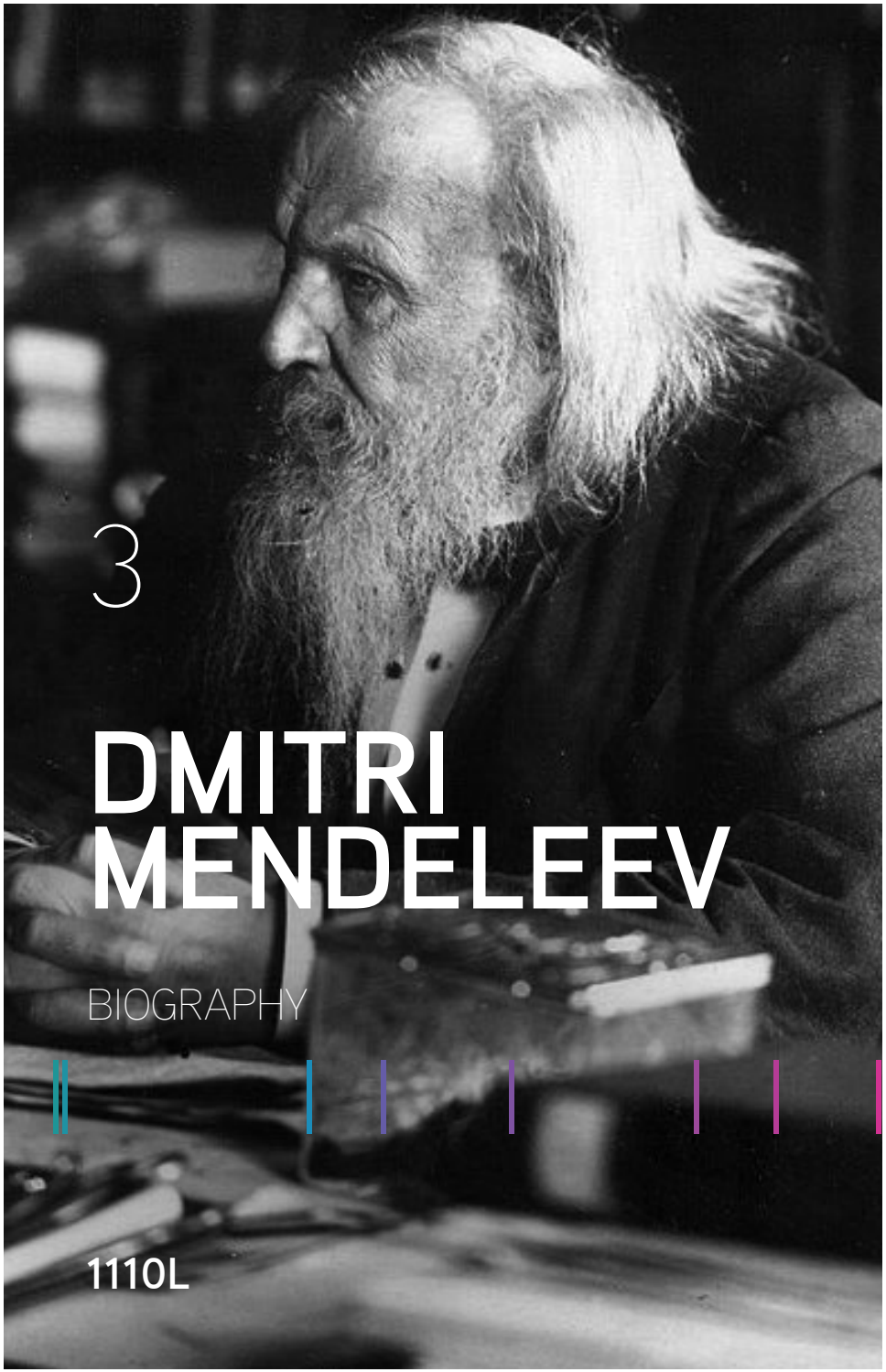


3

DMITRI MENDELEEV

BIOGRAPHY

1110L

BIG HISTORY PROJECT

Born
February 7, 1834
Tobolsk, Siberia, Russia

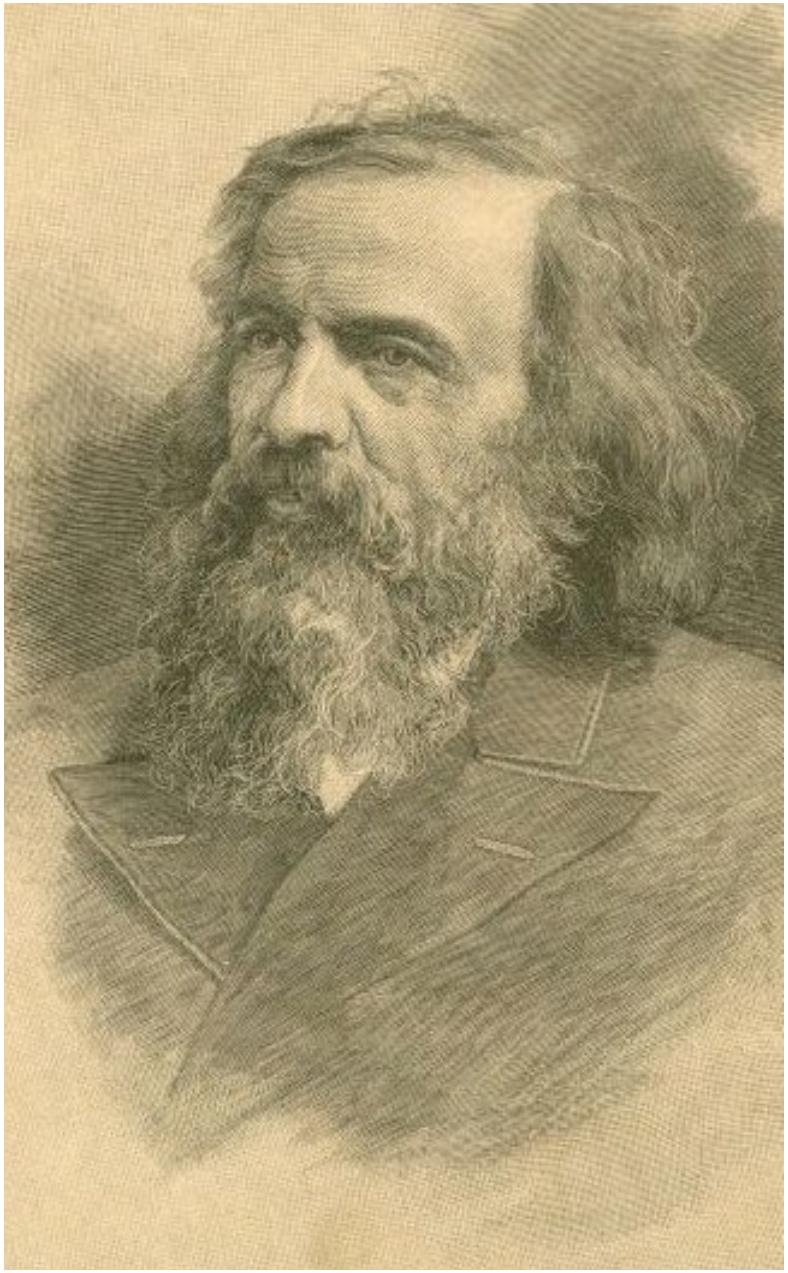
Died
January 20, 1907
St. Petersburg, Russia

DMITRI MENDELEEV

BUILDING THE PERIODIC TABLE OF ELEMENTS

By Michelle Feder

Dmitri Mendeleev, a Russian chemist and teacher, devised the periodic table — a comprehensive system for classifying the chemical elements.



Organizing matter

In the mid-1700s, chemists began actively identifying elements, which are substances made up of just one kind of atom. But a century later, they still used a variety of symbols and acronyms to represent the different materials — there just wasn't a common lexicon. In 1869, the Russian chemist Dmitri Mendeleev came to prominence with his tabular diagram of known elements. This basic ingredient list, of which all matter exists, became known as the periodic table. Here's what's especially amazing: Mendeleev's chart allotted spaces for elements that were yet to be discovered. For some of these missing pieces, he predicted what their atomic masses and other chemical properties would be. When scientists later discovered the elements Mendeleev had expected, the world got a glimpse of the brilliance behind the periodic table.

A difficult childhood

Mendeleev was born in 1834 in the far west of Russia's Siberia, the youngest of a dozen or more children (reports vary). His family faced one crisis after another. When Dmitri was little, his father, a teacher, went blind, and his mother went to work. She became the manager of a successful glass factory. Tragedy struck again in 1848, when the factory burned down, and the family faced poverty. Mendeleev's mother was determined to get him an education, and traveled with him a great distance, to Moscow and then to St. Petersburg, to do so. Ten days after he was enrolled in school, his mother died of tuberculosis, a disease that had also taken his father, at least one of his siblings, and which Mendeleev himself would battle as a young adult.

A young professor

In 1861, Mendeleev returned to Russia from research in Europe and later taught at the Technical Institute in St. Petersburg. He found that few of the new developments in the field of chemistry had made their way to his homeland — something he was determined to change, lecturing enthusiastically about the latest advances. Only 27 years old, he cultivated the persona of an eccentric, with a flowing beard and long, wild hair that he was known to trim only once a year. Still, he was a popular professor.

Mendeleev recognized that there was no contemporary textbook on modern organic chemistry (concerned with carbon compounds, including living things), so he wrote one. His *Organic Chemistry* (1861) was considered his era's most authoritative book on the subject. But the professor was painfully aware that many of his students "could not follow" him, as one student observed. Mendeleev knew that a critical reason for peoples' difficulty in understanding chemistry was the lack of any clear system for classifying the known elements. Without one, he could only offer particulars about specific building blocks of matter, but no framework that would explain the relationships between different substances.

As Mendeleev wrote:

> The edifice of science requires not only material, but also a plan, and necessitates the work of preparing the materials, putting them together, working out the plans and symmetrical proportions of the various parts. (Strathern, 2000)

A missed train and a dream

Next, Mendeleev began a text for inorganic chemistry (concerned with substances that are not organic, such as minerals), and the result, Principles of Chemistry (two volumes, 1868 — 1870), would become the standard text for the field until early in the twentieth century. His research for this book would also lead him to his most renowned work.

In 1867, when Mendeleev began writing *Principles of Chemistry*, he set out to organize and explain the elements. He began with what he called the "typical" elements: hydrogen, oxygen, nitrogen, and carbon. Those substances demonstrated a natural order for themselves. Next, he included the halogens, which had low atomic weights, reacted easily with other elements, and were readily available in nature. He had begun by using atomic weights as a principle of organization, but these alone did not present a clear system.

At the time, elements were normally grouped in two ways: either by their atomic weight or by their common properties, such as whether they were metals or gases. Mendeleev's breakthrough was to see that the two could be combined in a single framework.

Mendeleev was said to have been inspired by the card game known as solitaire in North America, and "patience" elsewhere. In the game, cards are arranged both by suit, horizontally, and by number, vertically. To put some order into his study of chemical elements, Mendeleev made up a set of cards, one for each of the 63 elements known at the time. Mendeleev wrote the atomic weight and the properties of each element on a card.

He took the cards everywhere he went. On February 17, 1869, right after breakfast, and with a train to catch later that morning, Mendeleev set to work organizing the elements with his cards. He carried on for three days and nights, forgetting the train and continually arranging and rearranging the cards in various sequences until he noticed some gaps in the order of atomic mass.

As one story has it, Mendeleev, exhausted from his three-day effort, fell asleep. He later recalled, "I saw in a dream, a table, where all the elements

Timeline of Mendeleev's life

1834
Born in Tobolsk, Siberia, a province of Russia, on February 7

1847
Father, Ivan Pavlovich Mendeleev, dies of tuberculosis

1849
Travels with mother and sister from Tobolsk to Moscow and St. Petersburg

1850
Enrolls in Pedagogical Institute in St. Petersburg; mother and sister die of tuberculosis

1855
Graduates as a science teacher and accepts post in Simferopol in Crimea

1856
Returns to St. Petersburg to defend his master's thesis and lecture in chemistry

1861
Publishes textbook, *Organic Chemistry*, which wins the prestigious Domidov Prize

1866
Becomes a professor of chemistry at University of St. Petersburg

1868
Helps to found the Russian Chemical Society; publishes first edition of *Principles of Chemistry*

1869
Devises the periodic table of elements

1876
Visits the United States to see the Pennsylvania oil fields

1830 | 1840 | 1850 | 1860 | 1870 | 1880

During the time of Mendeleev

1837
Inventor Samuel Morse patents his electric telegraph

1848
Karl Marx publishes *The Communist Manifesto*

1859
Naturalist Charles Darwin publishes *On the Origin of Species*

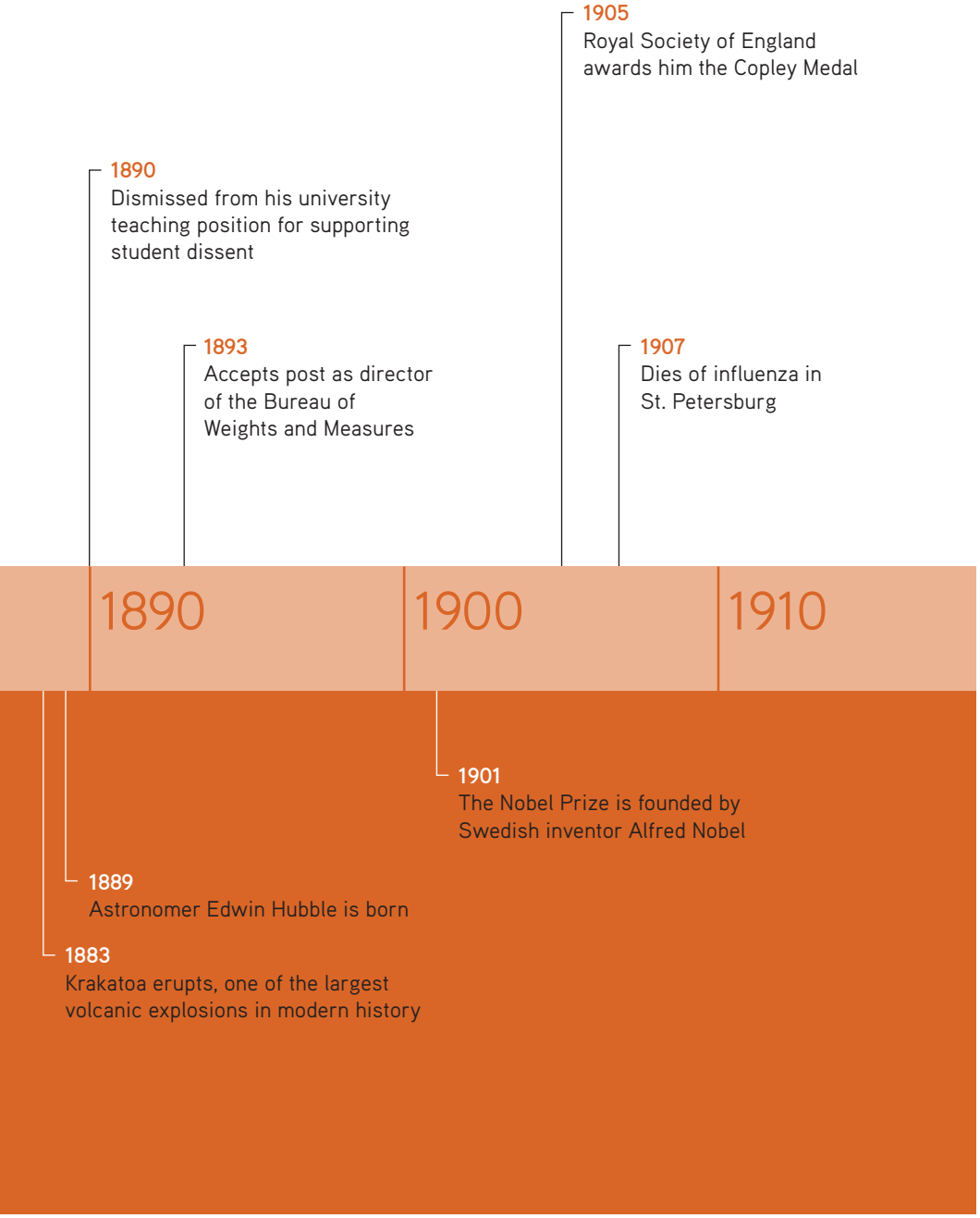
1860
Chemist Stanislao Cannizzaro discovers that molecules can contain more than one kind of atom

1866
Gregor Mendel publishes *Experiments on Plant Hybridization*, becoming the "father of modern genetics"

1867
Chemist and physicist Marie Curie is born Maria Sklowdowska in Warsaw, Poland

1868
Astronomer Henrietta Swan Leavitt is born

1879
Thomas Edison tests his first light bulb



fell into place as required. Awakening, I immediately wrote it down on a piece of paper." (Strathern, 2000) He named his discovery the "periodic table of the elements."

After his dream, Mendeleev drew the table he had envisioned. While arranging these cards of atomic data, Mendeleev discovered what is called the Periodic Law. When Mendeleev arranged the elements in order of increasing atomic mass, the properties where repeated. Because the properties repeated themselves regularly, or periodically, on his chart, the system became known as the periodic table.

In devising his table, Mendeleev did not conform completely to the order of atomic mass. He swapped some elements around. We now know that the elements in the periodic table are not all in atomic mass order. Although he was unaware of it, Mendeleev had actually placed the elements in order of increasing "atomic number," a number representing the amount of positively charged protons in the atom; also the number of negatively charged electrons that orbit the atom.

Mendeleev went even further. He corrected the known atomic masses of some elements and he used the patterns in his table to predict the properties of the elements he thought must exist but had yet to be discovered. He left blank spaces in his chart as placeholders to represent those unknown elements.

When the gap was in the middle of a triad, or trio of elements bearing similar characteristics, he would guess at the hypothetical element's atomic mass, atomic number, and other properties. Then he named these with the prefix eka, meaning "first" in Sanskrit. For instance, the predicted element designated as "eka-aluminum," he located below the known element aluminum. It was later identified as gallium.

Gallium, germanium, and scandium were all unknown in 1871, but Mendeleev left spaces for each and predicted their atomic masses and other chemical properties. Within 15 years, the "missing" elements were discovered, conforming to the basic characteristics Mendeleev had recorded. The accuracy of those predictions led to the periodic table's acceptance.

Building on others' achievements

Mendeleev did not develop the periodic table entirely on his own; he inherited and built on knowledge that was handed down from many chemists who spent their lives investigating matter. In the early 1800s, about 30 elements were known, and although chemists knew that some of these elements acted in similar ways or had similar characteristics, no one had found an overall, accepted pattern in their behaviors.

In 1860, scientists met at one of the first international chemistry conferences. They decided that hydrogen, the lightest element, be given a weight of 1. All other elements' weights would be compared to that of a hydrogen atom. That means that if an element is eight times heavier than hydrogen, its weight is 8. The concept of a systematic measure for atomic weights greatly contributed to the success of Mendeleev's periodic table.

In 1864, with about 50 elements known, the British chemist John Newlands noticed a pattern when he arranged the elements in order of atomic mass, or weight. He found that the properties of the elements seemed to repeat every eighth element. He called this the Law of Octaves, comparing it to musical scales. His ideas were rejected, and his peers joked that he may as well have arranged the elements in alphabetical order. After calcium (20 on today's periodic table), Newlands' order went amiss. He had grouped the very unreactive metal copper in the same group as the highly reactive elements lithium, sodium, and potassium. Far away in Russia, Mendeleev did not know about Newlands.

As can happen in scientific developments, another researcher arrived at the same theory as Mendeleev's at about the same time. In 1870, German chemist Julius Lothar Meyer published a paper describing the same organization of elements as Mendeleev's. Both scientists had similar backgrounds: They had studied in Heidelberg, Germany, in the laboratory of the chemist Robert Bunsen. Both had attended, in September 1860, the first international chemistry congress in Karlsruhe, Germany. The congress had addressed the need to establish a common system to measure the weights of the different elements. And both chemists were teachers working on textbooks for their students.

Was it fair that Mendeleev received all the credit for the periodic table while Meyer stayed unknown? It's possible that this happened because Mendeleev, confident in his theory, published his findings first.

Whatever the case, Mendeleev's periodic table, with placeholders strategically saved for upcoming discoveries, provided invaluable scaffolding to classify the building blocks of matter. The spaces he reserved reflected a confidence, also, in the ongoing search for knowledge.

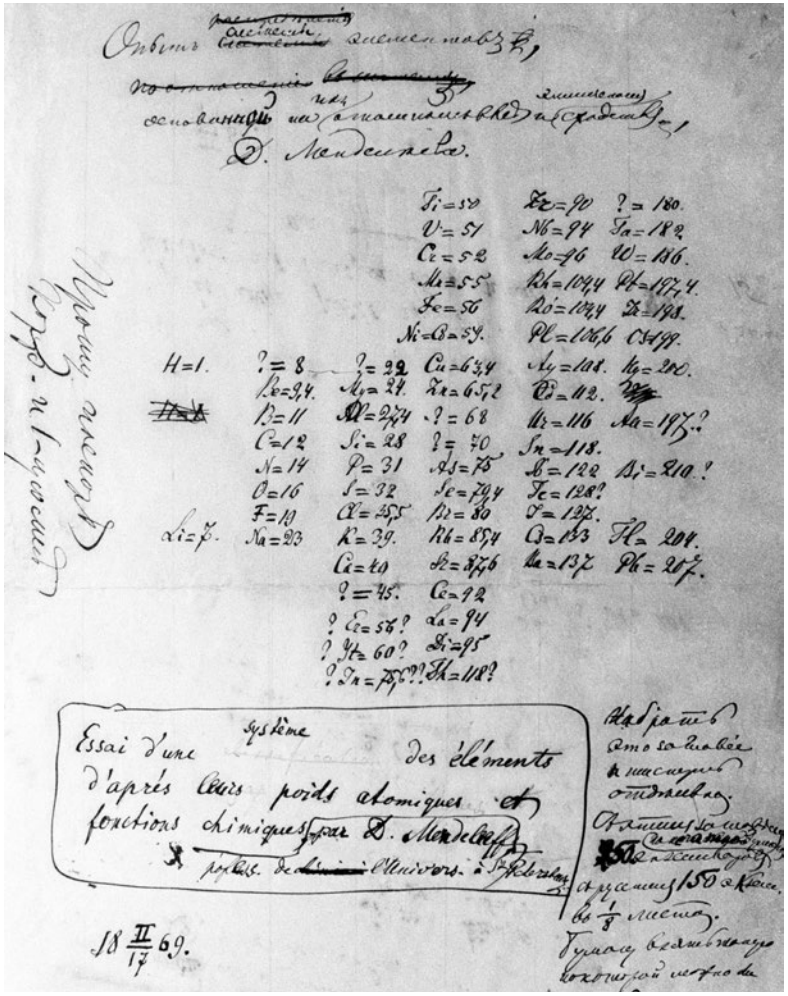
Completing the puzzle

The periodic table did not immediately affect the field of chemistry, though that changed with the discovery of the first missing element, gallium, in 1875. All of its qualities fit those Mendeleev had foreseen for the element he called eka-aluminum.

As invaluable a reference tool as it was, the periodic table left plenty of room for discovery and enhancement. In the 1890s, an entirely new and unexpected group of elements was detected: the noble gases. They were added to the table as a separate column. Helium, the second-most abundant element in the Universe, wasn't found on Earth until 1895. Another 60 or so elements have since been discovered and others may still be waiting to be found.

Beneath the contiguous periodic table, you can see two rows known as the "lanthanides" (atomic numbers 57–71) and "actinides" (atomic numbers 89–103), named after the first, left-most members of their groups. As scientists found the heavier elements and began to create many more, the newer elements have been separated to keep the table's cohesive shape.

As of 2012, the periodic table has a total of 118 elements. Some elements have been named after scientists, such as atomic number 99, Einsteinium, for Albert Einstein. Rutherfordium, atomic number 104, is named in honor of physicist Ernest Rutherford, who developed the modern model of the atom. Atomic number 101, Mendelevium, is named after the periodic table's architect.



The periodic table as first drawn by Mendeleev in 1869

The matrix

Mendeleev's periodic table presented a new paradigm, with all of the elements positioned within a logical matrix. The elements are arranged in a series of rows called "periods," so that those with similar properties appear in vertical columns. Each vertical column is called a "group," or family, of elements. This instantly shows one set of relationships when read up and down, and another when read from side to side. Some groups have elements sharing very similar properties, such as their appearance and their behavior. For example, each element has its own melting and boiling point, the temperatures at which it changes from a solid to a liquid and from a liquid to a gas. Another characteristic is how "reactive" an element is, meaning how quick it is to join up with other elements. Scientists recognize how an element will react based on its location on the table.

The elements are known by an atomic symbol of one or two letters. For example, the atomic symbol for gold is "Au," the atom's name is "gold," and its atomic number is 79. The higher the atomic number, the "heavier" an element is said to be.

Hydrogen is 1 on the periodic table, in the upper left corner. Its atomic number is 1; its nucleus contains one proton and one electron. About 98 percent of the Universe consists of the two lightest elements, hydrogen and helium.

Continuing the mission

Scientists continue to adjust the periodic table as new elements are found. Mendeleev's mission, to clarify chemistry, lives on. He dedicated his textbook to his mother with what he claimed were her last words to him:

> Refrain from illusions; insist on work and not on words. Patiently seek divine and scientific truth. (Strathern, 2000)

Sources

Bryson, Bill. *A Short History of Nearly Everything*.
New York: Delacorte Press. 2008.

Krebs, Robert E. *The History and Use of Our Earth's Chemical Elements*.
Westport, CT: Greenwood Press, 2006.

Strathern, Paul. *Mendeleyev's Dream: The Quest for the Elements*.
New York: St. Martin's Press, 2000.

Winston, Robert. *It's Elementary! How Chemistry Rocks Our World*.
New York: Dorling Kindersley Limited, 2007.

Zannos, Susan. *Dmitri Mendeleyev and the Period Table*.
Hockessin, DE: Mitchell Lane Publishers, 2005.

Image credits

Dmitri Mendeleev in 1897, public domain

An engraving of Mendeleev, public domain

Mendeleev's 1869 periodic table

NEWSELA

Articles leveled by Newsela have been adjusted along several dimensions of text complexity including sentence structure, vocabulary and organization. The number followed by L indicates the Lexile measure of the article. For more information on Lexile measures and how they correspond to grade levels: http://www.lexile.com/about-lexile/lexile-overview/

To learn more about Newsela, visit www.newsela.com/about.

The Lexile® Framework for Reading
The Lexile® Framework for Reading evaluates reading ability and text complexity on the same developmental scale. Unlike other measurement systems, the Lexile Framework determines reading ability based on actual assessments, rather than generalized age or grade levels. Recognized as the standard for matching readers with texts, tens of millions of students worldwide receive a Lexile measure that helps them find targeted readings from the more than 100 million articles, books and websites that have been measured. Lexile measures connect learners of all ages with resources at the right level of challenge and monitors their progress toward state and national proficiency standards. More information about the Lexile® Framework can be found at www.Lexile.com.