warming. Washington was awarded the coveted Tyler Prize for Environmental Achievement, often referred to as the "Nobel Prize for the environment," in 2019.

Born: August 28, 1936; Portland, Oregon
Primary field: Atmospheric science
Specialty: Climate science

EARLY LIFE

Warren Morton Washington was born on August 28, 1936, in Portland, Oregon. At the time of his birth, Oregon's population was predominantly White—less than one percent was African American—and the discrimination endured by Washington's family, which included four brothers, inspired him to become active in civil rights advocacy as a teenager. As vice president of the Jefferson High School chapter of the National Association for the Advancement of Colored People (NAACP), Washington developed the confidence to be a leader and community contributor.

Washington's parents, both college educated, encouraged his early interest in science. His father—who worked for the Union Pacific Railroad—bought him a telescope, and his mother often took him to the library so he could read about famous



Warren M. Washington in 2018. Photo by Oregon State University, via Wikimedia Commons.