REVIEWS OF SCIENCE AND SOCIETY EDUCATIONAL RESOURCES

William F. Ruddiman, Plows, *Plagues & Petroleum: How Humans Took Control of Climate*, (Princeton University Press, Princeton, 2005), 202 + xiv pp., ISBN 0-691-12164-8.

Ruddiman says that research into climatic and human history is like entering a crime scene thousands of years later and trying to figure out what happened, and that's what his book is about. The crime scene in this case is the historical record of concentration of methane and carbon dioxide in Earth's atmosphere, and Ruddiman relates his surprise upon noting an abrupt reversal of the declining concentration of methane 5000 years ago and a similarly abrupt reversal of the declining concentration of carbon dioxide 8000 years ago.

Normally a book about a crime scene investigation withholds the solution of the crime until the bitter end. But not Ruddiman. He states his thesis at the outset. The criminal responsible for these anomalous reversals in methane and carbon dioxide concentration is the human race, at the time in its evolution that it entered into an age of agriculture, "the largest alteration of Earth's surface from its natural state that humans have yet achieved," and the rest of the book is a defense of Ruddiman's "solution to the crime."

He shows how the reversal of methane concentration can be explained by irrigation to grow rice, also human waste, livestock emissions, and biomass burning. He explains the reversal of carbon dioxide concentration by deforestation (after all, there were no fossil fuels to burn then). Together, these account for a pre-industrial global temperature increase of 0.8^{o}C, which, according to the Sigma Xi report described in this issue, is the same as the post-industrial global temperature increase thus far. The former took place as the result of a smaller human impact over a longer period of time, the latter from a larger human impact over a shorter time. Ruddiman likens the former to the race run by the tortoise, the latter to the race run by the hare.

But stating his "solution to the crime" at the outset of his book does not mean that Ruddiman has no further surprises in store for his readers. If you'd like to read his book with the benefit of those surprises, I suggest that you stop reading this review and read Ruddiman's book now, but if you have been an astute observer of Ruddiman's title, you might have an inkling of what one of the surprises is.

When he gets to his twelfth chapter, he presents a smaller scale graph of the increase in atmospheric carbon dioxide, focusing on the last 2500 years rather than the previous graph spread out over the past 12000 years. Now the scattering of points during the historical era show up as three anomalous dips in an otherwise constantly increasing line. They occur between 200 and 600 AD, 1300 and 1400 AD, and 1500-1750 AD. Although Ruddiman could find no correlation with warfare or famine to account for these intermittent reductions in atmospheric carbon dioxide, he did find it with disease -- smallpox or bubonic plague un the last centuries of the Western Roman Empire, the death of 40 to 45% of Europeans due to the Black Death, and the death of up to 90% of the population of the Americas (now believed to have been much larger than previously considered) from diseases brought by European invaders.

Whether it be pre- or post-industrial emission of greenhouse gases, the relationship between them and the eventual warming that results depends on the different "response times" of different parts of the Earth. Land responds to an increase of greenhouse gases in the atmosphere with a temperature increase in hours to months, but water requires months to decades, and ice sheets millennia. The "global average" is "decades." Because of this decadal lag between increased atmospheric greenhouse gases and increased global temperature, Ruddiman reminds us that we have not reaped the full consequences of the greenhouse gases already emitted into our atmosphere. Over 70% of the industrial area greenhouse gas emissions have occurred since 1950, and he cites estimates expecting a further temperature increase of 0.6 to 0.7^{o}C (0.2^{o}C greater than the expectations of the Sigma Xi report) in addition to that already observed. He adds that the warming due to industrially-generated greenhouse gases is offset by up to 20% by sulfate aerosols resulting from sulfur dioxide emissions, but he cautions that their response time is on the order of weeks, so that shutting down coal-burning power plants would lead to an end of the offsetting effect of the aerosols before the end of the warming effect of the greenhouse gases.

With oil and natural gas expected to be more or less exhausted by the end of the 21st century, Ruddiman notes that coal will be the only carbon dioxide-producing fuel remaining. He considers two scenarios for future atmospheric concentrations of carbon dioxide -- a doubling and a quadrupling of the pre-industrial concentration of 280 ppm -- and expects reality to lie somewhere in between. He notes that the doubling will require considerable concerted effort of the world's population and, by the consensus of the IPCC (Intergovernmental Panel on Climate Change), this would increase global temperature by 2.5^{o}C. This level of carbon dioxide, Ruddiman observes, was last seen on Earth between five and ten (p. 167) or twenty (p. 164) million years ago, when there was no Greenland ice sheet and only a small Antarctic ice sheet. Yet, because the increase of atmospheric carbon dioxide will be in the form of a pulse (due to the finiteness even of the coal supply), Ruddiman expects that the bulk of the Greenland and Antarctic ice sheets will be able to survive, because of their long delay times (although he acknowledges recent analyses pointing to greater vulnerability, as does Resource #3 of this issue, written after Ruddiman's book). Ruddiman adds that although higher global temperatures will increase evaporation rates all around the globe, the resulting increased rainfall would not necessarily fall uniformly.

Ruddiman notes that a quadrupling of pre-industrial atmospheric carbon dioxide was last seen on Earth 50 million years ago, when there was no permanent ice at all. This quadrupling would be the result of what Ruddiman calls the "business as usual" scenario. But, because here too the increased carbon dioxide would come in the form of a pulse, Ruddiman feels that much of the Antarctic ice sheet would survive. Otherwise, he writes, sea level would rise 205 feet. For the current century, Ruddiman expects a sea level rise of only half a meter, though, and another meter in the 22nd century.

Ruddiman begins his Epilogue, which he considers to be his "'editorial' section," with a disclaimer not to have been involved in the polarizing debate about global warming or funded by groups at either polarity. In it he expresses his concern that the "debate" about global warming is being framed by groups at those extreme poles of the spectrum, which he has labeled "environmental" and "industrial." Both types of groups found something in the thesis of his book to further their cause, he writes, and he considers two issues related to global warming as represented by them -- rising sea level (which he feels is more critical for Bangladesh than Miami) and Arctic warming (which he sees a dooming Arctic ecosystems) -- and laments that scientists have been co-opted, and even paid, to write commentaries that selectively cite science to advocate a particular point of view.

Noting that avoiding the threat of global warming is a problem that requires bearing a huge cost up front in return for benefits that won't arrive until later -- the kind of situation that is opposite what most people and politicians prefer -- Ruddiman also questions how much people are willing to sacrifice. He thinks "the single most effective thing that can be done about global warming is to invest in technologies that will reduce carbon emissions, especially those that will come from the 200-year supply of coal we will eventually burn." (p. 183) This can delay and reduce the ultimate amount of global warming, he notes.

Finally, Ruddiman reminds his readers, especially those concerned about global warming, that the thesis of his book is that humans have affected their environment by transforming the surface of the Earth for 8000 years, not just 250. He sees as a larger environmental problem the consumption of Nature's "gifts," all at rates faster than the rates at which Nature can produce them. In addition to the three fossil fuels he lists water and topsoil and notes that all are needed for agriculture (petrochemicals for fertilizer). He wonders how the generation of his grandchildren will view what we have done with these "gifts."

- John L. Roeder

Jeremy Bernstein, *Plutonium* (Joseph Henry Press, Washington, 2007). 171 pp.

"Plutonium is so unusual as to approach the unbelievable. Under some conditions it can be nearly as hard and brittle as glass; under others, as soft as plastic or lead. It will burn and crumble quickly to powder when heated in air, or slowly disintegrate when kept at room temperature. It undergoes no less than five phase transitions between room temperature and its melting point. Strangely enough in two of its phases, plutonium actually contracts as it is being heated. It has no less than four oxidation states. It is unique among all of the chemical elements. And it is fiendishly toxic, even in small amounts."

There are many interesting and valuable quotes in Plutonium, by Jeremy Bernstein, but the above quote by Glenn Seaborg is probably the most concise and intriguing. In the preamble to the book, Bernstein describes the aboveground nuclear test he observed in Nevada in 1957. He includes information about the effect the test had on him, as well as the plutonium "pits" of atomic bombs he saw. He was given one to hold, and writes that it was "warm and about the size and weight of a bowling ball." He compares this with the 2.7 millionths of a gram that in September of 1942 was the entire world's supply of plutonium.

The book is very enjoyable to read. The first seven chapters contain a great deal of information about the history and development of radioactive materials. Chapter two ends with interesting information about the initial namesm used to identify yet to be discovered elements.

Dimitri Mendeleev, of Periodic Table fame, studied Sanskrit while at the university in St. Petersburg. Eka, dvi and tri represent one, two and three in Sanskrit. Mendeleev identified what were later named scandium, gallium, and polonium, eka-boron, eka-aluminum and dvi-tellurium.

The career of Ida Noddack is briefly described in Chapter five. Bernstein, "Putting the matter simply," indicates that in 1934, Noddack was suggesting that observations made by Enrico Fermi were indications of nuclear fission. He later wonders how different our world might be had fission been identified atthat time, including wondering if World War II might have been nuclear from the beginning!

The work and career of Glenn Seaborg is presented in chapter seven. The importance of a motivational high school chemistry teacher, Dwight Logan Reid, to Seaborg's career is identified, as well as professor G.N. Lewis, while Seaborg was at UCLA. Among other things, Glenn Seaborg discovered that plutonium is more fissile than uranium.

There are fourteen "plates" of pictures and diagrams in the book. Plate 14 is described as "A clear and present danger in Russia." The plate identifies more than 25 plutonium storage sites in Russia and former Russian states.

The varied properties of plutonium are detailed throughout the book. Chapter nine, "Los Alamos", includes some of this interesting information. Bernstein states that due to these varied properties "if you intend to use metallic plutonium to make a bomb, you will be confronted with a very significant metallurgical challenge."

Plutonium is produced in nuclear power reactors as a result of the beta decay of the neptunium-239 produced from the beta decay of the uranium-239 formed by the neutron absorption of uranium-238. The plutonium-239 that remains in the reactor can produce plutonium-240 by absorbing a neutron. The ability of Pu-240 to fission spontaneously causes a plutonium fission weapon to predetonate if Pu-240 is present.

Bernstein discusses the experiences of Ted Magel and Nick Dallas. Their experience in becoming the first people to produce enough pure uranium metal to see without a microscope is very interesting. Their subsequent contamination with plutonium, resulting in their membership in the You Pee Plutonium (UPPU) club, is interesting and eye-opening.

Chapter ten ends with a description of the fires at the Rocky Flats Nuclear plant in Golden, Colorado. These fires occurred as a result of the heat produced from the chemical conversion of plutonium into plutonium oxides. Bernstein describes these fires as ".an example of the postwar problems that have been, and are still being, caused by plutonium." In chapter eleven he details some of those problems. This includes information that China began producing plutonium in the 1960's, and that in the early 1990's, it was estimated ".that a total of about 2.8 metric tons of weapons grade plutonium had been produced."

As indicated at the beginning of this review, this book is 171 pages long. In preparing to review it, thirty six pages containing interesting and significant information were noted.

Everyone with even a mild interest in nuclear science or nuclear politics should read this enjoyable and informative book.

- Frank Lock

(*Editor's Note*: Frank Lock teaches at Lemon Bay H.S. in Englewood, FL. He has previously reviewed Thomas Gold's *The Deep Hot Biosphere* in our Winter/Spring 2002 issue and Roger Highfield's *The Science of Harry Potter* in our Fall 2003 issue.)

Michael D. Gordin, *A Well-Ordered Thing: Dimitrii Mendeleev and the Shadow of the Periodic Table* (Basic, New York, 2004). xx + 364 pp. $30.00 ISBN 0-465-02775-X.

Characterizing Mendeleev as "a public figure in at least three senses . . . a subject of public discussion, a public servant, and a prominent interpreter of chemistry," Gordin has chosen to describe "seven major episodes from Mendeleev's life" to show how Mendeleev brought the same characteristics to bear on all three aspects of his life pursuits. (pp. 10, 11)

The first of these is the achievement with which Mendeleev is most associated today -- the development of the periodic table of the elements. The story begins as Mendeleev returns to St. Petersburg in 1860 from a year of study in Heidelberg, where he was also in the company of chemist-composer Alexander Borodin. That year included participation in the Karlsruhe Congress, in which Mendeleev became acquainted with the world's leading chemists and was particularly impressed by "Cannizzaro's resurrection of Avogadro's hypothesis" (p. 23) and its impact on the measurement of atomic weights. This, plus the large number of newly-discovered chemical elements at the time, set the stage for developing the periodic table.

By 1867 Mendeleev became the tenured professor of general chemistry at St. Petersburg University, and he was faced with the need to write a textbook for the course in general chemistry he was to teach. By the time he completed the first of two volumes, he had considered only "organogens" (hydrogen, carbon, nitrogen, and oxygen) and the halogens -- only eight of the 63 elements then known. To organize his discussion of the other 55 elements in the second volume, he developed the precursor of the periodic table as a scheme of classification -- in February 1869 -- by ordering the elements by atomic weight while also noticing a cyclic recurrence of chemical properties (although tellurium and iodine violated the ordering by atomic weight).

The interesting part of the story is how this scheme of classification evolved from a textbook presentation into a predictive law. In fact, one can see that in his rough draft Mendeleev crossed out the word for "classification" and replaced it with the word for "system." The predictiveness of the periodic table came from going beyond the simple recognition of gaps in the periodic recurrence of chemical properties to predicting the properties of the elements that would eventually be discovered to fill those gaps. Indeed, all three elements so predicted -- gallium, scandium, and germanium -- were discovered during Mendeleev's lifetime by chemists living in the regions for which they named these elements, and Mendeleev's predictions of their properties were validated on all three counts. Yet, Gordin gives no play to the anecdote that Mendeleev developed his periodic table by cutting out and arranging cards on which he had written all the known properties of the then known elements.

The rest of the book consists of a chapter on each of the additional six episodes which Gordin addresses in his cultural biographical study, plus a conclusion. The next episode began on 20 December 1871, when Mendeleev shelved his work on rare earths in favor of a large scale experimental research program on gases. This was to be the first Russian "big science" project, with funds provided by the Russian Technical Society, which saw value to come for military and technological applications from research on gases in the high-pressure region. But Mendeleev's real interest was detecting the elusive luminiferous ether, and for that he focused on the low-pressure region, where he hoped to find evidence for the ether in deviations from what Gordin calls the Boyle-Mariotte law.

Deviations from this law at low pressures gave Mendeleev only short-lived ecstasy, and volume one of his *On the Elasticity of Gases* was focused on raising funds for an aerostat and an aeronaut to measure the upper region of Earth's atmosphere, the next place at which Mendeleev sought to find evidence of the ether. However, his 1878 trip to Western Europe in search of an aerostat resulted instead in modeling air resistance, leading to volume one of *On the Resistance of Liquids and on Aeronautics* in 1880, with no volume two of either series to follow. In fact, Mendeleev resigned from the project the following year, blaming the inability to replace the late Mikhail Kirpichev, whose mathematical skills were essential to the project, and citing a slew of other commitments as excuses.

The other episodes of Mendeleev's life described in this book do not all occur sequentially. In fact, the third, Mendeleev's attempt to debunk spiritualism, occurred during the decade of his gas measurements. And the fourth, Mendeleev's failure to win election to the St. Petersburg Academy of Sciences, occurred in the penultimate year of that decade, slightly before his divorce from his first wife.

Although the Academy seat denied Mendeleev went to a chemist who had contributed far more research toward chemistry, the support for Mendeleev's candidacy compared to what one would normally expect for an actor, dancer, or singer. And a decade after that (1890), Mendeleev resigned his professorship at St. Petersburg University and became the Director of the Chief Bureau of Weights and Measures. In this he saw a parallel with the life of Newton, whom he adulated, when Newton left Cambridge University to become Master of the Mint. As Gordin shows in tracing through the evolution of periodicity of chemical elements through eight editions of Principles of Chemistry, in which it became elevated to the status of law, Mendeleev even fancied himself playing in chemistry the role Newton played in physics and was frustrated by not being able to express the law of chemical periodicity in mathematical form, as Newton had done with the laws of motion.

The circumstances of Mendeleev's resignation of his professorship, however, revealed Mendeleev as far more than one who sought to model his life after Newton. To support his belief that the university should be autonomous, Mendeleev sought to moderate student grievances. When his attempt to transmit a student grievance petition was thwarted because of his oath of Imperial service, he resigned his professorship, only to have the unrest worsen when the students heard rumors that Mendeleev had been fired. Gordin writes, "The reaction undermined Mendeleev's faith in the Russian people's ability to take a gradualist path toward change, although it reinforced his belief in the need for such gradualism." (p. 203)

This incident in 1890 was minor compared to the changes that were to come to Russia, even in the "first revolution" of 1905, two years before Mendeleev's death. But, though he would continue as the Director of the Chief Bureau of Weights and Measures, dying at his desk there, he was becoming resistant to change, both in science and society. Until the entire family of noble gases was discovered, he viewed the discovery of argon as a threat to his periodic system, interpreting it as N_3 by analogy with ozone. And the discoveries of radioactivity and the electron conflicted with Mendeleev's belief that atoms were immutable. In fact, to explain radioactive decay, Mendeleev saw yet another way to establish the reality of the ether which had been his quest since 1871: he saw it occupying a place on the periodic table above helium. Moreover, since the ether could not be observed in the solar system, it would have had to escape even the Sun, from which Mendeleev calculated ether's atomic weight to be 0.000013. Gordin writes that the periodic law "was his only unqualified success," (p. 253) and notes that his "reputation as a leading Russian thinker hinged on his ability to marshal his periodic system to make predictions. . . . The chemical ether was his last such effort, born not of a desire to establish a new science of chemistry but in order to defend that science from threatening newcomers. . . . Unfortunately, the vast majority of his peers in chemistry did not hold to the metaphysical worldview that Mendeleev wanted to protect, did not see what was so awful about granting the disintegration of radioactivity status as natural phenomena." (p. 231)

- John L. Roeder