ART JOHNSON AND KIT NORRIS

The Beginnings of the Metric System

THE METRIC SYSTEM IS SLOWLY BUT surely becoming an integral part of American society. Two-liter bottles of soda, 100-meter dashes, and milligrams of medicine are now commonplace. It is more important than ever that students have a working knowledge of the metric system. When students study metrics in mathematics class, it can be beneficial for them to learn something about its origins. The historical underpinnings of the metric system can be instructive and entertaining for students in the middle grades.

The advent of the metric system extends back about 400 years. French mathematician Simon Stevin (1548–1620) published *De Thiende*, in which he advocated the use of decimal fractions as an efficient way to represent rational numbers. The pamphlet also suggested a measurement system based on powers of ten, but nothing resulted from it. Gabriel Mouton, the vicar of St. Paul's Church in Lyon, France, took up the metric cause about 100 years later. The basic unit in Mouton's system was one minute of the length of a line of longitude, about 34 meters, with subdivisions based on powers of ten. In 1675, Tito Livio Burattini proposed a *meter* as the standard unit of length for the world community. He envisioned a time when "all civilized people on Earth would use the same weights and measures despite differences in language and customs" (Strauss 1995).

The matter of a new measurement system lay dormant until 1789. In France at that time, over 800 different measures were in use. There were thirteen distinct measures for feet, ranging from 10.6 inches to 13.4 inches; twelve different pounds ranging from 0.758 to 1.143 pounds; and twenty-three different bushels. Some measurements, such as the *toise* (1.949 m), were unique to certain districts. With respect to measurement, France was not unique; most European countries contained provinces, districts, and even towns that used unique combinations of measures designed to meet local needs. In most countries, and in France in particular, there were continual calls to reform the confusing systems of weights and measures. The central government in France finally took steps to improve matters, but it took a revolution of historic proportions.

The French Revolution changed everything. While removing the monarchy, revolutionaries eradicated anything that smacked of the old regime. City names, clothing fashions, and even the calen-

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dar changed. The new revolutionary calendar was composed of twelve months of thirty days each and a short month of five days. The months themselves were also renamed. The late summer month, for example, was named *Thermidore* (the heat month), followed by *Fructidore* (the fruit month), and *Vendemiaire* (the vintage month). The days of the week were renamed in numeric terms according to their position: primidi, duodi, tridi, and so forth. Some citizens did not eagerly accept the new names. As Bishop Gregoire approached the guillotine, he scolded the revolutionaries with this statement: "Sunday has existed before you and it will survive you."

In the spirit of change, Count Talleyrand made a proposal in April 1791. He was a diplomat who had served the royal regime, the revolutionaries, Napoleon, and the returning royal family, in succession. He proposed to the National Assembly that the French Academy of Sciences devise a new measurement system that had logical, scientific backing, unlike the irregular development of the measurements used across France and Europe. On August 19, 1791, the formal proposal for the new system was presented to King Louis XVI, one day before his futile attempt to escape from France. Although he gave his enthusiastic approval, it is hard to know if he paid much attention, with his escape attempt only hours away.

In any event, the National Assembly soon directed the French Academy of Sciences to "deduce an invariable standard for all the measures and all the weights" (Johnson 1994). The new system of measures would be derived from the measurement of a line of longitude. Mathematicians, accountants, and scientists were assembled for the task, including scientist Antoine Lavoisier and mathematicians Adrien Legendre and Marie Condorcet. The group decided to use the basic unit

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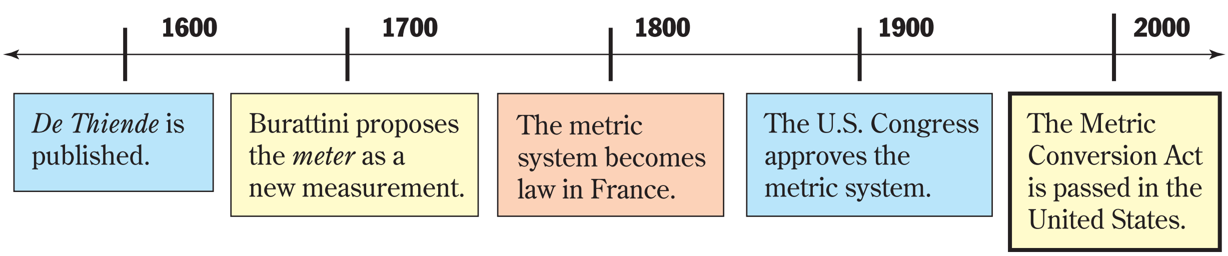
of the meridian length from the North Pole to the equator through Paris. This unit of length was called a "meter," derived from the Greek word *metron*, meaning "to measure." The meridian's length was to be determined by finding the length of a tenth of the meridian (or quadrant) of the distance from Dunkirk, on the English Channel, to Barcelona, Spain. This task, which would have been difficult under ideal conditions, took six years to complete because of frequent wars and changes in government and personnel.

The Provisionary Weights and Measures Committee appointed two astronomers, Jean Baptiste Delambre and Pierre Méchain, to survey the distance from Dunkirk to Barcelona using triangulation. From the start, the task was difficult and dangerous. Méchain was arrested while trying to leave Paris to begin work because his surveying instruments raised concern among the Revolutionary Guard. They feared Méchain was part of a plot to subvert the revolution and that the instruments he carried would be used to restore the monarchy. Fortunately, cooler heads prevailed, and Méchain and his assistants were freed from prison and a date with the guillotine. On another occasion, the surveyors were arrested because they were using white cloth as survey markers. White represented the royal family and using this cloth identified the surveyors as Royalists. The survey crew avoided the guillotine when they designed new sighting cloth containing the politically correct stripes of blue and red mixed with white. By 1793, the Revolution had claimed both Lavoisier and Condorcet as its victims. To avoid a similar fate, Delambre returned to Paris and turned in all his surveying instruments.

After laying out more than one hundred triangles (the triangle was used as a surveying unit of measure), the surveying team completed its task. In 1799, the metric system became law, eliminating the morass of weights and measures that had developed in France over the centuries. The metric system was presented to the French government, along with a platinum rod marking the meter and a platinum bar weighing a kilogram. The metric system, the official measurement system of France, took on this motto: "For all the people, for all time." The platinum rod and kilogram bar were stored in sterile conditions in the Pavillon de Berteuil, in Sèvres, outside Paris.

Old ways die hard, however, and in 1811 Pierre LaPlace (1749–1827) proposed calling the system Napoleonic Measures so as to insure its use and the Emperor's support. This new system did not win over the



French citizenry. In 1812, there was a brief return to metricized traditional units, which proved to be even more confusing than ever. In 1840, France returned to the metric system, never to depart again. Other European nations had adopted the system during the Napoleonic period as they fell under the influence of Napoleon's troops. Although Russia and England were holdouts, both came into the metric fold during the twentieth century. The United States remains the lone holdout among the world's industrialized nations.

Why didn't the United States adopt the metric system? As early as 1790, Thomas Jefferson had proposed some sort of metric measuring system. Some sources blame pirates who roamed the Atlantic Ocean 200 years ago. As the story goes, the French National Assembly sent a representative bearing a kilogram and a meter to the United States with news of that country's new measurement system. Pirates sank the representative's ship and enslaved all on board. Word of the new system did reach these shores, but along with the system came news of the excesses of the French Revolution, which poisoned many minds against anything metric.

Congress authorized the use of the metric system in national and local commerce with the passage of the Metric Act of 1866. In 1875, the United States and twenty other countries signed the Treaty of the Meter, which established the International Institute of Weights and Measures in Sèvres, France. Neither action furthered the use of the metric system in the United States. The Metric Conversion Act, passed in 1975, was "to coordinate and plan the integration of the metric system in the United States." Seven years later, the Metric Board was dissolved because of a lack of funding, interest, and success. In 1988, the Omnibus Trade and Competitiveness Act finally made some progress; four years later the Act mandated that any commercial contracts with the federal government must stipulate metric measures. As a result, the metric system entered the world of commerce, but the standard system of feet, pints, and pounds remains the entrenched measurement system of daily life in the United States.

There have been few changes in the metric system since it was first developed over 200 years ago. It continues to serve modern society as well as it served Napoleonic Europe. There have been advances in the standard meter, however. The original platinum rod with marks that designated the length of a meter is now simply an item of curiosity in a French museum, because it is inaccurate. Because Earth is not a perfect sphere, the original measurements by Méchain were in error. The actual length of

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of the distance from the Equator to the North Pole is 0.2 millimeter longer than the meter inscribed on that platinum rod. Since 1983, a meter has been considered the distance that light travels in a vacuum in

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of a second. (In a similar fashion, the second is now defined as the time it takes a cesium-133 atom to vibrate 9,192,631,770 times.) The kilogram remains the same as the platinum bar that was submitted to the French government 200 years ago. Le Bureau International des Poids et Mesures in Sèvres still houses the original kilogram, a cylinder of platinum in a bell-jar vacuum, which in turn is housed in another bell-jar vacuum.

Despite attempts to keep the original kilogram bar free of pollution and any other atmospheric effects by sealing it in multiple jars, it keeps gaining weight. In 1989, the last time the original kilogram, affectionately known by metric aficionados as Le Grand K, was removed for weighing and cleaning, scientists found that it had changed mass. It had gained, on average, about 20 billionths of a gram per year. Although this is roughly the weight of a pepper grain, it meant that the kilogram was not uniform.

The last vestige of the old way of measuring needs to be replaced with a standard that will never change. The problem for scientists is how to define a kilogram's weight in terms of modern science. One school of thought suggests defining the kilogram as a specific number of silicon atoms. However, silicon atoms have irregular atomic structures, never mind the sheer number of atoms needed for the definition. The number of gold atoms that weigh a kilogram is represented by twenty-five digits. Another more promising approach involves creating an electromagnetic force that exactly balances the force of gravity on a kilogram. Scientists at the National Institute of Standards and Technology in Gaithersburg, Maryland, have built a pan balance that is nearly two stories tall. Whatever combination of voltage and current balances a kilogram on this highly delicate balance would become the new definition of the kilogram. So far, researchers have spent more than twenty years making adjustments and readjustments to find the elusive numbers. Thus far, Le Grand K has resisted attempts to render it a mere number. Le Grand K lives, but for how long?

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