

# ABOUT THE COVER: CHARLES DARWIN, LORD KELVIN, AND THE AGE OF THE EARTH

## FEATURE

What are two statues, honoring two distinguished gentlemen of the 19th century, doing on our cover, which celebrates the Enlightenment of the 18th century? Charles Darwin and William Thomson (a.k.a. Lord Kelvin) carried the illumination of the Enlightenment forward, in biology and in physics respectively. They stand at the intersection of the primary theme of this issue of *Radiations*: “Relumine the Enlightenment.” Kelvin also stands in the center of a second theme of this issue, concerning absolute zero.

### I

The pinnacles of nineteenth century physics included electrodynamics, statistical mechanics, energy conservation, and thermodynamics. In thermodynamics, for instance, the Kelvin-Planck statement of the Second Law asserts that no engine can operate with 100 percent efficiency (see p. 5), which leads to profound criteria for spontaneous processes, and, in the longer view, the ultimate “heat death” of the universe. Thermodynamics, says Rigden, “was developed in such a way that Einstein identified it as a model of what physical science should be.” The achievements of nineteenth century physics grew from the spirit of the eighteenth century Enlightenment, which grew in turn from the Scientific Revolution of the seventeenth century. Nineteenth century physics and its segue into the Relativity and the Quantum of the twentieth century admirably “lumined the Enlightenment.”

But today, disturbing trends in the politics of public education prompts Rigden to warn, “Could the people of the 21st century reverse the transformation that occurred 200 years ago by rejecting the methods of science in favor of the assertions by authority?...[T]he very definition of science is being challenged with the goal of bringing into the science classroom material that lies outside the scope of the current definition. This could change science as we know it. I believe these challenges are serious.” Because hostile confrontations are counterproductive and pointless, Rigden urges the scientific community to take a *positive* approach in engaging these challenges.

In the mid-nineteenth century, Charles Darwin and Alfred Russell Wallace made the case for biological evolution by natural selection. Evolution requires enormous quantities of time, and geologists were also beginning to suggest that age of the

earth must be counted at least in the hundreds of millions of years.

The parts of a scientific theory that do *not* fit are always the most interesting. In 1862, Thomson showed that, according to the thermodynamics of heat conduction, a half-billion-year-old Earth that began in an molten state should have thoroughly solidified and cooled aeons ago. By his calculation, the planet’s present temperature gradient was too great to support the notion of an ancient Earth.

The energy budget of the sun also came under Thomson’s analytical scrutiny. In 1868 he showed how known mechanisms for producing radiant energy fell ridiculously short of accounting for the solar luminosity over the alleged geological timescales. In charming 19th century prose, Thomson wrote,

*...Yet what an amount of mechanical energy is emitted from the sun every year! If we calculate the exact mechanical value of the heat he emits in 81 days, we find it equivalent to the whole motion of the earth in her orbit around the sun....But suppose the earth’s motion were destroyed, what would become of the earth? Suppose it were to be suddenly, by an obstacle, stopped in its motion round the sun? It would suddenly give out 81 times as much heat as the sun gives out in a day, and would begin falling towards the sun, and would acquire on the way such a velocity such that, in the collision, a blaze of light and heat would be produced in the course of a few minutes equal to what the sun emits in 95 years. That is, indeed, a prodigious amount of heat; but just consider the result if all the planetary bodies were to fall into the sun. Take Jupiter with its enormous mass, which, if falling into the sun, would in a few moments cause an evolution of 32,240 years’ heat. Take them all together—suppose all the planets were falling into the sun—the whole emission of heat due to all the planets striking the sun, with the velocities they would acquire in falling from their present distance, would amount to something under 46,000 years’ heat. We do not know these figures very well. They may be wrong by ten or twenty or thirty per cent, but that does not influence much the kind of inference we draw from them. Now, what a drop in the ocean is the amount of energy of the motion of the planets, and work to be done in them before they reach their haven of rest, the sun, compared*

*(continued on next page)*

with what the sun has emitted already! I suppose all geologists admit that the sun has shone more than 46,000 years?

“...If, then...we have strong reason to believe that there is no continual supply of energy to the sun, we are driven to the conclusion that it is losing energy...[W]e may imagine the sun to be merely a heated body cooling; but imagine it as we please, we cannot estimate more on any probable hypothesis, than a few million years of heat...The estimates here are necessarily very vague, but yet, vague as they are, I do not know that it is possible, upon any reasonable estimate, founded on known properties of matter, to say that we can believe the sun has really illuminated the earth for five hundred million years.”

One can imagine that such pronouncements from so eminent a physicist were greeted with glee by those who opposed the ideas of an ancient earth and biological evolution. But Thomson had raised a genuine scientific question. As he implied, the answer to the paradox would be found not by invoking a “God of the gaps,” but in more science. While Thomson’s calculations were correct given the underlying assumptions, he could not have known about radioactivity and nuclear reactions when he made them. After the discovery of radioactivity by Henri Becquerel in 1895, by 1905 Ernest Rutherford had discovered that alpha particles were helium ions. Along with Soddy, the Curies, and others, Rutherford measured exponential decay curves and energy released. The energy source remained mysterious until  $E = mc^2$  came along in 1905. Meanwhile, it was clear that, whatever the mechanism, the energy emitted by radioactive materials was enormous. It occurred to Rutherford that radioactivity might settle Thomson’s old argument with the geologists about the antiquity of the earth. Rutherford described his announcement as follows:

*“I came into the room, which was half dark, and presently spotted Lord Kelvin in the audience and realized that I was in for trouble at the last part of my speech dealing with the age of the earth, where my views conflicted with his. To my relief, Kelvin fell fast asleep, but as I came to the important point, I saw the old bird sit up, open an eye and cock a baleful glance at me! Then a sudden inspiration came, and I said Lord Kelvin had limited the age of the earth, provided no new source was discovered. That prophetic utterance refers to what we are now considering tonight, radium! Behold! the old boy beamed upon me.”*

## II

In 1882, Thomson realized that Carnot’s Theorem made possible an absolute scale of temperature. Carnot’s Theorem shows that all reversible two-temperature engines operating

between the same two temperatures would have identical efficiencies. From the definition of efficiency, the ratio of heat output to heat input would therefore be identical for all such engines. Since the heat reservoirs are characterized by their temperature, an absolute scale would be a meaningful concept. Thomson wrote,

*“The relation between motive power and heat, as established by Carnot, is such that quantities of heat, and intervals of temperature, are involved as the sole elements in the expression of the amount of mechanical effect to be obtained through the agency of heat; and since we have, independently, a definite system for the measurement of the quantities of heat, we are thus furnished with a measure for intervals according to which absolute differences of temperature may be estimated.”*

The absolute scale of temperature was later named in honor of Thomson, the Kelvin scale.[1]

Sigma Pi Sigma and the Society of Physics Students are proud to support a public television program called *Absolute Zero*, scheduled to be broadcast next spring, based on the book of the same title by Tom Schachtman.[2] *Absolute Zero* traces the history of the “conquest of cold,” from the development of refrigeration to Bose-Einstein condensation.

As a co-founder of thermodynamics and originator of the absolute temperature scale, our support of *Absolute Zero: The Conquest of Cold* directs us to Kelvin. As a veteran of arguments over the age of the earth, as an inheritor of Enlightenment values committed to reason and honesty before the evidence, Kelvin would be on the front lines of “Relumining the Enlightenment” in today’s struggle for the place of science in society.

— Editor

[1] When made a Baron, Lord Kelvin took his title from the Kelvin river that ran through his estate.

[2] Tom Schachtman, *Absolute Zero<sup>o</sup> and the Conquest of Cold* (A Mariner Book, Houghton Mifflin Company, 1999).

Papers quoted: Sir W. Thomson (Lord Kelvin), “On Geological Time,” *Transactions of the Geological Society of Glasgow*, Vol. III (1868); “Of Geological Dynamics,” *Transactions of the Geological Society of Glasgow* (1869); “On the Secular Cooling of the Earth,” *Transactions of the Royal Society of Edinburgh*, Vol. XXIII; “On the Absolute Thermometric Scale founded on Carnot’s Theory of the Motive Power of heat, and calculated from Regnault’s Observations,” *Philosophical Magazine*, October 1848. These and others are conveniently available through [http://sapatopi.net/kelvin/papers/\[paper\\_title\]/html](http://sapatopi.net/kelvin/papers/[paper_title]/html)

Rutherford quote from Emilio Segrè, *From X-Rays to Quarks: Modern Physicists and Their Discoveries* (Freeman, 1976), p. 59.

