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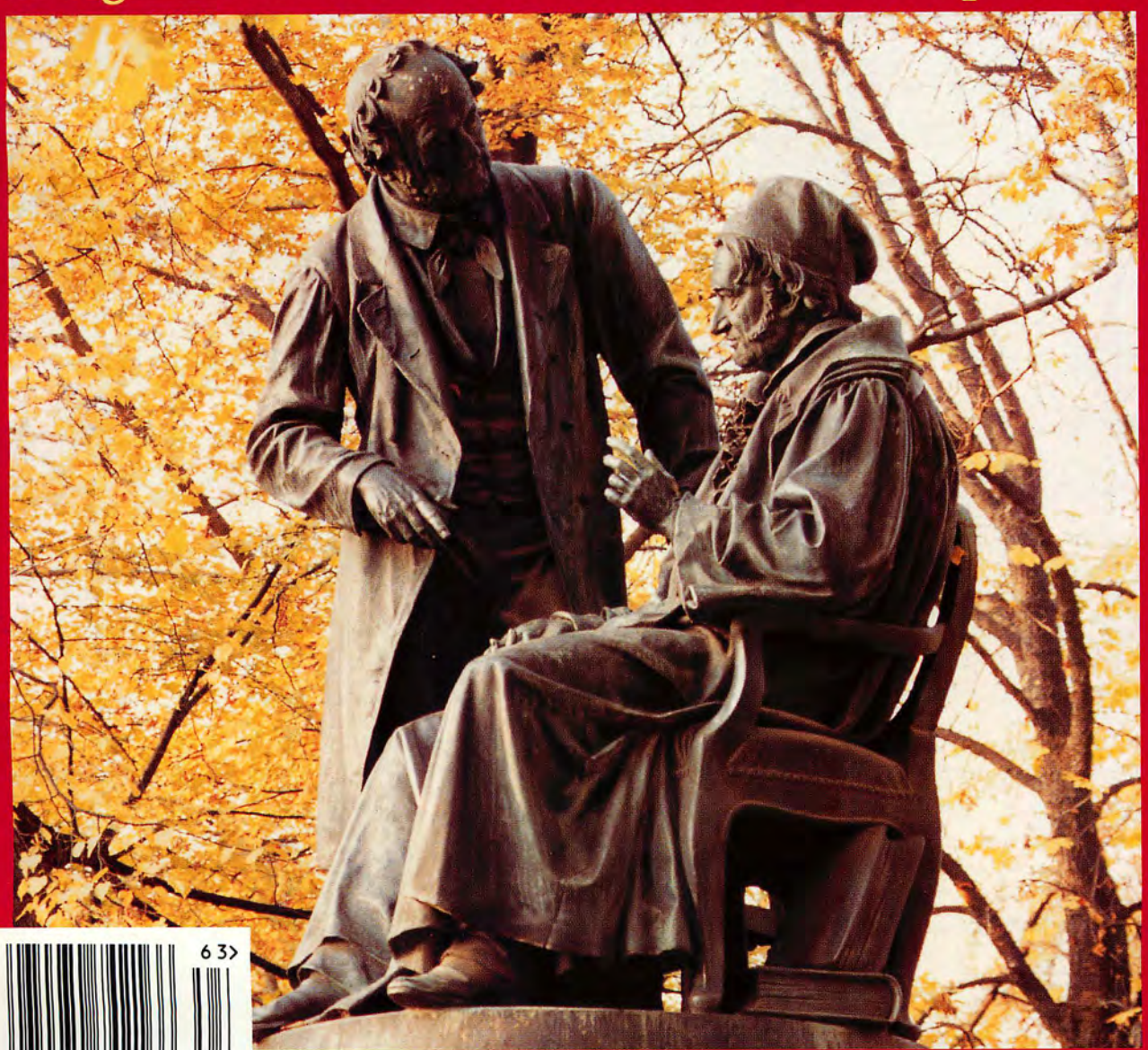

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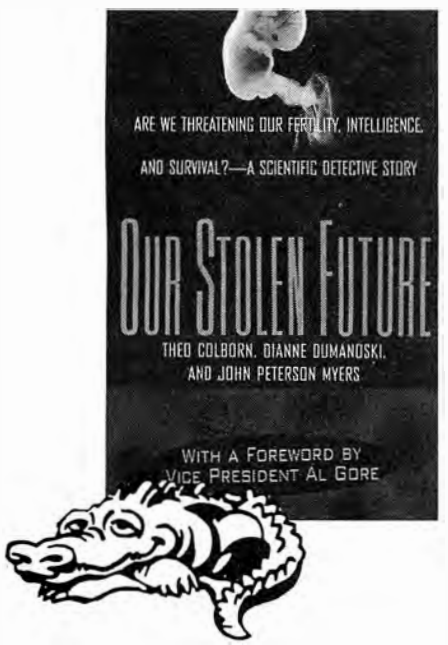

The new infertility myth: Entomologist J. Gordon Edwards takes on the latest chemical scare story in his review of Our Stolen Future, *p. 52.*

On the cover: Wilhelm Weber (standing) and Carl Friedrich Gauss are memorialized in this statue at Göttingen University, sculpted by Prof. F. Hartzen and cast by W. and P. Gladenbeck. The statue was dedicated in 1899 and paid for by funds raised by prominent scientists. Photo courtesy of Göttingen Tourist Office; cover design by Rosemary Moak.

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An Introduction to 'The Significance of the 1845 Gauss-Weber Correspondence'

by Jonathan Tennenbaum

In the middle of last century, Carl Gauss, Wilhelm Weber, and a close circle of collaborators effected a revolution in physics—a revolution whose actual nature and content, however, are nearly entirely unknown to the scientific world today.

Working with a handful of simple, but highly ingenious electrodynamic measurements, Weber and his collaborators were able to demonstrate, and to actually *measure,* the existence of a rigorously defined *singularity* in the microscopic domain of physical space-time. In that way, they anticipated the main subject-matter of what was much later to become quantum and atomic physics, as well as the so-called relativity theory. And they did that from a far superior methodological standpoint, than that which has dominated physics throughout the 20th century. It would be no exaggeration to say, that modern physics has still not caught up with the full implications of what the Gauss and Weber school had already accomplished, 150 years ago.

This should be enough, to recommend the reading of this issue's feature article by associate editor Laurence Hecht[1] to a wide circle of scientific readers.

Hecht's article attempts to bring the revolutionary discovery of Gauss, Weber, et al. back to life, at the same time helping to cut through layers of myth and obfuscation, which have permeated the teaching of electrodynamics and related topics, since Maxwell, Helmholtz, Clausius, and others conspired to bury the work of the Gauss-Weber-Riemann circle, beginning no later than the 1850s. If Hecht has succeeded in prying open some skeleton-filled closets, awakening sleeping dogs, and so forth, behind the all-too-smooth exterior of textbook science, then this is part of the fun, and very useful, too. Perhaps this may provoke people, involved in such fields as controlled nuclear fusion, plasma physics, relativistic beams, astrophysics, and biophysics, to cast off some of the mental blocks, which tend to inhibit progress in potentially revolutionary areas.

However, in order to "cash in" on the promised benefits of Hecht's article, readers will have to overcome rather considerable conceptual difficulties. These difficulties are not so much connected with the specific physical subject-matter per se; rather, they derive from more than a century of *systematic miseducation* concerning the very nature of scientific work and the principles which have guided the extraordinary advances in science and technology since the European Renaissance.

To try to locate the area of difficulty, I want to focus on the general problem

of "measurement"—a topic that is rather poorly understood nowadays, although the underlying issues were extensively dealt with by Nicholas of Cusa in the 15th century. In fact, Cusa's ideas, as carried forward by Kepler, Leibniz, and others, provided the essential basis for the work of Gauss and Riemann on measurement and the geometry of physical space-time. The latter investigations, in turn, were both immediately connected with, and provided the conceptual context for, the program of electrodynamical experiments carried out by Wilhelm Weber and his collaborators.

Measurement, Hypothesis, And Singularities

Cusa sets forth the problem of measurement in most popular terms in his dialogue, "Idiota de Sapientia." In that dialogue, which is well worth reading today, Cusa emphasizes, that *there is no such thing as measurement without hypothesis.* Even the most seemingly self-evident, "objective" and commonplace forms of physical measurements, such as determination of weight, length, or even number, presuppose whole sets of basic assumptions concerning the nature and organization of our Universe.

Furthermore, just as mere weighing could never tell us the value and physical nature of a "pound" or "kilogram" as unit of measurement, so, the *source* and the *authority* of the hypotheses, upon which any form of measurement is based, cannot be found in the measurement-process itself; rather, these must be sought in *another domain*—a domain peculiar to scientific revolutions, and which separates the practice of science proper, from mere engineering.

The significance of Cusa's point comes most powerfully to the fore, when we examine the history of the process by which human knowledge has been progressively extended, from the scale-length range of ordinary sense experience, ever deeper into the domains of the "very large" and "very small." As we drive our investigations toward the extremes of scale and intensity of physical action, we are repeatedly witness to the event, that seemingly well-established concepts and assumptions, which had been supported by wide ranges of experimental evidence, suddenly fail us. We are obliged to acknowledge the fundamentally flawed and inadequate nature of existing knowledge, and to frame new hypotheses, making what might be described as "daring leaps into the unknown."

Chris Lewis

"The source and the authority of the hypotheses, upon which any form of measurement is based, cannot be found in the measurement-process itself." Here Jonathan Tennenbaum examines the device designed by Gauss for precise measurement of angular deflection, used in conjunction with the magnetometer. *(See page 35.)*

The result is an ongoing *series* of successive hypotheses, each of which introduces a *new principle of measurement*—and, implicitly, a new species of technology—enabling us to expand the experimental domain beyond the relative boundary-limits of scale and validity, associated with the earlier hypothesis. Those limits, of course, take on a *precisely determined form* only from the standpoint of the new, superior hypothesis. The *change* from the earlier, relatively inferior, to the next, relatively superior hypothesis, constitutes a definite *singularity;* a singularity which lays claim to *physical existence* within the boundary region where the new principle of measurement diverges from the earlier ones. Wilhelm Weber's discovery, aided by Gauss, of an electromagnetic *singularity* in the microscopic domain, provides us with a beautiful case-study.

Chris Lewis

Prof. G. Beuermann (right) of Göttingen University explains to the author the workings of the portable magnetometer, which is part of the Historical Collection at the university's I. Physical Institute. See page 35 for a description of the instrument.

Physical Space-time

Situating the Gauss-Weber discovery in this way is important, since most readers nowadays will otherwise tend to misinterpret Hecht's presentation of the Gauss-Weber work, by projecting onto it an aprioristic conception of space-time, which is actually the opposite of what the Gauss-Weber-Riemann school stood for.

The problem here goes all the way back to Paolo Sarpi and Galileo Galilei's attacks on the Platonic-geometrical method of Johannes Kepler. It consists in the stubborn tendency to regard as self-evident, the notion that our Universe has the form of an array of discrete objects moving about in a fixed, perfectly continuous, indefinitely extended space. In the back of our minds, many of us still suffer from a strong, almost animal-like fixation on the lumpen objects of sense perception. As a result, we find it difficult to accept the idea, that our Universe might be based on objects of a very different sort.

To begin to grasp the *Platonic* physical conception of Gauss-Weber-Riemann, we must overcome in our own minds, the supposed primacy of objects of sense-perception, and focus instead on *changes in the characteristics of action* as a relatively more real, more substantial species of "object." The *form* of a *change in the geometry of physical space-time* is not something we can "see" directly; it must be adduced, *conceptualized,* by means which at first glance might often appear quite indirect.

One of the earliest and most beautiful examples of this, as Lyndon LaRouche has pointed out,[2] is the method which Erathosthenes employed, to detect and rather precisely estimate the curvature of the Earth, 21 centuries before the Earth's spherical form became visible to the eyes of orbiting astronauts. It is no accident, that Gauss and Riemann's generalized notion of a *curvature of physical space-time,* plays a central role in the vast scheme of experimental investigations, which Gauss and his international network of collaborators carried out in the fields of astronomy, geodesy, geomagnetism, electrodynamics, and so on.

Here it is crucial to realize, that the Gaussian conception is something very different from a mere formal-mathematical generalization of elementary Euclidean geometry. Rather, in the work of Gauss and Riemann, "curvature" plays the role of a rigorous sort of *metaphor*—a metaphor which subsumes a general notion of the sort of hypothesis-based mode of discovery, through which Eratosthenes and others were able to attain a remarkably precise knowledge of the shape of the Earth and the dimensions of the solar system, more than 2,000 years ago.

Keeping these matters in mind, the reader will avoid falling into such traps as the often-repeated story, that "Weber was a Newtonian." It is necessary, for example, to appreciate the unmistakable irony underlying Weber's formal presentation of his electrodynamic law in terms of pairwise interactions of "electric masses." As a matter of fact, that formal method has the function of an *artifice,* through which Weber arrives at a conclusion which not only is totally anomalous, but actually demolishes the entire Newtonian scheme. Weber was naturally well aware of this; Helmholtz was, too, and that is one reason why he and the gang of Maxwell, Kelvin, et al. went to great lengths to bury the work of the Gauss-Weber-Riemann school.

It is from the standpoint of having demonstrated and measured a *new degree of curvature of physical space-*

time, that Weber develops his extraordinary conclusions concerning the "quantization" of matter at characteristic scale-lengths, which he himself had estimated from his program of electrodynamic experiments. The singularity in this business, however, is not to be found in some mythological picture of "elementary particles" as hard little balls flying around Newtonian empty space, but in the successful change of hypothesis concerning the *anti-Newtonian,* implicitly *highly discontinuous* geometry of space-time itself.

This leads us to a final remark, no less important than the rest:

Of all the things that might provoke choruses of growling and snarling from within the scientific community, the most provocative aspect of Gauss, Weber, and Riemann's work is surely the implication, that any rigorous notion of physical space-time must include the process of hypothesis-formation itself as its central, determining feature. "Unscientific!" will be the cry: "You are introducing subjective considerations!" "You can't attribute objective physical existence to a mere idea!"

And yet, it is those singularities of successful change of fundamental hypothesis, which are the root *cause* of technological progress, and thereby of the expansion of Man's *physical power* over the Universe. Are we not obliged to attribute physical existence to that which is manifestly shown to cause rather large, and growing, physical effects? The theoretical accomplishments of the Gauss-Weber-Riemann school, for example, are inseparably connected with a series of breakthroughs in *experimental design,* leading to orders-of-magnitude improvements in the precision with which various physical effects could be observed and measured. The incorporation of such new design principles into new instruments and machines of production, led to a sustained "pulse" of increase of human productive power, from which mankind still benefits today.

What this suggests, is an approach to the deeper question, how one might *measure* the process of hypothesis-formation itself! And related to that, the question, how we might define the notion of "scientific rigor," bearing in mind, that this cannot consist in mere logical reasoning, but rather in the ability to maintain an ongoing process of *successful* "leaps into the unknown," in the way so beautifully embodied in the work of the Gauss, Weber, and Riemann.

This topic, however, leads us into another domain, the domain of physical economy, which the brief space allotted to this introduction does not permit us to enter in upon.[3]

Dr. Jonathan Tennenbaum heads the Fusion Energy Foundation in Europe and is the editor-in-chief of the German-language magazine Fusion. *He is a member of the scientific advisory board of* 21st Century.

Notes

1. Larry Hecht has written his article while serving a 33-year jail sentence in Virginia, as an innocent victim of the cruel and vindictive campaign of political persecution, carried out under the auspices of George Bush and his friends, against the political and philosophical movement of Lyndon LaRouche. We would hope that a speedy and complete exoneration of LaRouche and his collaborators, will allow Mr. Hecht in the future to pursue his scientific work under more conducive personal circumstances.
2. See the lead and other articles in the feature package, "The Compelling Power of Astronomy," *21st Century,* Summer 1996, pp. 28-64.
3. See *So, You Wish to Learn All About Economics?* by Lyndon H. LaRouche, Jr. Second edition (Washington: EIR News Service, 1995), as well as LaRouche's article, "Riemann Refutes Euler," in *21st Century,* Winter 1995, p. 36.

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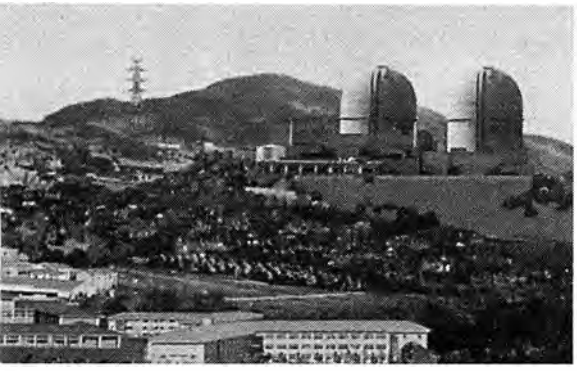


KEDO Annual Report, 1995

Artist's depiction of the completed pressurized light water reactors at Sinpo City in North Korea.

KOREAN NUCLEAR GROUP TO BREAK GROUND FOR 2 REACTORS IN NORTH

The Korean Peninsula Energy Development Organization (KEDO), organized by the Clinton administration for the United States, South Korea, and Japan to build nuclear reactors in North Korea, will soon break ground for two 1,000-MW nuclear plants near Sinpo City. Stephen Bosworth, U.S. Ambassador to KEDO, reported in a Sept. 10 press briefing: "We're going to be able to physically break ground within the next several weeks, before the ground freezes for winter. We'll soon have a significant number of South Korean technicians in place, and we'll be hiring more and more North Korean workers. We'll be constructing transportation infrastructure, then worker housing, working through the winter to prepare for reactor construction in spring."

Bosworth noted that the KEDO project continued to have financing problems. "Fortunately," he said, "the Japanese government provided a special financing facility of $19 million which was vital in bridging our requirements. . . . This program is too important to all the governments involved to fail for lack of money. . . ."

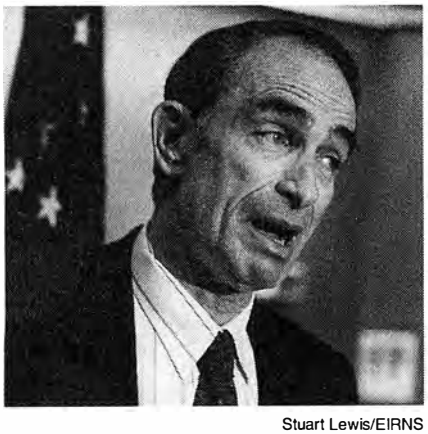
LOS ALAMOS NATIONAL LAB FASHIONS LASER 'LIGHTNING RODS'

A research team at the Los Alamos National Laboratory in New Mexico, headed by Xin Miao Zhao, has created a revolutionary new way of getting laser beams to travel efficiently through the air and over long distances, using a powerful infrared titanium-sapphire laser. When the light pulse from this laser reaches a threshold intensity, the beam self-focusses into a tight filament and propagates over long distances through the air. The laser beam passes through a channel two or three times the thickness of a human hair and propagates indefinitely through the air with little loss—something that conventional lasers have not been able to do.

Although the beam seems not to follow the ordinary laws of light propagation—dispersion, diffraction, and normal scattering—the researchers believe that the intensity of the beam produces nonlinear effects that mask the appearance of these phenomena. Among the potential applications of this laser is a new type of laser lightning rod.

GREEN REFERENDUM INITIATIVE AGAINST GERMAN WATERWAY FAILS

The Green Party in Germany failed to get enough signatures to hold a referendum against modernization and deepening of the Havel waterway, which connects Hanover, Magdeburg, and Berlin, it was announced Sept. 1. More than 80 green groups had spent four months trying to collect the required 80,000 signatures. The modernization of the 280-kilometer-long waterway is one of 17 priority projects in the government's National Transportation Development Plan. It would give the water a depth of 3.5 meters to allow the use of combined barges with a total length of 185 meters—which is essential for making the waterway navigable for bulk transport between Germany's West and the Berlin region.



Stuart Lewis/EIRNS

Biologist Paul Ehrlich: Through the years, his predictions of doom have all proved wrong.

AAAS FEATURES 'MISUSE OF SCIENCE IN PUBLIC DECISION-MAKING'

The American Association for the Advancement of Science held a breakfast press briefing in its Washington, D.C., office Sept. 25, billed as a discussion of "anti-environment campaigns and the use and misuse of science in public decision-making." The featured speakers are experts at the latter: Stanford University biologists Paul and Anne Ehrlich, known for their view that the optimal world population is 1.5 billion. The AAAS press office declined to return phone calls from this publication. *21st Century*'s question is how the Ehrlichs intend to scientifically begin culling their friends and family in order to do their part to reach their desired optimal world population.

BRAZIL REVIVES NUCLEAR PROGRAM; WILL COMPLETE ANGRA II

The Brazilian government has decided to complete its second nuclear power plant, Angra II, which has been in limbo for several years. The decision to finish Angra II indicates a broader change, according to Guilherme Camargo, head of the Brazilian Association for Nuclear Energy (APEN): "The country is reinaugurating its nuclear program in full force, a program for generating electric energy through nuclear power plants as sources of energy produced nationally." Angra II is scheduled to begin operation in 1999, and raise the country's energy capacity to 1,300 megawatts. The plan is then to transfer Angra II's technology to a third nuclear plant, Angra III.

Klever Cosensa, manager of thermonuclear generation at Angra II and III, said that financial problems had prevented the government from proceeding with the original goal of the Brazilian Nuclear Program, which was to install eight nuclear power plants before the year 2000. But now, he said, the government is ready to resume the plan to achieve nuclear self-sufficiency, as well as control of the complete nuclear fuel cycle.

EIRNS

Brazil's Angra I nuclear plant under construction in 1982. Angra II is now scheduled for completion by 1999.

TENNESSEE, TVA SPONSOR WATER DEVELOPMENT CONFERENCE IN BEIJING

"Economic Opportunities Through Water and Energy" was the title of a three-day conference in early September, sponsored by the Tennessee Valley Authority (TVA) and the state of Tennessee in Beijing. The conference continues a 60-year history of collaboration between economic planners and engineers in China and the TVA, using the experience of the development of the seven-state Tennessee Valley in the 1930s as a model for the taming and multi-use development of China's vast rivers. Although the primary goal is stopping the devastating floods that have plagued China for centuries, other goals include the construction of hydro-electric power plants and the movement of water from wet to dry regions for irrigation and other uses. Among the speakers were U.S. Ambassador Jim Sasser (former senator from the state of Tennessee), and TVA Chairman Craven Crowell.

A memorandum of understanding was signed between the Chinese Ministry of Water Resources and the TVA to cooperate in modernizing and automating China's aging hydroelectric power plants.

CHINA FINISHES ANOTHER 'GREAT PROJECT': THE BEIJING-KOWLOON RR

Another of China's ambitious transportation projects, the Beijing-Kowloon railroad, began service Sept. 1. The new line is the third north-south line in China, and runs through central China, to connect the capital with the Pearl River delta, the most rapidly developing area in China. The 1,500-mile line traverses 150 tunnels and crosses 1,045 bridges, including one over the Yangtze River more than a half-mile wide.

The Chinese government is giving priority to 10 key national projects linking cities in the southeast and northeast with its central rail network. China's Minister of Railways, Han Zhubin, had announced in October 1995, a 15-year plan to bring the railway system up to the international standards of the 1990s. China's rail transport can accommodate only 60 percent of current demand for passengers and freight.

MASHHAD-SARAKHS RAIL LINK COMPLETED ALONG THE 'NEW SILK ROAD'

A crucial rail link, between Mashhad in Iran and Sarakhs in Turkmenistan, was finished in May, bringing closer to completion the world's largest rail connection—the "New Silk Road" that will link the east of China to Western Europe. The southern route of the Silk Road will run from Singapore, through Vietnam, Cambodia, Kunming in southern China, and central Asia, all the way to Western Europe. The original Silk Road was known to Europe from the time that Louis IX sent an envoy to the East, some 20 years before the better-known departure of the Venetian Marco Polo for the Mongol court in 1271.

The Mashhad-Sarakhs link is the recently completed piece of the New Silk Road's southern route. The New Silk Road is envisioned by the Chinese government as a continental land-bridge that will bring human society into a new era of development.

Science Vs. Humbugging

EDITOR'S NOTE

Joseph Henry (1799-1877), the preeminent American scientist of the 19th century, was known throughout the world for his pioneering experiments in electromagnetism and in developing the telegraph. As secretary of the Smithsonian Institution from 1846 until his death, he was committed to educating American scientists and in spreading knowledge of science throughout the American population.

These excerpts from Joseph Henry's Aug. 22, 1850, speech as outgoing president of the American Association for the Advancement of Science, demonstrate his broad scientific outlook and insistence on the pursuit of truth. At the same time, his remarks provide a historical perspective in which to view the scientific hoaxes of today. Henry warns the association to beware of those who would "delude and defraud the public," and categorizes the forms of such fraud, from outright "forging" to "cooking" and "trimming" of data.

This speech is reprinted in a 1980 collection of Henry's works, A Scientist in American Life: Essays and Lectures of Joseph Henry, *published by the Smithsonian Institution Press (Washington, D.C.). The subheads are added.*

* * *

. . . The object of this Association as declared in its title is the advancement of science or in other words the promotion of all branches of knowledge which may be stated in general propositions. Though we discard no general truths which may be presented for our consideration, we are more particularly interested in promoting discoveries in the operations of the physical world.

Our attention is not particularly directed to any one branch of material science. We give no preference to the apparently great over the apparently small. The world exhibited in a drop of stagnant water by our brother of the microscope is as replete with interest to us as the universe of suns and stars

Joseph Henry

revealed by him of the far sight. Nothing which God has seen fit to present to our contemplation in the vast regions of Creation around us is too great for our thoughts to attempt to grasp or too small to be beneath our notice. It is enough for us that it is the production of infinite wisdom to challenge our admiration and prompt our investigation.

Though the object of this Association is the advance of science we do not discard the beautiful either in mind or matter, and while we cultivate the intellect we would seek to improve the moral perceptions and to direct and control the moral emotions. There is poetry in science and the cultivation of the imagination is an essential prerequisite to the successful investigation of Nature.

"There is poetry in science and the cultivation of the imagination is an essential prerequisite to the successful investigation of Nature."

We do not believe in the proposition industriously set forth by some that the operations of the head tend to repress the warm pulsations of the heart. The proper exercise of each is necessary to a harmonious condition of the whole man.

Our objects are not utilitarian in the lower sense of the term, and we leave to others with less elevated aim the application of our discoveries to useful purposes in the arts. We ask not the commercial value of science nor boast of its power. It is sufficient for us that its developments are truths belonging to the great system of Nature and adapted to satisfy the craving of the intelligent mind.

The Purpose of Science

We do not meet for the purpose of diffusing knowledge even however laudable such an object might be. We do not expect to have our time occupied particularly in the Sections with popular expositions of any branch of science. We are supposed to be familiar with the elementary truths of the portions of knowledge which fall within the scope of our investigations. We are assembled to discuss new thoughts, to give more precision to our conceptions and applications of old truths. We are each expected to contribute something to the existing stock of positive knowledge, to bring forward some new fact, some new observation, some new experiment or, still more important, some new principle. We meet to give each the history of his labors during the past year, to compare the results of our investigations, to receive each some suggestion from the other, and, in the collision of mind with mind, to elicit new truths and to explode old errors.

That Associations of this kind have an important bearing on the advance of knowledge is proved by abundant experience. The history of discovery will show that those who have secured for themselves immortal honor by their labors in extending the boundaries of knowledge have always appeared in groups. We know that the light and heat evolved from an isolated portion of fuel is far less intense than when it is burned in connection with other combustibles; each portion increases the power of the other until the whole becomes excited to an intense glow, shedding its genial influence all around. So in the reciprocal action of mind on mind there is an excitement produced highly favorable to the per-

ception of new truths; each mind illumines the other. The historian, the critic, or the poet finds men everywhere who can enter into his pursuits and who can appreciate his merits and unite with him in his labors; but the man of Science, whose abstract researches pertain not immediately to the wants of life, finds few men who can sympathize with his pursuits or who do not look with indifference on the objects of his research. His world consists of a few individuals, in some cases less than 10 or 12 in a whole country, who can fully appreciate him and from whom he is primarily to receive that reputation which the public generally will afterwards concede to him.

Besides this, science has become so much extended that few persons can properly cultivate more than one branch. Yet the whole is so intimately connected and interwoven that some knowledge of each branch is necessary to the proper understanding of the other. We have seen from the reports of our Association that the Botanist may with advantage ask questions of the Mathematician and the Astronomer avail himself of the labors of the Electrician.

There is another way in which an Association of this kind can be of great importance to the advance of true science, viz by properly directing public opinion, by combining to protect its members and the cause of truth against the attacks of the prejudiced and the encroachments of the pretender and the knave.

There are persons of narrow minds who think nothing true or worthy of attention which is not in conformity with their prejudices, who affect to despise science, to deny its conclusions, and attempt to hold it up to ridicule. There are men in every country who would share the honors and enjoy the emoluments of science without the labor or the talents necessary to earn them. There are others again who invade the domain of science for the spoils it may yield, who unscrupulously appropriate the labors of others to themselves or apply the facts of science to delude and defraud the public.

"There are persons of narrow minds who think nothing true or worthy of attention which is not in conformity with their prejudices. . . ."

Methods of Deception

The various methods of deception may be classed under comparatively few heads, and perhaps I can not render better service to the cause of truth than by occupying your time for a few minutes in briefly describing some of them. An exposition of this kind may serve to guard the public against these frauds and to deter those who would be disposed to enter upon these practices from so doing by showing that their arts are seen through by men of science and well known to the initiated.

In giving this sketch I shall adopt the classification of the celebrated author of the calculating machine. Mr. [Charles] Babbage arranges scientific frauds under four heads to which he gives the somewhat quaint but descriptive titles of Hoaxing, Forging, Trimming, and Cooking; to these we may add Humbugging and Quackery. The last term is used conventionally because quackery enters less or more into all scientific deceptions.

Hoaxing. This is a deception, says Mr. Babbage, intended to last for a time and then to be discovered to the ridicule of those who have credited it. The only excuse for a deception of this kind, if any can be offered, is that of exposing the ignorance of pretenders to science.

One of the most notable examples of this deception on record, perhaps, is that known as the Moon hoax which purported to be an account of a series of wonderful discoveries made by Sir John Herschel at the Cape of Good Hope. This hoax is remarkable on account of the celebrity which it obtained, notwithstanding the absurdity and extravagance of its character. It afforded a lamentable exposition of the state of physical knowledge among the educated classes of our country, for it owed its celebrity to their ignorance and credulity, as much as to any talent displayed in its fabrication. Hundreds who ought to have known at a glance that it was false, received it as true; and after the deception was acknowledged, with nervous anxiety to put aside the merited ridicule joined in the general exclamation of, What an admirable production! How well it was done! Even we were deceived! This hoax has produced a large crop of imitators and scarcely a month passes even now without some silly attempts to impose upon the public in the same way.

Truth is of too sacred a character to be trifled with even in jest, and no man of proper moral principle would employ himself in the fabrication of such deceptions. They are indeed always the invention of low and vicious minds and are generally shallow falsehoods without the least shadow of redeeming wit.

"Science does not consist in a knowledge of facts but of laws. It essentially relates to change, is dynamical rather than statical."

Forging. This differs from hoaxing inasmuch as the author of the hoax intends it only to last for a time and then to be discovered, whereas the Forger is one who really wishes to acquire scientific repute and therefore publishes observations and experiments which he never made. One of the most remarkable frauds of this kind in the History of Science is that mentioned at the last meeting of the Association in a communication of Dr. Gould, of the comet described by the Chevalier D'Angos, which was afterwards proved to exist only in the imagination of the writer. We have also a remarkable instance of forgery in the history of Electricity, which for a time per-

plexed the scientific world. Fortunately examples of forging are not very common.

Since the operations of nature are not confined to any place, the experiments which one man has made another can repeat—hence the forger of an experiment is certain of being detected; the discovery is a mere matter of time.

Trimming. The object of this fraud is to gain a reputation for extreme accuracy in making observations. It consists in clipping off little bits here and there from those observations most in excess from the mean and sticking them on to those which are too small, a species of equitable adjustment which, though tolerated in the partitioning of Kingdoms, is inadmissable in the republic of science.

This fraud is perhaps not so injurious (except to the character of trimmer) as some others. The reason of this is that the average given by trimmed observations is the same as that which would be given by the untrimmed. The trimmer from a prudent foresight does not distort the mean result he gets from nature, and hence it is usually difficult except by those who are practiced in the use of the same instrument to detect him. He has more sense or less adventure than the Cook.

Of Cooking. This, says Mr. Babbage, is an art of various forms, the object of which is to give to ordinary or very common observations the appearance and character of those of the highest degree of accuracy. One of the numerous processes is [to] make multitudes of observations and out of [these] to select those only which agree best with each other. If 100 observations are made the cook must be very unlucky if he cannot pick out 15 or 20 which will do for serving up.

In this way it may happen that the cook procures a temporary reputation at the expense of permanent fame.

Humbugging. This species of deception frequently begins in folly and ends in fraud. The author of it generally imagines at first that he has discovered some very important principle in nature which is directly applicable to useful purposes in the arts.

To this belief, like the Arabian impostor, he first converts his friends and neighbors. His discovery is afterwards published in the newspapers and he is soon elevated to an unenviable notoriety from which he has neither the magnanimity nor the courage to let himself down by confessing his error. He therefore seeks to discover methods by which the deception may be extended and continued and generally ends in defrauding all who may have become his dupes.

I could mention a number of cases of this kind. They are more numerous in this country than any other because a smattering of scientific knowledge is here more widely diffused.

In other cases fraud is intended from the first. The sole object of the deception is to swindle the public. Frequently, however, the attack is confined to the Treasuries of the State or Federal Governments.

If a man of science honestly expresses his opinion relative to the merit of one of these projects, his opposition is referred to jealousy, prejudice, or want of knowledge, and he may think himself fortunate if he escapes the annoyance of a prosecution in which reasonable damages are placed at several thousand dollars.

Though it is by no means pleasant for a sensitive man to be obliged to run atilt against the windmills of the day, yet when he is called upon for an opinion it is a duty he owes to the public and the cause of science to give a cautious but candid exposition of his views and thus prevent in many cases extensive and, it may be, ruinous frauds.

I trust that it is a very rare occurrence that men of scientific reputation are to be found who would participate in or connive at frauds of this kind. If any such exist let him be excluded forever from the communion of the brotherhood of science.

Quackery. Under this head may be classed a great variety of petty artifices by which the vain, the superficial, and the unprincipled endeavour, generally at the expense of the labors of others, to elevate themselves into notice and to impose upon the credulity and ignorance of the public.

It should never be forgotten that true reputation must always be based on the favorable opinion of the few in any country who are capable of properly appreciating the labors of him who would claim to have enlarged the bounds of human knowledge or to have done any thing worthy of commendation by his fellow men.

The higher and more abstruse the character of the investigations he professes to have made, the smaller is the number of those who are capable of rendering a proper verdict. In this case especially the votes must be weighed, not counted.

He therefore who seeks approbation for his labors by appealing to a tribunal which from its character and pursuits is not qualified to appreciate them is practicing a deception and is justly entitled to the name of a quack.

The man of honorable feelings and imbued with the true spirit of science presents the results of his investigations to some learned society or to the editor of some scientific journal where they will be scrutinized before they are published and where they will be presented to the eye of men capable of pronouncing on their merits.

The Man of True Science

The man of true science must of necessity be a little in advance of his age and be beyond the appreciation of the multitude. He therefore scorns an appeal to so low a tribunal and would prefer to be the author of a discovery the importance of which but a few men in the whole nation would be capable of appreciating.

How different is the proceeding of the quack; he affects to despise the opinion of men of science and accuses them of jealousy, prejudice, and ignorance.

He appeals immediately to the public generally through the newspapers, and for approbation calls not on the few who are capable of judging of his merits but the many who know nothing of the subject.

How many wonderful surgical operations are performed in our country every year and how rapidly are we increasing in our knowledge of this part of the healing art, if the public prints are to be credited. I would say to *the* public beware of those whose merits

are thus continuously proclaimed to the world, in whatsoever line they may be. Be not quick to trust your purse or your life in their hands. . . .

It should be the duty of this association to endeavour to establish a standard of American Science and to combine to elevate the estimation of an American reputation. We must respect ourselves or others will not respect us.

For this purpose let the members of our association adopt the strictest code of scientific ethics and frown upon all who would in the least degree depart from it.

Let them cherish a spirit of brotherhood and expel from their breasts every rising cloud of envy or jealousy. Let each hail the discoveries of the other as a new conquest over nature which so far from narrowing the field of his own research opens new vistas for the admission of new light and the better cultivation of his own domain.

What Is Science?

What is science? Is it a collection of facts? Does it consist in a knowledge of the mere results of experience? Is a person entitled to be called a man of science because he can give the name and, it may be, the properties of every stone or of every plant he may meet with in his path? Then is the gossip who knows the name and history of every man, woman, and child of his village a profound savant.

Science does not consist in a knowledge of facts but of laws. It essentially relates to change, is dynamical rather than statical. Permit me to illustrate this. Suppose an intelligent being with powers of perception sufficiently exalted to take in at a single glance an idea of the form, color, size, chemical composition, relative position, etc., of all the objects of nature as it were in a state of rest, he would then possess the elements of the knowledge of descriptive Natural History. He would then have the materials of a descriptive catalogue of nature's effects—an important prerequisite to science—but not science itself in the more strict meaning of the term.

Suppose again that the same being should, after a lapse of time, examine the condition of the objects before described. He would perceive that they were not the same—that summer had succeeded winter, the bud had expanded into the flower, the flower had been transformed into fruit, the egg had been developed into the living, moving sentient animal. A new condition had been introduced, that of time, and with this is indissolubly coupled the idea of change.

But what is the character of this change? Is it capricious, without order of succession? Or if order is observable, is it that of perpetual recurrence? Do all things after a given lapse of time return to precisely the same condition in which they were at some previous time? To these enquiries philosophical experience answers that there is an order of succession but that this order within our experience is not recurring. No moment has its fellow. Each instant of recorded time has its separate history. We are not the same beings we were a moment ago, and we never shall be again what we now are. Every breath we exhale carries off dead portions of our body and every pulse of our heart tends to supply the loss by the deposition of new matter. We are constantly wasting away and constantly being renewed.

I am not now speaking to precisely the same audience I was addressing a few moments ago. New thoughts have passed through the mind of each and left their effect indelibly upon the character.

The change may be inappreciable, but it is none the less certain. We are not intellectually, physically, or morally the same beings from one instant to the other, and the change in us is the epitome of the great system of change going on around us.

What then, it may be asked, in this universe of ceaseless and ever varying change is constant? The answer is the laws of change. These are as immutable as the purposes of *Him* who knows no change.

A knowledge of these laws with the power of predicting and in some cases of controlling the operations of nature constitutes the highest wisdom to which unaided man has yet attained and is emphatically denominated science.

I know we are frequently and particularly at the South accused of a species of Atheism in thus referring all the phenomena of nature to the operation of physical laws, but this, so far from being atheistical when properly understood, appears to me to be in perfect accordance with the highest spiritual conceptions of the character of the Deity. Blind indeed is he who would be led from the mere use of words without attending to their signification to confound a law—that is a rule of action—with action itself.

The essential characteristic of matter is inertness, or inability to change its state without extraneous force, and the higher meaning of the term *law of nature is our conception of the mode in which divine wisdom invariably operates in producing the phenomena of nature.* A universe without law would be a universe without order, without the possibility of science, and the manifestations of an intelligent governor and creator.

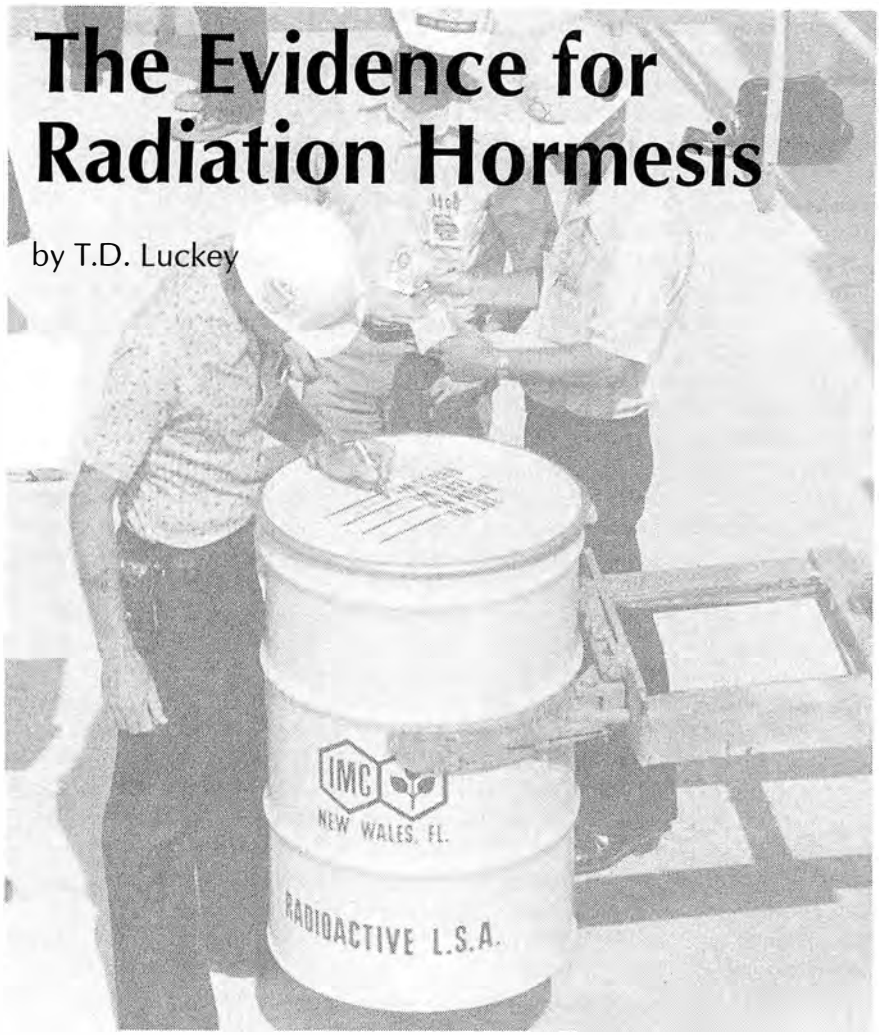
It is in the invariable operations of God, in accordance with the laws he has prescribed to his own acts, that he reveals his wisdom in the succession of the phenomena of nature; that he exhibits his goodness in giving to man the experience of the past to direct him in the blindness of the future; that he manifests his justice and truth in the unchangeableness of his character. A universe unregulated by law would indeed be a universe without God.

In referring the phenomena of nature to invariable laws, the man of science merely [adopts one of the fundamental propositions of the Westminster confession of faith, namely,] God had foreordained every thing which cometh to pass, but in such a way as not to interfere with the freedom of will or moral responsibility of the individual.

If I am asked how these two facts can coexist the answer is, *I do not know,* but I am certain that each is true. The one is a deduction from the idea of God and confirmed by all the experience of science; the other is a revelation of my own consciousness, the truth of which I can no more deny than that of my own identity, but to reconcile them with my present faculties is impossible. . . .

The Evidence for Radiation Hormesis

by T.D. Luckey



DOE

Studies of thousands of nuclear workers show that those exposed to higher radiation levels had lower rates of cancer mortality. Here, technicians process a uranium shipment.

EDITOR'S NOTE

Today's radiation dose standards and regulations are based on the idea that all radiation is harmful, that there is no threshold below which radiation is harmless, and that the harm can be calculated as a linear extrapolation from the known effects of damage from high-dose radiation. This is not competent science; yet, just such a linear extrapolation is the basis governing radiation standards. Furthermore, such a policy feeds an irrational fear of anything nuclear.

This report reviews the evidence of the beneficial effects to health of low-dose radiation, a process termed hormesis, from the Greek word hormein, *to excite. The body of evidence for hormetic effects is so compelling that after 12 years of discussion, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recently acknowledged the existence of radiation hormesis. Now many nuclear and radiation scientists have challenged the current linear, no-threshold basis for setting radiation standards.*

Author T.D. Luckey, one of the pioneers of hormesis research, reviews the evidence and, briefly, suggests the cellular mechanisms that may account for the hormesis effect. In what may be a startling proposal for some, he calls for a research program to study the possibility of combatting the detrimental effects of radiation deficiency.

Life began and adapted to 10 times more ionizing radiation than we have in our present environment. The first primitive cells and metabolic systems developed in a milieu of ionizing radiation, where survival required a balance between the destruction of too sensitive systems and a tolerance or utilization of this potentially destructive energy source.

Although much research prior to the atom bomb involved low doses, the most recent research has been directed toward the harmful effects of large doses of ionizing radiation. As a result, in the past half century, most information about the biological effects of low-dose irradiation was obtained incidental to studies on the effects of high-dose irradiation. Although our present information about radiation hormesis is fragmented, it is the prologue for vital research and understanding of new physiological mechanisms and a suggested rationale for supplementing some human beings deficient in ionizing radiation.

The hormesis thesis is that low doses of an agent may stimulate a system which is depressed by high doses of the same agent. The effects of ionizing radiation follow this thesis: Large doses of ionizing radiation are lethal or inhibitory to microbes, plants, and animals, including humans, while small doses of ionizing radiation stimulate most physiologic and cellular systems (Luckey 1980, 1991). Paradoxically, more than one reaction may be stimulated in the same organism at the same time. For example, low doses may stimulate both the growth of cancer cells and the destruction of cancers by increased immune competence. The latter appears to predominate when the cancer is small. The immune system is less effective when the cancer becomes large.

The concept of the stimulatory effect of low doses of potentially harmful chemicals has been studied for centuries. In the 8th century B.C., the Syrian physicians of King Sargon II understood that the plant, *Atropa belladonna*, was "both a healing and a poisoning herb" (Thorwald 1962). About 400 B.C., Hippocrates observed that in opposition to reasonable wine intake, "undiluted wine drunk in large quantity renders a man

feeble" (Adler 1952). And in the 16th century, Paracelsus said that all things are poison and none without poison, and only the dose makes the poison (Waite 1994).

Physical, chemical and biologic agents may be hormetic. Low doses of cold, heat, pressure, electricity, electromagnetism, light, and ionizing radiation stimulate a variety of physiological parameters in microbes, plants, and animals (Luckey 1959). Each physical agent may induce a variety of chemical reactions in the affected tissues.

The beneficial effect of low-dose irradiation was discovered 100 years ago at the University of Missouri, where Professor W. Shrader inoculated guinea pigs with diphtheria bacillus. Unexposed controls died within 24 hours. When animals were exposed to X-rays before inoculation, they survived. Stimulation by low doses of radiation was studied in the first half of this century (Luckey 1980) by Selye, who emphasized the great variety of agents, including ionizing radiation, which would induce a protective "general adaptive syndrome" in laboratory animals and in humans (Selye 1950). He reviewed the protective action of the general adaptive syndrome following low doses of chemical, physical, and biological stressors.

Hormesis Vs. the Zero Thesis

The basic premise of the zero thesis of ionizing radiation is that all ionizing radiation is harmful, and that there is no threshold below which it is not harmful. The zero thesis is invalidated by consistent, statistically significant results showing hormesis (Luckey 1991, 1994a). It is a media mirage sustained by scientists who have ignored the radiobiologic literature; this includes 55 reviews from 1896 to 1977, which presented evidence of stimulation by low-dose irradiation (Luckey 1980).

"Hormesis with Ionizing Radiation," a comprehensive review by this author, with 1,200 references, was published in 1980. Although this awakened many radiobiologists to the large amount of evidence showing radiation hormesis, the zero thesis and its linear models are entrenched in government agency recommendations and national laws.

A threshold for ionizing radiation is a vital part of the hormesis thesis. The hormesis results also invalidate another, little discussed "threshold" concept, which specifies that there are *no* effects of radiation with any dose between that of the unexposed controls and the zero equivalent point, ZEP. (ZEP is a threshold that differentiates so-called low-dose from high-dose radiation. All doses less than the ZEP are low doses. The ZEP defines limits for public safety, and theoretically, doses less than the ZEP should not be considered harmful for the average person.)

The Geographical Evidence

Ionizing radiation is ubiquitous. Air, water, soil, plants, animals, people, food, paper, machinery and buildings are radioactive. The diversity in background radiation throughout the world reflects differences in Earth radiation and altitude. Most variation in our background radiation comes from the elements in the soil (Luckey 1980, 1991).

Cosmic radiation doubles for each 2 km above sea level. Since cosmic radiation is absorbed by air, much more cosmic radiation hits mountains and high plateaus than the ground at sea level. Airline personnel and frequent flyers may average 8 to 10 hours a day of flight 10 to 13 km above sea level. This may expose them to 7 to 8 milligray/year more than people at sea level. (A gray measures radiation delivered; 1 gy equals 100 rads.)

Populations living with high natural radiation backgrounds often show indications of superior health. No unusual disease or poor health effects have been attributed to populations living in 10 times our levels of natural radiation.

The negative correlation between natural levels of ionizing radiation and cardiovascular, respiratory, and cancer death rates in the United States (Figure 1) is good evidence that low-level irradiation is not a major cause of these diseases (Sauer 1982). Athough altitude, oxygen, and air pressure were also negatively correlated, this study found no correlation between the high death rates in the southeastern area of the United States and about 40 environmental, social, economic, and racial factors.

A similar negative correlation between background radiation and leukemia mortality has been noted in many studies for the population of the United States (Luckey 1991).

In contrast, as shown in Figure 2, the negative correlation between radiation and cancer death rates in India are not

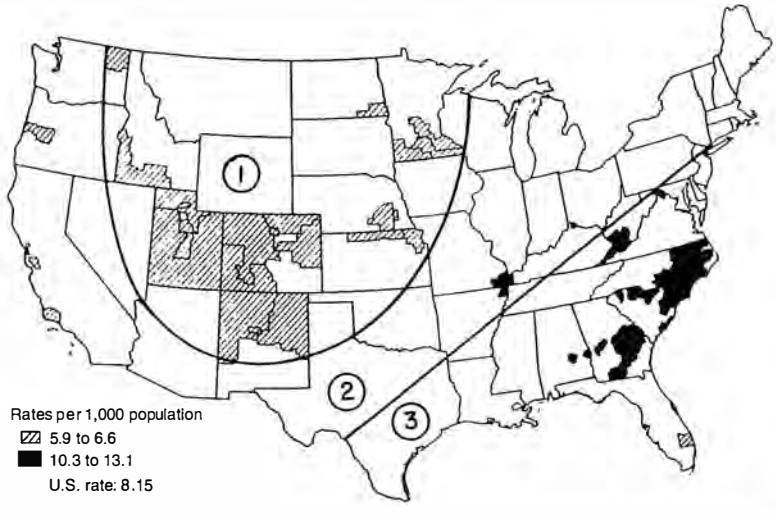


Figure 1
NATURAL RADIATION CORRELATED WITH MORTALITY OF WHITE MALES AGE 35-79 FOR THE YEARS 1960-1972

Cardiovascular, respiratory, and cancer mortality rates of the East Coast states of the United States, area 3, are much higher than those of the Western states, area 1. Earth and cosmic radiation in area 1 is 2 to 3 times that in area 3. This map shows the 25 State Economic Areas with the lowest death rates from cardiovascular diseases, and the 25 with the highest.

Sources: Sauer 1982; Luckey 1991, used with permission of CRC Press, Inc.

related to altitude or air pressure (NRCP 1987). These results from the United States and India are supported by the more rigorous studies of Chinese peasants. In each of the three countries there was a three-fold difference in radiation levels between low- and high-dose populations.

The best studied populations are two groups of Chinese peasants, about 70,000 each, in Yangjiang County (Wei 1994). Leukemia and total cancer mortality rates appear to be lower for peasants living in the high background radiation area. A correlation of leukemia deaths with age (Figure 3) also suggests an important difference in radiation sensitivity between infantile and adult leukemia.

Several populations in other countries live with much more natural radiation than the world average of about 3 mGy/y. A rough comparison of the radiation to which different populations are exposed is given in Table 1. That population in China which was exposed to about 1 mGy/y provides a convenient standard (Wei 1994). Although most have not been well studied, several populations have lived in health with relatively high levels of ionizing radiation for many generations (Luckey 1991). Reproduction is normal and there is no excessive mortality from cancer or cardiovascular diseases. Some, as those in Kerala and Iran, are noted for exceptional health and long average lifespan of the people.

Another mass of data exists concerning radon levels and cancer: Where radon levels in homes are high, lung cancer rates are low. The negative correlation between radon concentrations in homes and lung cancer mortality rates (Figure 4) was well established by nu-

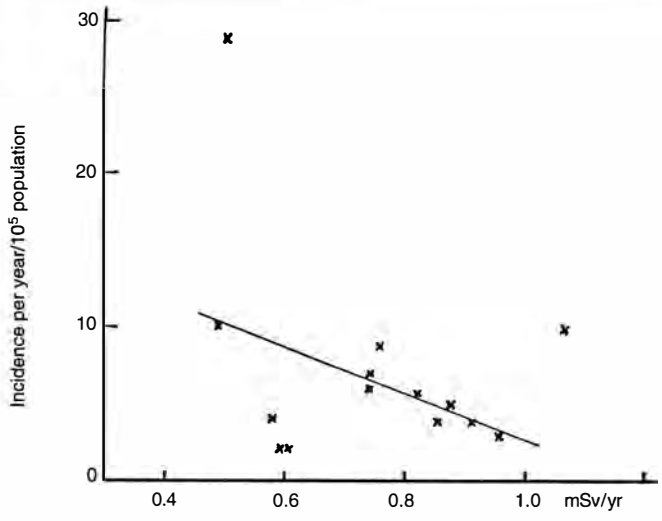


Figure 2
NATURAL RADIATION VS. CANCER MORTALITY IN INDIA

Cancer mortality in regional hospitals in India shows an inverse relationship with natural radiation levels. The two values high above the slope are from hospitals that take patients from other areas.

Sources: Nambi et al. 1987; Luckey 1991, used with permission, CRC Press, Inc.

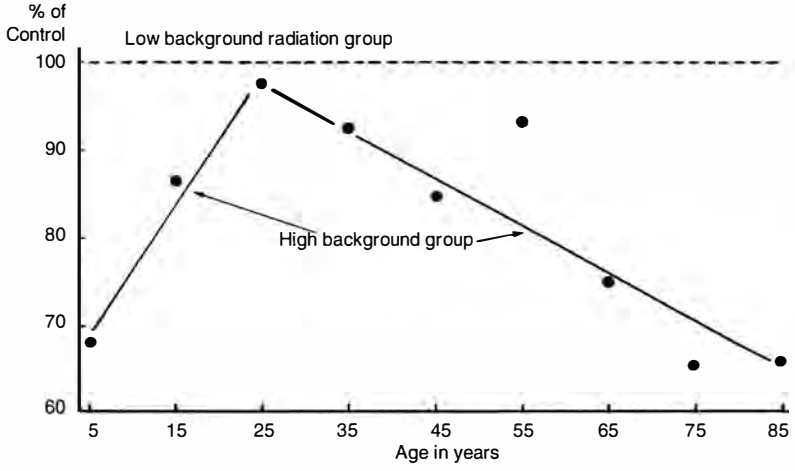


Figure 3
LEUKEMIA VS. AGE IN THE CHINA STUDY

Leukemia mortality in peasants of the high-background group in China show two different reactions based upon age, when compared with the low-background control group.

Sources: Wei 1986; Luckey 1991, used with permission, CRC Press, Inc.

Table 1
NATURAL LEVELS OF IONIZING RADIATION

Place	mGy/y
China (low)	1.3
United States	2.0
China (high)	3.3
Nile delta	3.5
Exposed U.S. workers[1]	3.6
Proposed allowance	5.0
Chernobyl[2]	5.0
Jet air flyers[3]	6-8
Kerala, India	4-13
Guarapara, Brazil	10-18
Meaipe, Brazil	22
Gerais, Brazil	23
Kerala beach towns	23
Proposed worker limit	26
Araxi, Brazil	35
Optimum	100
Ramasar, Iran	243
Guarapari beach	263
The ZEP[4]	10,000

Notes
1. This includes natural plus industrial exposures.
2. The evacuation limit used to displace 200,000 persons.
3. Assume 8 hours per day at 6 to 8 km above sea level.
4. The Zero Equivalent Point, a threshold dose which is the upper limit of "low dose irradiation."

clear scientist Bernard Cohen (Cohen 1992). Comparable curves were obtained with males and females, with and without smoking corrections.

These data contradict media concepts regarding the role of radon in lung cancer mortality and are incompatible with the U.S. government position that persons having more than 4 pCi/l of radon in their homes should institute means to reduce this gas at any expense. (One curie, Ci, = 3.7×10^{10} nuclear disintegrations per second.) The data also refute the warning of the National Council on Radiation Protection and Measurements (NCRP) that ". . . the inhalation of the short-lived decay products of radon-222 indoors is the most significant source of natural exposure" (NCRP 1987).

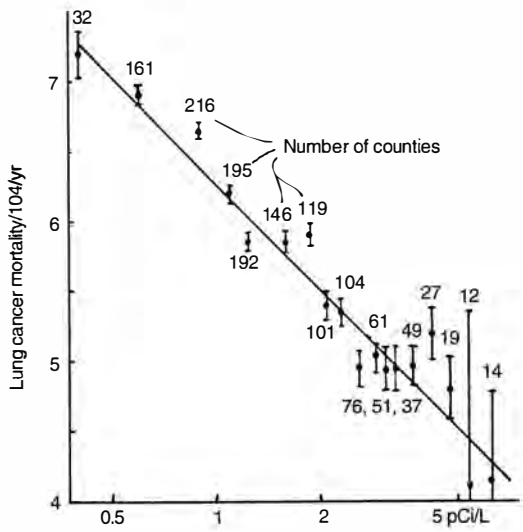


Figure 4
CORRELATION BETWEEN LUNG CANCER MORTALITY AND RADON IN HOMES

The radon concentration in homes in 1,600 counties of the United States is inversely correlated with lung cancer mortality in males. Vertical lines indicate one standard deviation. The number of counties in each sample is shown. Radon concentration is in picocuries per liter of air.

Source: Cohen 1992, used with permission of *Rad. Protect. Manag.* and *J. Occup. Med. Toxicol.*

Table 2
AGE CORRECTION FOR CANCER MORTALITY IN BRITISH NUCLEAR WORKERS

Exposure in mSv	<10	10-49	50-99	>100	Source
Avg. mSv	2	24	70	252	Tab. 2.7
Number	58,945	21,336	6,667	8,269	Tab. 2.10
Dead of cancer	584	369	194	288	Tab. 2.18
Dead of cancer/10^4	99.1	173	241	348	
Avg. age[1]	26	43	61	72	Tab. 2.10
Age ratio[2]	1	5.8	48.7	106	U.S.A.
Reciprocal	1	0.1724	0.0205	0.00943	
Cancer deaths[3]	9.9	3.0	0.49	0.33	

Source: Tables 2.7, 2.10, and 2.18 in Kendall et al. 1992.

Notes
1. Excludes persons younger than 19 years of age.
2. Age-adjusted cancer mortality ratio from U.S. Dept. of Commerce, 1988.
3. Age-corrected dead per 1,000 workers.

Hormesis at the Workplace

There is very little evidence which contradicts radiation hormesis in humans. On the positive side, studies of more than 7 million person-years in nuclear workers indicate that, compared with unexposed workers, radiation-exposed workers have significantly lower mortality rates for total deaths, leukemia, and solid tissue cancer mortality.

Studies on exposed nuclear workers are most important for information about living with background radiation which is perceptively higher than that of unexposed workers and the general population. Recent reports, reviewed here in detail, are exceptional because both control and exposed workers have the same socioeconomic background and work in the same plants under the same general conditions. This use of an internal control eliminates the usual "healthy worker effect" for these studies of chronic, whole body exposure of humans to low doses of ionizing radiation. However, location within the plant, turnover in certain types of personnel, job differences, and smoking regulations remain variables.

The results utilize only "lagged" death rates; that is, leukemia and cancer deaths are counted only after the worker has worked 2 and 10 years, respectively. Emphasis is given to total cancer and leukemia mortality rates; the relative paucity of examples would make it difficult to accurately assess each of the many different types of cancer.

Although most of the workers were white, male adults, the available information also suggests that exposed females have lower leukemia and total cancer mortality rates than unexposed females in the same plants.

Not discussed in detail is the fact that the exposed workers and the total of both groups usually have lower Standardized Mortality Rates (SMR) than the nearby general population. SMR values are used when other data are not provided.

British Nuclear Workers

Studies of the National Radiological Protection Board (NRPB) gave enough information to provide a simple correction for age in exposed and unexposed nuclear workers in Britain (Kendall 1992). Uncorrected data are available in the *British Medical Journal*. Since G.M. Kendall and associates did not correct for age, calculations were made to pro-

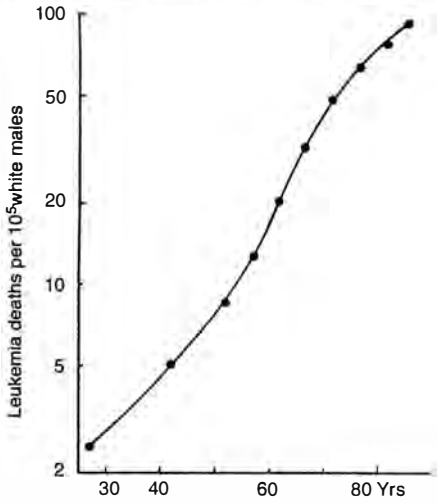


Figure 5
LEUKEMIA MORTALITY RATES VS. AGE IN THE UNITED STATES
The leukemia mortality rate of white males increases with age. These data allow an age correction to be applied to the leukemia mortality rates in the British nuclear worker study. See Table 3.

Source: U.S. Dept. of Commerce, 1988

Table 3
AGE CORRECTION FOR LEUKEMIA DEATHS IN BRITISH NUCLEAR WORKERS COMPARED TO AVERAGE U.S. LEUKEMIA DEATH RATE

mSv	Age	Kendall number	Leukemia deaths[1]	Deaths per 10^4	U.S. deaths[2] per 10^4	Age Ratio	Factor[3]	Corrected[4]
2	26	24,507	24	9.79	2.8	1.0	1.0	9.79
24	43	39,199	14	3.57	5.0	1.79	0.556	2.00
71	61	21,638	6	2.77	18	6.43	0.156	0.43
252	72	9,860	15	15.21	48	17.14	0.058	0.88

Notes
1. G.M. Kendall, C.R. Muirhead, B.H. McGibbon, et al., 1992.
2. U.S. leukemia death rate (U.S. Dept. of Commerce, 1988).
3. Reciprocal of the ratio.
4. Age-corrected leukemia death rate per 10,000 workers.

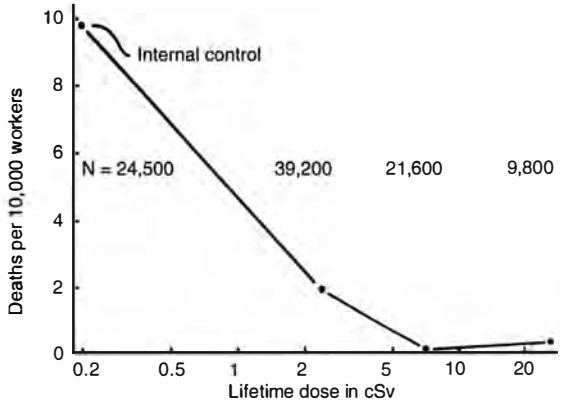


Figure 6
AGE-ADJUSTED LEUKEMIA MORTALITY IN BRITISH NUCLEAR PLANTS
The leukemia mortality rate of 70,600 exposed nuclear workers is less than that of 24,500 unexposed workers in the same plants. The optimum lifetime exposure appears to be greater than 5 cSv. Statistical significance of the correlation for all 3 samples of exposed workers is good, at $p < 0.001$.

Source: Kendall 1992

vide age-corrected lifetime dose-response data for cancer and leukemia, respectively (U.S. Department of Commerce, 1988). The calculations are evident from the data in Tables 2 and 3.

These results from more than 95,000 nuclear workers, more than 3 million person-years, negate the zero thesis and should stop the use of linear, no-threshold models. The data suggest that the optimum lifetime exposure is approximately 250 mSv above background exposures. Because several workers received more than 400 mSv, the optimum for white, male adults may be as high as 20 mSv/y for 20 years. (The sievert measures radiation absorbed in living tissue.)

The leukemia mortality rates of exposed British workers, corrected for age using data from Figure 5 and Table 3, were significantly reduced by low-dose irradiation (Figure 6). The relative reduction was comparable with that for total cancer mortality rates.

Canadian Nuclear Workers

J.D. Abbatt and associates compared the cancer mortality rate of white, male nuclear workers with that of other white, male workers within a Canadian energy plant (Abbatt 1983). The data for a 20-year period were given as SMR values. Their age-adjusted results (Figure 7) show that 4,000 nuclear workers had a lower cancer mortality rate than the 21,000 coal and gas workers in the same company. The cancer death rate of the control cohort was comparable with that of the nearby population. There were no leukemia deaths in the nuclear workers during this period.

A later study found no hormesis in Canadian nuclear workers (Gribbin 1993). M.A. Gribbin and co-workers made an "age adjustment" without giving enough data to perform a simple age correction.

U.S. Nuclear Workers

In an extensive study of nuclear workers, G.M. Matanoski evaluated about 70,000 white, male nuclear workers in eight U.S. shipyards for the years 1960-1981 (Matanoski 1991). Age-adjusted total mortality rates were given for 32,510 unexposed workers and 38,230 exposed workers. The main causes of death were cancer, cardiovascular, and respiratory diseases. The SMR for the total death rate of unexposed workers was 1.00, the same as that for the general population.

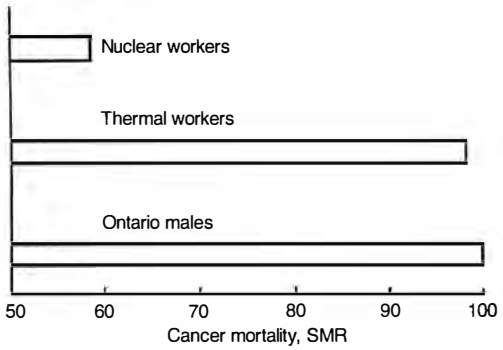


Figure 7
CANCER MORTALITY OF CANADIAN NUCLEAR WORKERS
The cancer mortality rate of 4,000 male nuclear energy workers was significantly less than that of 21,000 male thermal energy workers.

Source: Abbatt 1983, used with permission of *J. Occup. Med. Toxicol.*

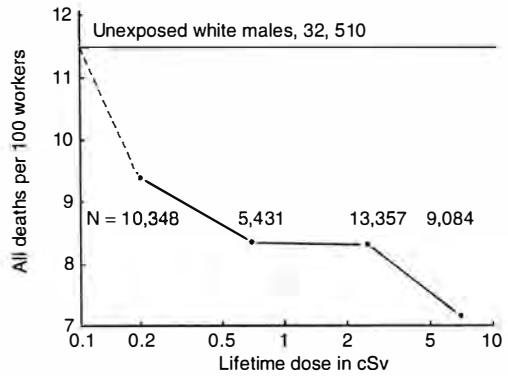


Figure 8
TOTAL DEATH RATES IN U.S. NUCLEAR SHIPYARD WORKERS
The total death rate of about 38,000 exposed nuclear shipyard workers was significantly less than that of about 32,500 unexposed workers in the same plants ($p < 0.001$).

Source: Matanoski 1991, used with permission of *J. Occup. Med. Toxicol.*

The SMR for the total death rate in workers with exposures of more than 50 mSv was 0.76. This was significantly less than that of the unexposed workers. The total death rate of exposed workers was inversely related to the lifetime dose (Figure 8).

The leukemia death rate of United States shipyard workers who were exposed to a lifetime dose of less than 10 mSv was about half that of unexposed workers. Thus, this sensitive criterion suggested radiation hormesis. The leukemia mortality rate of all exposed workers was not significantly lower than that of the unexposed workers.

Most specific cancer types showed no significant differences between exposed and unexposed shipyard workers. However, workers with a lifetime dose greater than 200 mSv had a significantly lower lung cancer mortality rate than the unexposed workers. No corrections were made for either smoking or diesel fumes. A correction for asbestos was made from an evaluation of mesothelioma.

U.S. Weapons Plant Workers

Workers in United States nuclear weapons plants have been studied by several groups. The inverse correlation between radiation exposure and total mortality of nuclear shipyard workers was very similar to that for cancer mortality with increased exposure to ionizing radiation for workers in U.S. nuclear weapons plants.

In 1989, E.S. Gilbert and associates found the SMR for total deaths of all male and female workers in nuclear weapons plants was 0.79 (Gilbert 1989). The SMR for cancer and leukemia mortality of the combined male and female workers in these nuclear weapons plants were 0.85 and 0.71, respectively. Although the data were lagged 10 and 2 years for cancer and leukemia, respectively, and although no medical evaluation was used to screen for potential cancer incidence, the "healthy worker effect" may explain part of these low values. There was a slight, statistically insignificant, increase in prostate cancer deaths in the total population of the three plants. The data provide strong evidence that there is no harmful effect of lifetime exposures to low doses of ionizing radiation.

The conclusion from this early study

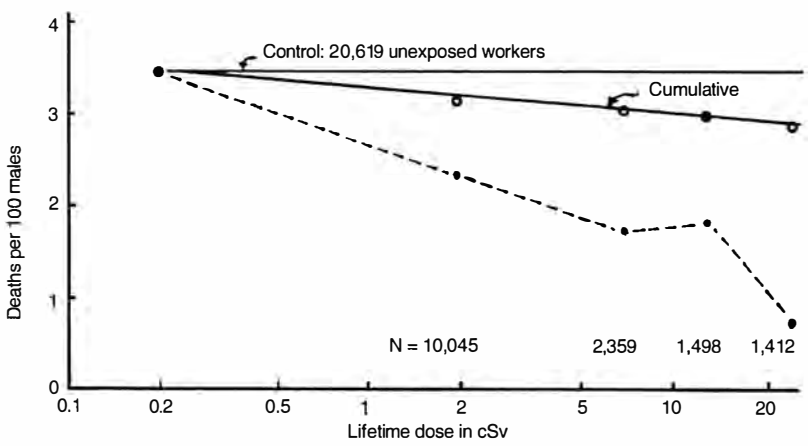


Figure 9
CANCER MORTALITY RATES IN THREE NUCLEAR WEAPONS PLANTS
The cancer mortality rate of exposed nuclear weapons workers was lower than that of unexposed workers in the same plants, and mortality decreased with increased lifetime dose. The cumulative cancer mortality rate includes control data. Statistical significance is good at $p < 0.001$ in each case.

Source: Gilbert 1989, used with permission of *J. Occup. Med. Toxicol.*

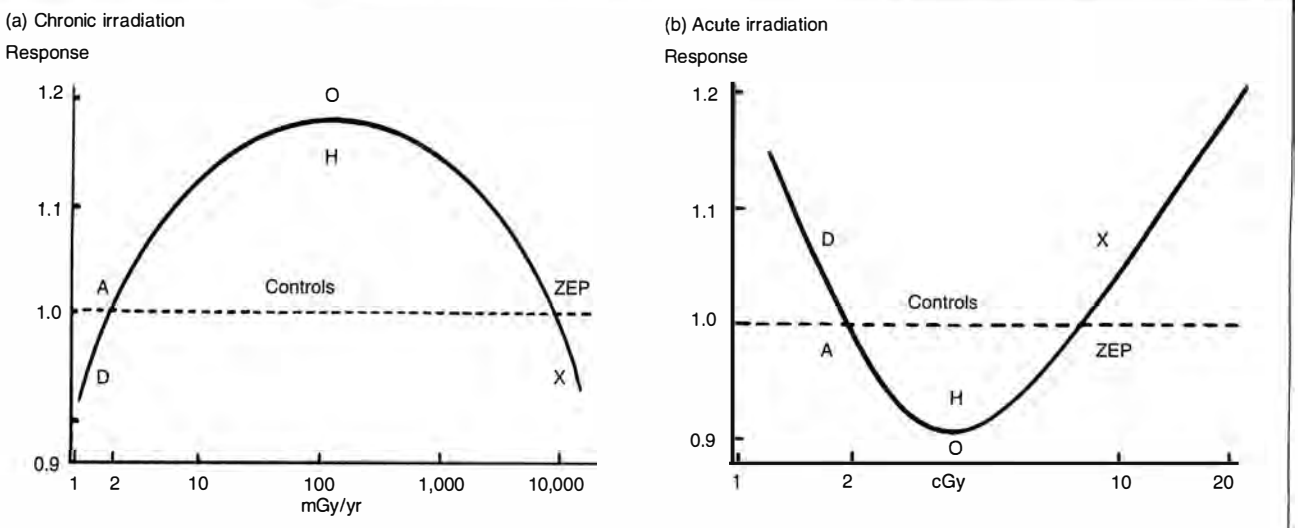


Figure 10
COMPLETE DOSE-RESPONSE CURVE

In chronic irradiation (a), all doses that show an effect greater than that of the controls are hormetic. The left intersection, A, *represents the response of controls at ambient levels of ionizing radiation. All values above the dashed line are hormetic. The optimum,* O, *is not well defined. At the dose represented by the zero equivalent point (ZEP), the response is comparable with that of the control value. All values below the dashed line are harmful;* D *represents a radiation deficiency and* X *represents an excess of radiation. The inverse of the rainbow curve (b) is often used for cancer mortality studies such as those of the survivors of atom bombs. The symbols used are the same as those in (a).*

was confirmed with a study of 35,933 white, male workers in three nuclear weapons plants: Oak Ridge National Laboratory, Rocky Mountains Nuclear Weapons Plant, and the Hanford Site (Gilbert 1989, 1990). A decreased cancer mortality rate with increased lifetime exposure was noted (Figure 9). These differences were significant, for each exposure examined. Leukemia mortality rates appeared to be lower in exposed workers. However, the sample size was too low for this to have statistical significance. Lung cancer mortality rates for workers exposed to less than 100 mSv appeared to be lower than that of the unexposed workers; however, the differences were not statistically significant (Luckey 1994a). Workers exposed to more than 200 mSv had a significantly lower lung cancer mortality rate than unexposed workers.

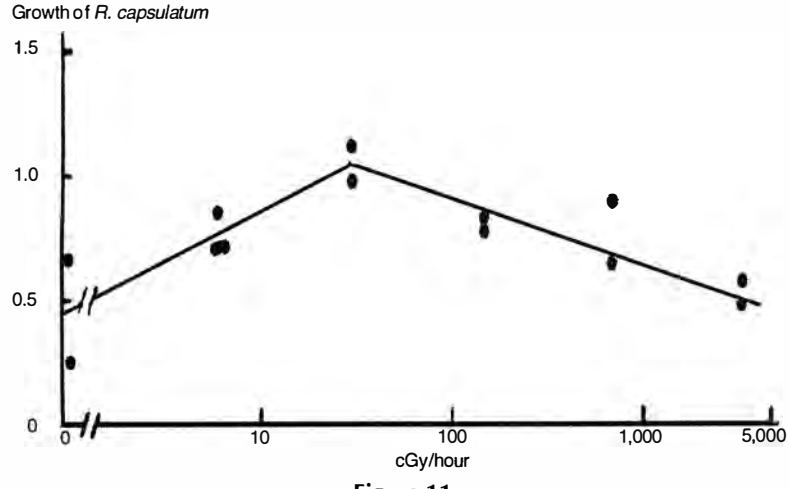


Figure 11
EFFECT OF GAMMA RADIATION ON THE GROWTH OF AN ALGA

The reproduction of the alga R. capsulata *was increased by continuous exposure to cobalt-60 gamma radiation. The optimum appeared to be about 50 cGy/hr; the ZEP was about 50 Gy/hr.*

Lightly exposed workers (303 white males) in a fourth nuclear weapons plant, Los Alamos National Laboratory, were found to have slightly lower mortality rates than 15,420 white, male unexposed workers (Wiggs 1994). When the death rate of unexposed workers was used as the standard, 1.00, the death rate of workers exposed to 10 to 50 mSv were: all cancers, 0.77; all leukemia, 0.35; and lung cancer, 0.51. Workers exposed to more than 50 mSv showed no benefit from the exposures. Brain cancer mortality of exposed workers was somewhat greater than that of the control group. The small numbers of workers reduce the impact of this Los Alamos study.

The results from exposed British, Canadian, and U.S. nuclear workers confirm the inverse correlation between radiation levels and cancer mortality rates. This concept is further substantiated in humans exposed to acute (atomic bomb) radiation and animal studies involving both acute and chronic

Table 4
CANCER AND LEUKEMIA DEATHS IN ATOM BOMB SURVIVORS

Dose in cSv	0-0.9	1-1.9	2-4.9	5-9.9	10-19.9	20-49.9	>50
Persons	45,148	7,430	9,235	6,439	5,316	6,271	6,681
Leukemia	81	11	14	8	11	21	75
Leukemia/10^5	179	148	152	124	207	335	1123
Change/10^{5*}	0	−31	−27	−55	+28	+156	+944
Other cancers	3,246	498	717	516	400	533	573
Other cancers/10^4	719	670	776	801	752	850	858
Change/10^{4*}	0	−49	+57	+82	+33	+131	+139

Source: Shimizu at al., 1992, p. 72

Notes
*Indicates change from control (first col.) to exposed at each dose

Table 5
CUMULATIVE CANCER AND LEUKEMIA DEATHS IN ATOM BOMB SURVIVORS

Dose in cSv	0-0.9	1-1.9	2-4.9	5-9.9	10-19.9	20-49.9	≥50
Persons	45,148	7,430	16,665	23,104	28,420	34,691	41,372
Leukemia	81	11	25	33	44	65	140
Leukemia/1,000	1.79	1.48	1.50	1.43	1.55	1.87	3.38
Change/10^{5*}	0	−31	−29	−36	−24	+8	+159
Other cancers	2,346	498	1,215	1,731	2,131	2,664	3,237
Dead/1,000	71.9	67.0	72.9	74.9	75.0	76.8	78.2
Change/10^{4*}	0	−49	+10	+30	+31	+49	+63

Source: Shimizu at al., 1992, p. 72

Notes
*Indicates change from control (first col.) to exposed at each dose

exposures (Luckey 1991).

Atomic Bomb Survivors

In 1945, atom bombs were exploded in the air over Hiroshima and Nagasaki and survivors were acutely exposed to different doses of ionizing radiation. In the intervening 50 years, the effects of acute doses of ionizing radiation have been studied separately from the physical trauma caused by the blast and flying debris. The cancer deaths of these survivors exhibit the "J" curve (Figure 10). Lightly exposed people have lower solid tissue cancer and leukemia death rates than controls (Table 4) (Shimizu 1992). These data confirm the hormesis thesis and show that the overall effect in humans is similar for both acute and chronic exposures: low doses are hormetic.

Shimizu and associates offered two conflicting data sets for cancer mortality rates, in that their figure misrepresents the data in their accompanying table (Shimizu 1992). In contrast to cancer mortality rates, they used the same data for leukemia mortality rates in both table and graph. Both sets show hormesis.

In acute exposures, the ZEP for non-leukemia cancer mortality appears to be 2 to 4 cSv for direct and cumulative exposures (Table 5). This means that persons receiving less than 2 cSv could be disregarded from the viewpoint of their cancer mortality response to ionizing radiation. The triage dose of 2 cSv is a useful criterion for effective direction and utilization of medical staff and medical resources following a nuclear disaster.

Leukemia mortality is of particular interest because leukemia is considered to be a very sensitive index of ionizing radiation. The data in Table 4 show the ZEP for leukemia mortality is about 10 cSv (Shimizu 1992). Persons exposed to less than 10 cSv appear to have a lower leukemia mortality rate than the controls. When the cumulative data are examined (Table 5) the ZEP appears to be about 20 cSv. This would be the triage dose to guide physicians and health physicists for leukemia mortality rates in a radiation catastrophe.

Theories of Hormesis Mechanisms

The benefits of low-dose irradiation are attributed to several overlapping mechanisms. Low-dose irradiation stimulates cell metabolism including photosynthesis; this is called radiogenic metabolism. Low-dose irradiation also stimulates DNA, RNA, and membrane repair in addition to the production of many cytokrines and cellular reactions which provide increased immune competence. Increased immune competence accounts for statistically significant decreased mortality rates from infection and cancer in both animals and in humans. The most important mechanism is the essential nature of ionizing radiation.

Radiogenic metabolism. Radiogenic metabolism is the promotion of metabolic processes by ionizing radiation. Radiogenic metabolism has been noted in algae, bacteria, and protozoa (Luckey 1978, 1980). Algal utilization of high energy photons (X- and gamma-rays) suggests this energy source was utilized before low energy photons, light, penetrated the clouds and volcanic dusts of primordial Earth. G.F. Atkinson observed an increased growth rate in a bluegreen alga when exposed to X-rays (Atkinson 1898). This was amply confirmed by Planel and associates with a bluegreen alga maintained in lighted boxes (Conter 1980). The key to the utilization of high energy radiation in photosynthesis was found in the response of photosynthetic bacteria and algae to filtered cobalt-60 gamma rays in the absence of visual light. An example is the response of an alga, *Rhodopseudomonas capsulata* (Figure 11). The optimum chronic dose rate appears to be 50 cGy/hr. Note that there appears to be no harm to the growth rate of this organism with very high exposures, up to 5 kGy/hr. This suggests a vestigial origin for the utilization of ionizing radiation in cell metabolism. It also suggests the use of ionizing radiation in microbial fermentations and photosynthesis.

It is probable that both activation of cell repair systems and radiogenic metabolism contribute to the increased immune competence in lightly irradiated animals.

Radiation hormesis in immunity. The second general mechanism involves the complex immune system (Luckey 1973). The main function of the immune system is to search out and destroy "non-self" cells and their constituents, including invading microbes and minute cancers. Immune competence involves thymus, spleen, a bursa equivalent, bone marrow, pituitary, and

a variety of leukocytes, hormones, and cytokrines.

Low-dose irradiation appears to decrease the dominance of suppressor T cells to allow more effective action of helper T cells, killer cells and functional T cells (in antibody production, for example). Increased immune competence could account for decreased infection and cancer mortality rates. Either could be responsible for the increased average lifespan consistently observed following either high- or low-dose irradiation.

Increased immune competence in lightly irradiated animals was noted early in this century. These effects were amply confirmed during the following decades (Taliaferro 1969). Recent research has focused upon molecular models for different aspects of the immune system. Data suggest that enhanced immune competence following low-dose irradiation involves interactions with the central nervous system as well as genetic expression (Makinodan 1992, Liu 1994, Hattori 1994, Zu 1996).

Nurture with ionizing radiation. There is an important general mechanism of nurture by means of ionizing radiation, which encompasses cell repair, radiogenic metabolism, the immune system, and the essential nature of ionizing radiation. Is ionizing radiation essential for life? If so, this would dramatically change our basic concepts about this ubiquitous agent. In order to live in harmony with nature, we must determine whether ionizing radiation is an essential agent.

A "Rosetta Stone" is needed to help translate the effects of low-dose irradiation into an understanding of the role of this ubiquitous agent in our lives (Luckey 1994b).

Overcoming Radiation Deficiency

Increased exposure to low-dose irradiation contributes to health and increased average lifespan. The evidence shows that workers exposed to about 5 mGy/y (a total of about 7 mGy/y) have longer average lifespans and decreased cancer mortality rates than the general population or unexposed workers in the same plants. More information comes from combining human and animal data.

Our present knowledge suggests that a safe, conservative allowance would be 2 to 3 times greater than what we have at present. A minimum of 5 to 10 mGy/y will provide increased health for adult populations. As shown in Table 1, generations have lived in different parts of the world with several times this exposure, and effects in many generations of humans and animals indicate that this is a reasonable guide for whole populations. However, more research is needed before adequate data are available to support a recommended allowance of more than 10 mGy/y. Conservatively, we can say that the health of people and the wealth of nations would improve by increasing environmental exposures to ionizing radiation from their present levels of 1 to 3 mGy per year, to 5 to 10 mGy per year.

References

J.D. Abbatt, T.R. Hamilton and J.L. Weeks, 1983. "Epidemiological studies in three corporations covering the nuclear fuel cycle," in *Proc. International Atomic Energy Agency Symposium* (Vienna: IAEA), pp. 351-361.

M.J. Adler, 1952. "Hippocrates, Galen," in Vol. 10, p. 7 of *Great Books of the Western World* (Chicago: Encyclopedia Britannica).

G.F. Atkinson, 1898. "Report upon some preliminary experiments with Roentgen rays on plants," *Science*, Vol. 7, No. 7.

B.L. Cohen, 1992. "Compilation and integration of studies of radon levels in U.S. homes by states and counties," *Crit. Rev. Environm. Control*, Vol. 22, pp. 243-364.

A. Conter, D. Dupouy, and H. Planel, 1980. "Demonstration of a biological effect of natural ionizing radiation," *Int. J. Rad. Biol.*, Vol. 43, pp. 421-432.

E.S. Gilbert, S.A. Fry, L.D. Wiggs, G.L. Voelz, D.L. Cragle, and G.R. Petersen, 1989. "Analysis of combined mortality data on workers at the Hanford site, Oak Ridge National Laboratory, and the Rocky Flats Nuclear Weapons Plant," *Rad. Res.*, Vol. 120, pp. 19-35.

———, 1990. "Methods for analyzing combined data from studies of workers exposed to low doses of radiation," *Am. J. Epidem.* Vol. 131, pp. 917-927.

M.A. Gribbin, J.L. Weeks, and G.R. Howe, 1993. "Cancer mortality (1956-1985) among male employees of Atomic Energy Limited with respect to occupational exposure to low linear energy transfer ionizing radiation," *Rad. Res.*, Vol. 133, pp. 375-380.

S. Hattori, 1994. "State of research and perspectives on radiation hormesis in Japan," *Intern. J. Occup. Med. Toxicol.*, Vol. 3, pp. 203-217.

Z. Jaworowski, 1994. "Hormesis: The Beneficial Effects of Radiation," *21st Century Science & Technology*, Fall, pp. 22-27.

G.M. Kendall, C.R. Muirhead, B.H. McGibbon, et al., 1992. "Mortality and occupational exposure to radiation: first analysis of the National Registry for Radiation Workers," *Br. Med. J.*, Vol. 304, pp. 220-225. See also "Occupational Exposures to Ionizing Radiation and Mortality," Nat. Rad. Prot. Board, NRPB-R251, Chilton, 1992.

S. Kondo, 1993. *Health Effects of Low-Level Radiation* (Osaka: Kinki University Press).

S.Z. Liu, 1992. "Multilevel mechanisms of stimulatory effect of low dose radiation on immunity, in T. Sugahara, L.A. Sagan and T. Aoyama, eds., *Low Dose Irradiation and Biological Defense Mechanisms* (Amsterdam: Excerpta Medica), p. 225. See also *Intern. J. Occupat. Med. Toxicol.*, Vol. 3, pp. 107-117, 1994.

T.D. Luckey, 1959. "Antibiotics in Nutrition," in *Antibiotics, their Chemistry and Non-Medical Uses*, ed. H.S. Goldberg (New York: D. Van Nostrand Company), pp. 174-322.

———, 1973. *Thymic Hormones* (Baltimore: University Park Press).

———, 1980. "Radiogenic metabolism," *Abst. 6th Conf. Mol. Biol. Photosyn. Procaryotes*, Vol. 80, pp. 55-57.

———, 1980. *Hormesis with Ionizing Radiation* (Boca Raton, Fla.: CRC Press).

———, 1991. *Radiation Hormesis* (Boca Raton, Fla.: CRC Press).

———, 1994(a). "Radiation hormesis in cancer mortality," *Intern. J. Occup. Med. Toxicol.*, Vol. 3, pp. 175-194.

———, 1994(b). "A Rosetta Stone for Radiation," *Rad. Prot. Manag.*, Vol. 11, pp. 73-79.

T. Makinodan, 1992. "Cellular and subcellular alterations in immune cells," in T. Sugahara, L.A. Sagan and T. Aoyama, eds., *Low Dose Irradiation and Biological Defense Mechanisms* (Amsterdam: Excerpta Medica), p. 233.

G.M. Matanoski, 1991. "Health Effects of Low-Level Radiation in Shipyard Workers" (Washington, D.C.: Department of Energy), Final Report, E1.99 DOE/EV/10095-T1 and 2.

K.S.V. Nambi, and S.D. Soman, 1987. "Environmental radiation and cancer in India," *Health Phys.*, Vol. 52, pp. 653-657.

National Council on Radiation Protection and Measurements (NCRP), "Exposure of the Population of the United States and Canada from Natural Background Radiation," Report No. 914.

H.T. Sauer, 1980. "Geographic Patterns in the Risk of Dying and Assorted Factors, Ages 35-74 Years" (Washington, D.C.: Dept. Health and Human Services, Public Health Service) DHHS Publ. PHS 80-1402.

H. Selye, 1950. *Stress* (Montreal: Acta, Inc.).

Y. Shimizu, H. Kato, W.J. Schull, and K. Mabuchi, 1992. "Dose-response analysis among atomic-bomb survivors exposed to low-level radiation," in T. Sugahara, L. Sagan and T. Aoyama, eds., *Low Dose Irradiation and Biological Defense Mechanisms* (Amsterdam: Excerpta Medica), pp. 71-74.

W.H. Taliaferro and L.G. Taliaferro, 1951. "Effect of X-rays on immunity," *J. Immunol.*, Vol. 66, pp. 181-212. See also *Science*, Vol. 144, pp. 268-272 (1964) and *J. Immunol.*, Vol. 103, pp. 559-563 (1969).

J. Thorwald, 1962. *Science and Secrets of Early Medicine* (New York: Harcourt, Brace and World).

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), 1994. *Adaptive Responses to Radiation in Cells and Organisms*, Document A/AC.82/R.542.

U.S. Department of Commerce, 1988. *Statistical Abstract of the United States, 1988* (Washington, D.C.).

A.E. Waite, 1894. *The Hermetic and Alchemical Writings of Aureleo Phillipus Theophrastus Bombast, of Hohenheim, called Paracelsus the Great* (London: J. Elliot).

L.-X. Wei, J.-Z. Wang, 1994. "Estimate of cancer risk for a population continuously exposed to higher background radiation in Yangjiang, China," *J. Occup. Med. Toxicol.*, Vol. 3, pp. 195-199.

L.D. Wiggs, E.R. Johnson, C.A. Cox-de Vore, and G.L. Voelz, 1994. "Mortality through 1990 among white male workers at the Los Alamos National Laboratory: Considering exposures to plutonium and external ionizing radiation," *Health Phys.*, Vol. 67, pp. 577-588.

G.Z. Zu, ed., 1996. *Biological Effects of Low Level Radiation* (Changchun: N. B. Univ. Press).

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The Atomic Science Textbooks Don't Teach

The Significance of the 1845 Gauss-Weber Correspondence

by Laurence Hecht

The 1830's experiments of Carl Friedrich Gauss and Wilhelm Weber to test Ampère's electrodynamic theory, led to the conception of the electron and atomic nucleus, more than 50 years before their empirical confirmation.

A letter of 19 March 1845 from Carl Friedrich Gauss to his younger collaborator, Wilhelm Weber, ranks as one of the most singular interventions of all time by an individual in changing the course of history. Modern atomic science, physics, and chemistry, and everything in the modern world that depends upon them, would not have existed without it. It is, thus, one of the clearest proofs of the existence of the consumer fraud, which passes for university science education today, that the issues discussed in the letter are scarcely known to any but a few specialists today, and that not even one among these shows any adequate understanding of the fundamentals involved.

The point at issue in the cited correspondence, is the existence of a special form of scientific concept, known to Plato as the *Idea,* which had been introduced into electrodynamics by André-Marie Ampère some 20 years earlier. No other scientist in the world at the time recognized the significance of this aspect of Ampère's work. Gauss, in the 1845 letter, points to precisely this, and successfully provokes a reorientation of Weber's thinking. As a result, Weber develops a generalization of Ampère's law that leads, by no later than 1870, to the theoretical recognition of the existence of the charged atomic nucleus and oppositely charged orbiting electrons, decades before any empirical identification of the phenomena could be made. By that year, Weber had also derived the precise formula (e^2/mc^2) for the atomic measurement later known as the *classical electron radius,* and identified the nuclear binding force, a phenomenon for which there was no empirical evidence until the 20th century.

The fact that these discoveries of Weber are virtually unknown today, is itself a scandal, although not the main point of our treatment here. We focus rather on the more crucial underlying point: the method of Ampère, Gauss, and Weber; that is, the actual scientific method, which alone leads to fundamental discovery. The 1845 correspondence offers a precious inside view into the process.

First, the essential background:

In 1820, Hans Christian Oersted first demonstrated the effect of an electrical current on a magnet (Figure 1). Biot, Savart,

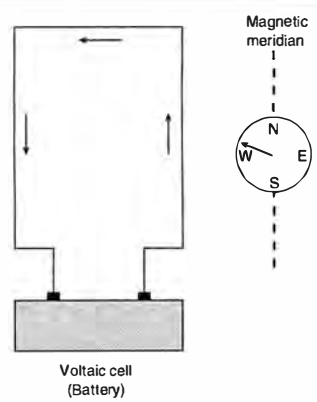
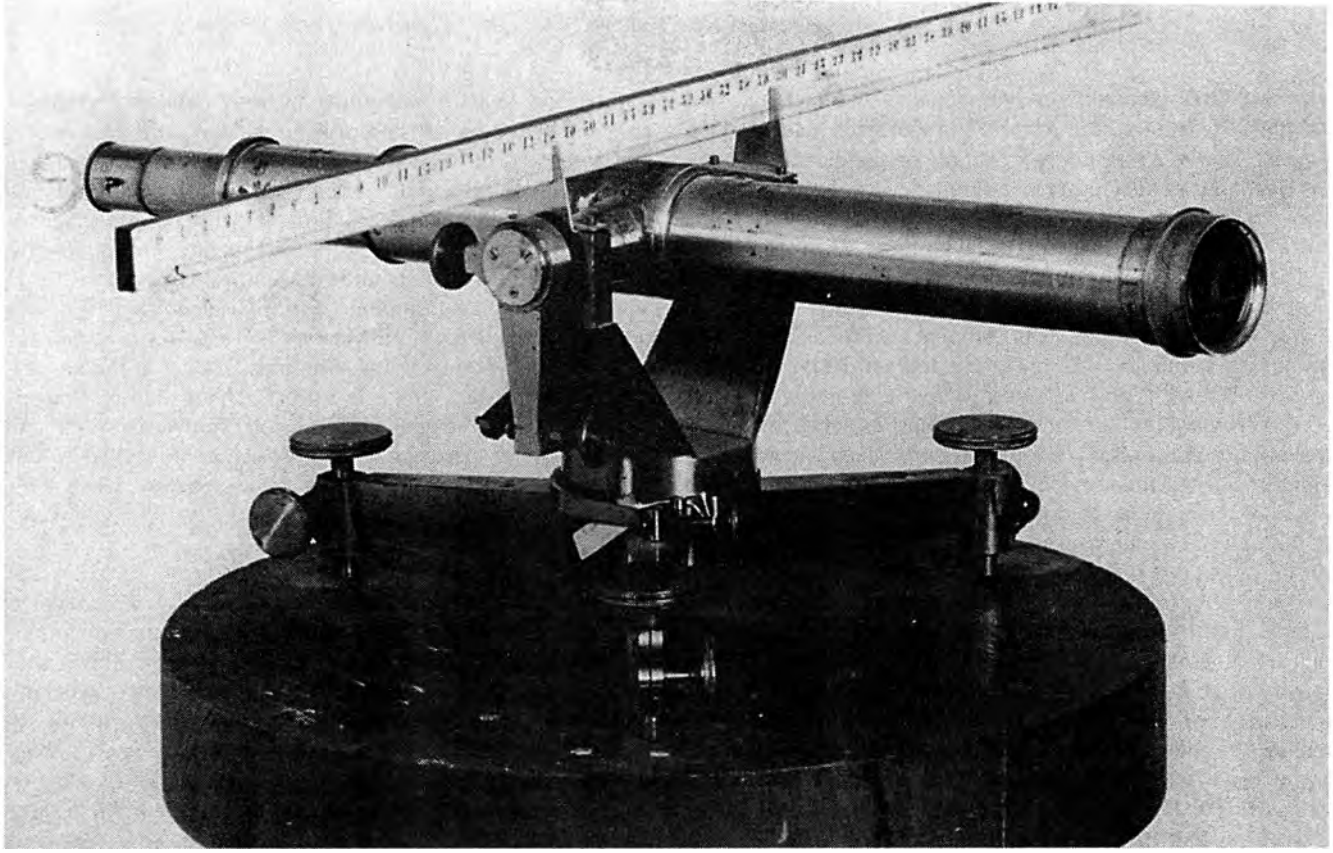


Figure 1
THE OERSTED EXPERIMENT
Hans Christian Oersted first definitively demonstrated a relationship between electricity and magnetism. He showed that a magnetic compass needle, placed near a current-carrying wire, will turn in the direction of the wire.



Historical Collection of the Göttingen University I. Physical Institute

This telescope and meter stick were built by the firm Utzschneider und Fraunhofer of Munich, probably in 1880. It is, in principle, the same as that devised by Gauss in 1832 for the precise observation of angular deflection in connection with his determination of the absolute intensity of the Earth's magnetic force. A plane mirror, attached to a rotatable magnet, projects the image of whatever part of the meter stick it faces, into the telescope tube. The scale numbers are thus mirror-reversed and inverted for reading through the telescope sight. Weber's 1841 version of the apparatus could produce an angular precision of about 18 seconds of arc. (See Figure 1.3, page 37 for details of the Spiegel und Fernrohr *apparatus.)*

and others among the leading establishment physicists in France, encouraged by Laplace, undertook empirical investigations to determine the measurable effect of the conducting wire on a magnet. Ampère, recognizing that current (Galvanic) electricity represented a completely new phenomenon, saw in Oersted's demonstration the possibility of gaining fundamental new knowledge of magnetism and the atomic constituency of matter. Hypothesizing that magnetism itself may be the result of electrical currents surrounding the molecules of matter, he set out first to determine if two electrical conductors affected each other in the same way that a single electric wire affects a magnet. His first experiments established that two parallel conducting wires attract or repel, depending on whether their currents flow in similar or opposing directions. He next demonstrated that, by passing a current through a helically coiled wire, the configuration, which Ampère first named a solenoid, developed north and south magnetic poles, just like a bar magnet (Figure 2).

Having thus discovered, within a few weeks' time, the first empirical laws of a new science—he named it *electrodynamics*—Ampère next set himself the task of determining its fundamental laws. He thus proposed to find a formula expressing the interaction between two hypothetical, very small portions of electrical current, which he called *current elements,* in adjacent conducting wires. His results were sensational. At the time, the laws of gravitation, static electricity, and magnetism had all been found to be dependent on the inverse square of

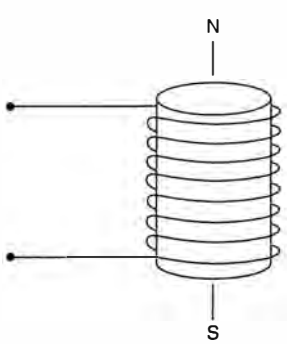


Figure 2
THE AMPERE SOLENOID

Ampère hypothesized that the true cause of magnetism is the motion of resistance-less electrical currents in tiny orbits around the molecules of matter. To prove it, he constructed the world's first electromagnet, a conducting wire coiled around a cylinder, which he named a solenoid. When the solenoid is attached to a battery, the ends of the cylinder become like the north and south poles of a bar magnet. Ampère believed that the large-scale circular motion of the electricity in the solenoid coil mimicked the tiny circular orbits which he conceived to be present in a magnet.

the distance of separation of their elements (mass, charge, and magnetic *molecules*). But Ampère's law of force for current elements showed a dependence not only on the distance, but on the directions of the current elements.

The Method of Hypothesis

The existence of such an anomaly, defying the neat unification of forces only recently established, was disturbing to many. For more than 20 years, Ampère's work, although well known to scientists, was never treated seriously. Although many criticized it, no one before Weber ever troubled to test it. The essential problem militating against its acceptance, was the philosophic outlook known as *empiricism.* A prevailing view in science then, as now, empiricism demanded that no physical phenomena could be measured, and thus subjected to the rigorous mathematical analysis expected of the pure sciences, unless one could see, hear, feel, smell, or taste it.

The method of hypothesis employed by Ampère, assumes, rather, that the so-called *data* of the senses are completely delusional. Nothing that one can see, hear, feel, smell, or taste is what it appears to be. Take a simple object like a magnetized steel bar, for example. An empiricist might measure and analyze the effect on it of an electrical wire all day long; he might cut it in half, grind it up into a powder, dissolve it in acid, or melt it in an oven, and never yet arrive at the simple *hypothesis* that its magnetic property derives from the existence of very small, electrical currents circling the invisible particles which constitute it.

But to merely formulate such an idea, is only the first small step in the pursuit of the method of hypothesis. It is necessary, above all, to seriously *believe* in the existence of such non-observable things. One must have a truly passionate belief, not unlike the proper meaning of the word *faith,* in the *reality* of such a mere idea. Only by such a driving passion, a *love of the idea,* can a person be motivated to pursue it, as Ampère did, through five years of experimental design and mathematical analysis, before he felt sure of its truth. And if the *idea* is of a fundamental sort, as was Ampère's concept of electrical action, it will tend to overthrow previously existing conceptions. In this case, the existence of a force dependent on angular relationship, clearly challenged the Newtonian conception. The laws of physics would not allow it—and yet it existed.[1]

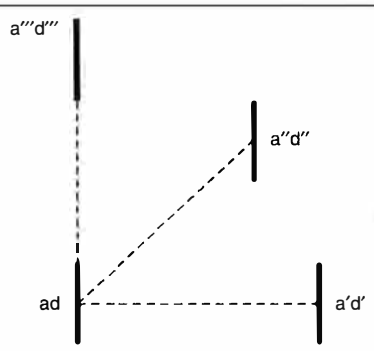


Figure 3
THE FORCE BETWEEN CURRENT ELEMENTS
Early experiments with two parallel wires showed that the wires attracted each other when the current flowed through them in the same direction, and repelled in the opposite case. From this Ampère could conclude that any two parallel, small sections of the wire (current elements) would behave accordingly. This is the relationship of element ad to a′d′ in the diagram. But what if the second element is in another position, such as that of a″d″ or a‴d‴? Direct observation could not decide these more general cases.

Gauss appreciated Ampère's accomplishment as few, if any, others did. His letter of 19 March 1845 focusses on an aspect of Ampère's hypothesis, that is an Idea, known as the *longitudinal force.* This is a simple construct, relying only on elementary relationships of geometry, but so controversial that many have denied its existence for almost two centuries. As an understanding of it is crucial for the rest of the story, let us summarize how Ampère develops it.

1. The Essentials of Ampère's Law

Consider first, two current elements, *ad* and *a′ d′*, parallel to each other and perpendicular to the line connecting their midpoints (Figure 3). Ampère knew from his first experiment with parallel wires, that the current elements will attract or repel depending on whether the current in the wires of which they are a part flows in the same or opposite directions. But what about the current elements in other positions, such as *a″d″* or *a‴d‴?* How does the force between them differ when the second current element is positioned *longitudinally,* that is, on a straight line with the first, as at *a‴d‴?* Let the ratio of the force between the current elements in the longitudinal position to those which are parallel be designated by the constant *k*. What is its value? Two current elements cannot be isolated from the circuits of which they are a part, to be placed in these positions. Thus it is not possible to carry out a direct empirical measurement of the force between them. The method of hypothesis is the only one available to answer the question. Here is how Ampère proceeds in what is known as his Second Equilibrium Experiment:

Two parallel, vertical columns are placed a small distance apart on a laboratory table. Between them, a rectangular wire circuit is placed so that one side of the rectangle is parallel to the two columns and forms a common plane with them. The rectangle is free to swing on a vertical axis (Figure 4). In the first case, straight conducting wires are led up each of the vertical columns, and a current is made to flow through both of them in the same direction, either up or down. A current of the opposite direction is caused to flow through the parallel side of the rectangle *GH*. When the current is turned on, he finds that the rectangle remains positioned in the center between the two columns, being equally attracted or repelled by the two parallel wires in the vertical columns.

In the second case, the wire, *kl,* running up one of the columns, *RS,* is made to snake arbitrarily back and forth in the plane perpendicular to the paper—Figure 4 (b). But when the current is turned on, it makes no difference. The side, *GH,* of the movable rectangle still positions itself in the center between the two columns, and does so even when the pattern of bends in the wire *kl* is changed.

To explain this paradox, Ampère analyzes the current flow in the bent wire into its components in the vertical and horizontal direction. Both the bent and straight wires stretch along the same vertical length, hence the sum of the vertical components of *kl* is the same as *bc*. As the first case shows that no

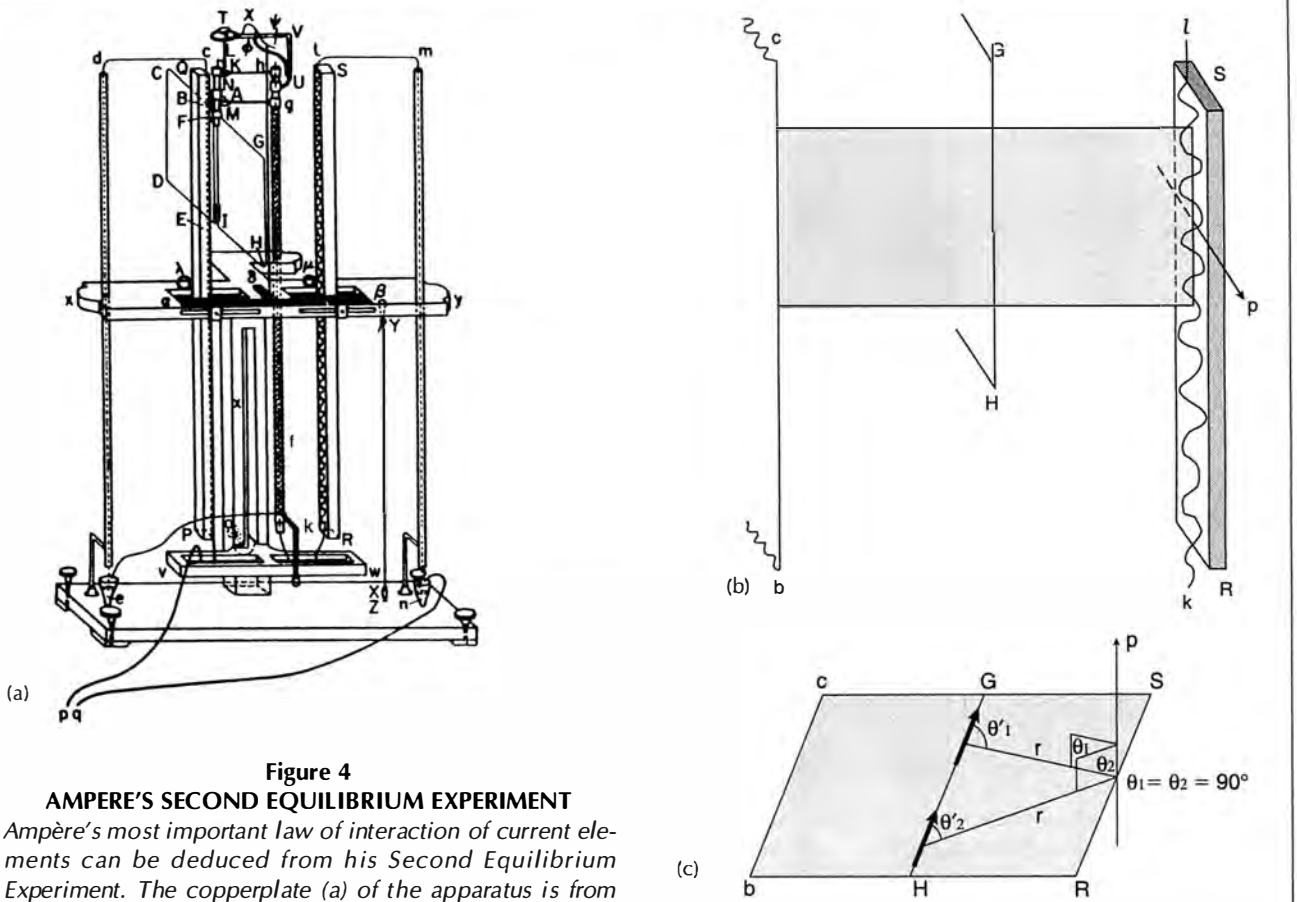


Figure 4
AMPERE'S SECOND EQUILIBRIUM EXPERIMENT

Ampère's most important law of interaction of current elements can be deduced from his Second Equilibrium Experiment. The copperplate (a) of the apparatus is from Ampère's 1826 Memoir. The two wooden posts PQ, RS are slotted on the sides which mutually face each other. A straight wire runs up PQ, while the wire in the slot of RS snakes back and forth in the plane perpendicular to PQRS. The wire rectangle CDGH also conducts a current and is free to rotate about the axis MI.

The purpose of the experiment is to determine whether the snaking of the wire in RS causes a rotation of the wire rectangle CDGH. The circuit is arranged so that current flows up the two fixed conductors in PQ and RS and down the side of the movable rectangle denoted GH. The entire apparatus is a single circuit. Current enters at the mercury-filled trough v, and leaves through the mercury cup at n. The wire passing up the vertical glass tube fgh is wound helically to negate its magnetic effect in a lateral direction. The vertical columns de and mn are glass tubes for the return circuit.

In (b) we see a schematic detail of the relationship of the two fixed conductors and the side GH of the movable rectangle: p is the horizontal component of current flow at an arbitrary point of the snaky wire kl. The shaded rectangle depicts the plane RScb to which p is perpendicular.

In (c), the rectangle RScb has been rotated 90 degrees so that the current element p now appears vertical. The midpoints of the two arbitrary current elements depicted in the plane RScb are connected by the lines r to the midpoint of p. The angle formed by r at p (θ_1, θ_2) is always right. The experiment shows that regardless of the other angle (θ'_1, θ'_2), the current element p exerts no force on any current element in the plane RScb.

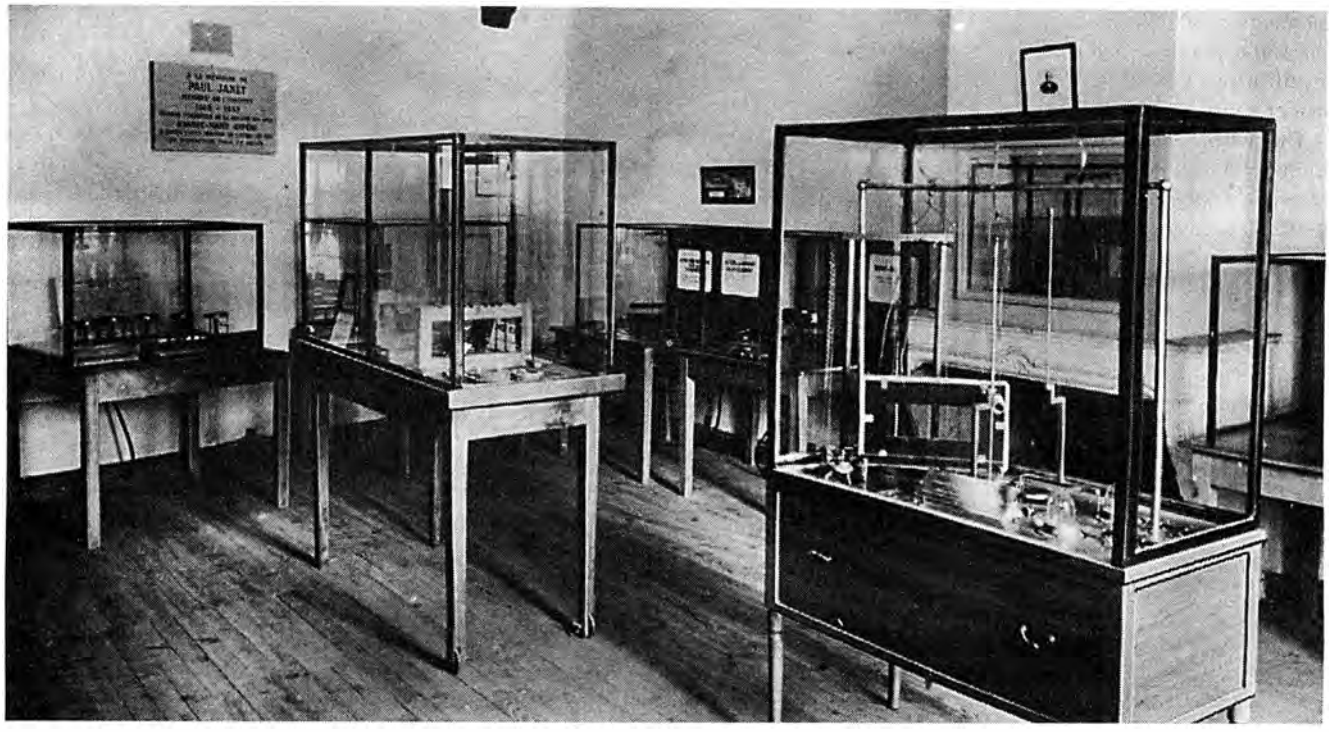
motion arises from two parallel vertical wires, the vertical components of *kl* may thus be ignored. Thus the problem reduces to an examination of its horizontal components.

Take any horizontal component, for example the one at the arbitrary position *p* in Figure 4(b), which is, by definition, perpendicular to the shaded plane *RScb*. Consider its relationship to any current element in the movable wire *GH*. By virtue of the fact that *GH* does not move, we can conclude that the arbitrarily chosen horizontal component must have no interaction with any current element along the length of *GH*. If it had any interaction, a disequilibrium of forces would necessarily arise from the arbitrary bends in the wire, causing *GH* to move.

From this experimentally deduced fact, Ampère is able to adduce the following theorem for the interaction of current elements:

> . . . that an infinitely small portion of electrical current exerts no action on another infinitely small portion of current situated in a plane which passes through its midpoint, and which is perpendicular to its direction. [Ampère 1826, p. 202]

Figure 4(c) helps us to see how the generalization is made. The plane *RScb* has been rotated 90 degrees. The horizontal component is here pictured as the arrow, *p*, passing vertically through the plane. The other two arrows represent arbitrary



Ampère's electrical apparatus is on display at a small museum in his childhood home at Poleymieux, France.

current elements in *GH*. These may make any angles whatsoever with the lines *r* connecting them to the midpoint of *p*. Since the experiment shows that the current element *p* exerts no action on any of them, the generalization is made that *p* exerts no action on any current element anywhere in the plane.

One might first imagine that we could establish the same result by simply placing two wires perpendicular to each other, a certain distance apart, and directly measuring the effect. The problem is that it is only the infinitesimal elements of the two wires, precisely at the point of perpendicularity which concern us, while in the mooted simplified configuration, all the other elements of the two wires will also contribute to the measured effect. One sees then, the genius of the Second Equilibrium Experiment, that it allows us to isolate—although only by abstraction—precisely the effect we wish to measure. This is true, indeed, of all four equilibrium experiments; the reader should know that Ampère carried out many dozens, perhaps hundreds, of other experiments before being able to reduce his presentation to deduction from the four equilibrium experiments presented in his final 1826 *Memoire* on electrodynamics.

The theorem deduced from the second experiment is the key that allows Ampère to solve the problem posed in connection with Figure 3. Return to Figure 3, where *ad* and *a'd'* are two parallel current elements. The question he poses is how the force between them changes as the current element is repositioned from *a'd'* to *a'''d'''*. Ampère determines that he will define the force as a function of the current element lengths, the intensities of the current of which they are part, and their relative position; the force is to be represented as acting along the line *r*.

Since the current elements under consideration lie in a plane, their relative position will be completely described by the length of the line, *r*, connecting their midpoints, and the angles θ, θ' which they form with it—Figure 5(a). "Consideration of the diverse attractions and repulsions observed in nature," writes Ampère,

> led me to believe that the force which I was seeking to represent, acted in some inverse ratio to distance; for greater generality, I assumed that it was in inverse ratio to the *n*th power of this distance, *n* being a constant to be determined. [Ampère 1826, p. 200]

If the very small lengths of the current elements are represented as *ds, ds'*, their intensities as *i, i'*, and θ, θ' designate the angles they form with the line connecting them, then the force between them, based on the assumptions so far, will be

$$\frac{ii'\ ds \cdot ds'}{r^n}\ \phi(\theta, \theta')\ ,$$

where ϕ represents the unknown function of the angles between the two current elements.

This leaves two unknowns to be determined: the value of the exponent, *n*, and the angle function, ϕ. The results of the second equilibrium experiment make it an easy matter to find the angle function ϕ. Take two arbitrary current elements in a plane, *ds* and *ds'*, and resolve their directions into two perpendicular components, as pictured in Figure 5(b). The parallel components will be represented by $ds\ \sin\theta$ and $ds'\ \sin\theta'$. The longitudinal components will be represented by $ds\ \cos\theta$ and $ds'\ \cos\theta'$. By the theorem derived from the second equilibrium experiment, we see that the force between $ds\ \sin\theta$ and $ds'\ \cos\theta'$, and also that between $ds'\ \sin\theta'$ and $ds\ \cos\theta$ is zero. This may appear confusing at first, because the two perpendicular

elements under consideration in Figure 4 are not, in general, in the same plane. But the theorem deduced from the Second Equilibrium Experiment subsumes the planar case, as the reader can see from Figure 5(c).

The action of the two elements *ds* and *ds'* therefore reduces to the two joint remaining actions, namely the interaction between *ds* sinθ and *ds'* sinθ', and between *ds* cosθ and *ds'* cosθ'. It is easy to see that these two pairs of actions are between components which are either *parallel* or *longitudinal*. The first can be represented as

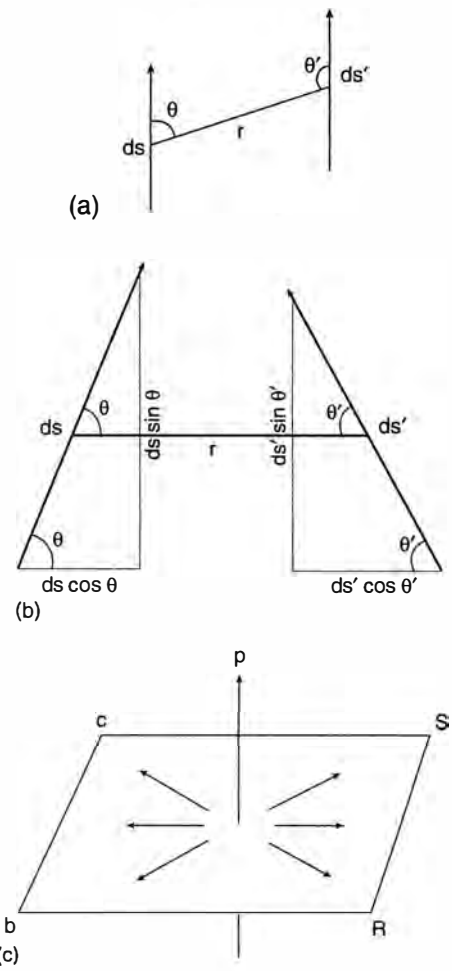


Figure 5
DEDUCTION OF THE AMPERE FORCE LAW

In (a), two parallel current elements ds, ds' form the angles θ, θ' with the line r joining their midpoints.

The horizontal and vertical components of two arbitrary current elements ds and ds' are pictured in (b). These are ds sinθ, ds' sinθ', dscosθ, and ds' cosθ'. The theorem deduced from the Second Equilibrium Experiment allows the elimination of two of the interactions (ds cosθ · ds' sinθ' and ds' cosθ' · ds sinθ).

In (c) are depicted current elements in the plane RScb, which also form a common plane with the perpendicular p.

$$\frac{ii'\ ds\cdot ds'\ \sin\theta\ \sin\theta'}{r^n},$$

and the second as

$$\frac{ii'\ ds\cdot ds'\ k\cos\theta\ \cos\theta'}{r^n},$$

remembering that k represents the ratio of the longitudinal to the parallel force, taking the parallel force as unity. It is only necessary to add these to obtain the total force between the two current elements, which produces:

$$\frac{ii'\ ds\cdot ds'}{r^n}(\sin\theta\ \sin\theta' + k\cos\theta\ \cos\theta')\,. \qquad \textbf{Eq. 1}$$

With only one simplification, introduced to ease the reader's burden, this is the general expression for the Ampère force under discussion in the 1845 correspondence between Gauss and Weber. For simplicity's sake, we derived the formula for the plane only. If the two current elements are not restricted to a plane, but may lie in planes whose angle with each other is represented by ω, then the full expression for the Ampère force becomes:

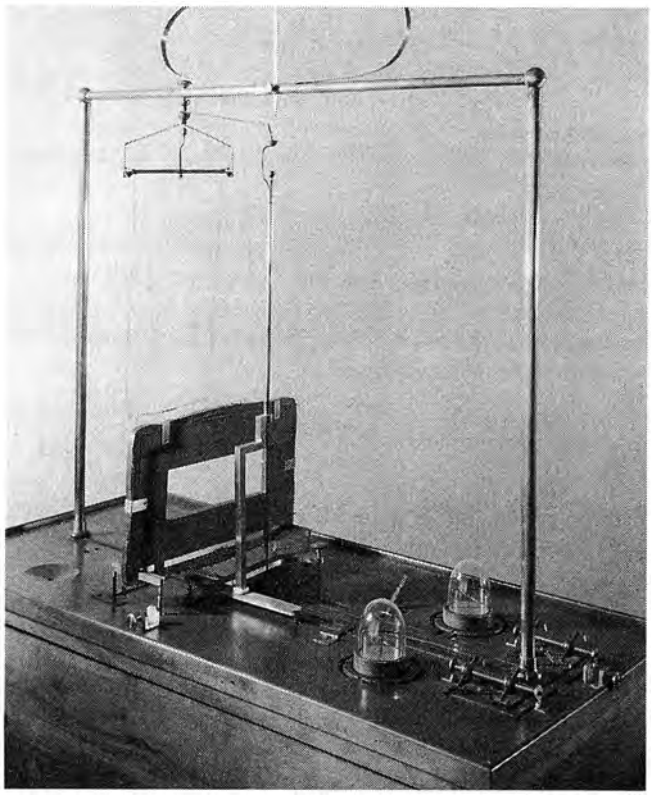
$$\frac{ii'\ ds\cdot ds'}{r^n}(\sin\theta\ \sin\theta'\ \cos\omega + k\cos\theta\ \cos\theta')\,.$$

The determination of the values of the constants n and k, required two additional equilibrium experiments, which allowed Ampère to derive the values $n = 2$ and $k = -1/2$.

2. The Ampère Formula and the Correspondence

In 1828, Wilhelm Weber, a young physics graduate who had distinguished himself through original research into acoustics and water waves, met Carl Friedrich Gauss, then the leading astronomer and mathematician of Europe, at a scientific conference in Berlin. Gauss needed help to carry out the researches he planned in magnetism and electricity, and Alexander von Humboldt encouraged their cooperation. Weber was awarded a professorship at Göttingen University and began work there in 1831. Their joint researches on magnetism led to the first determination of an absolute measurement of the Earth's magnetic force and a seminal paper by Gauss on the subject in 1832. In 1833, the two constructed the world's first electromagnetic telegraph, running from the university observatory to the physics laboratory. Gauss had identified the confirmation of Ampère's law as one of the leading tasks facing science, and Weber began a long series of experiments to that end. The Gauss magnetometer was adapted into an instrument, the electrodynamometer, for bringing to electrical measurements the precision which Gauss had achieved for magnetism. (See accompanying article, p. 35.)

In 1845, Weber, now at Leipzig, was preparing a treatise on his results, which he wished to present to the Royal Society in Göttingen. Uncertain of his conclusions, he sent a copy to Gauss on 18 January 1845, asking for his evaluation. On 1 February 1845, Weber sent a second letter explaining a change he had made in the Ampère formula,



Deutsches Museum

This experimental apparatus for replicating the electrodynamic experiments of Ampère was designed by H. Pixii in 1824, and is on display at the Deutsches Museum in Munich.

> which I seek to justify, by means of the consideration that the empirically derived definition of the coefficient of the second term, which I have discarded, seems completely untrustworthy, because of the unreliability of the method, and hence that coefficient, so long as it lacks a more precise quantitative determination, by the same reasoning would have to be set = 0.

The coefficient Weber refers to is that identified just above as k. The second term, $k \cos\theta \cos\theta'$, is the longitudinal force, which Weber proposes to drop. It is perhaps not irrelevant that in the year 1845, an article by Hermann Grassmann in the physics journal, Poggendorf's *Annalen,* challenged the angle dependency of the Ampère force, describing the existence of such an effect as "improbable." Weber was a friend of the journal's editor, Poggendorf, and had recently worked with him in Berlin. Weber would thus have likely known in advance of Grassmann's contribution on the topic that had occupied him for more than a decade. Perhaps Grassmann's effort, combined with his separation from Gauss, propelled Weber into self-doubt about the reality of the Ampère hypothesis.

Gauss's rejoinder of 19 March is the singular intervention referred to in opening this article. In his 70th year, Gauss begins with regrets over the loss of time caused by his poor health, and his decade of removal from work on the topic. But, of the proposed modification of the law, Gauss writes, with no loss of acuity:

> . . .I would think, to begin with, that, were Ampère still living, he would decidedly protest . . . [I]n the present case, the difference is a vital question, for Ampère's entire theory of the interchangeability of magnetism with galvanic currents depends absolutely on the correctness of [his formula] and is wholly lost, if another is chosen in its place.
>
> . . . I do not believe that Ampère, even if he himself were to admit the incompleteness of his experiments, would authorize the adoption of an entirely different formula, whereby his entire theory would fall to pieces, so long as this other formula were not reinforced by completely decisive experiments. You must have misunderstood the reservations which, according to your second letter, I myself have expressed. . . .

To see clearly what Gauss is saying, the reader must know that prior to Ampère, magnetism had been explained as a separation (polarization) of two *magnetic fluids,* boreal and austral, within the particles (*magnetic molecules*) of a magnetizable substance. Magnetizing an iron bar was seen to consist of polarizing and aligning the magnetic molecules along a given axis of the bar. Ampère suggested rather that the magnetic molecule is an electrical current loop, a *"galvano-electric orbit,"* as Gauss was to characterize the Ampère magnetic hypothesis in his 1832 study of magnetism. Magnetization, for Ampère, consisted of aligning these microscopic current loops along the magnetic axis. In his 1826 treatise, Ampère had elaborately developed the interdependence of his new magnetic hypothesis with his formula for the force between two current elements.

Weber completely accepted Gauss's correction and wrote back on 31 March:

> It has been of great interest to me to learn from what you were kind enough to write, that Ampère, in the definition of the coefficient he calls k in his fundamental law, was guided by other reasons than the ones from immediate empirical experience which he cites at the beginning of his treatise, and that hence the derivation, which I first gave, because it seemed somewhat simpler, is inadmissible, because it does not reproduce Ampère's law with exactness; yet, by means of what seems to me to be a slight modification in my premise, I have easily obtained the exact expression of Ampère's law.

3. The Development of Weber's Law

Over the previous 10 years, Weber had been engaged in the experimental confirmation of Ampère's law. The measuring instrument he had developed, the *electrodynamometer,* consisted of a fixed and a rotatable helically wound electromagnet. (See accompanying article, p. 35.) The rotatable one, suspended by two wires whose torsion could be accurately measured, came to be known as the *bifilar coil.* A precisely measured current was passed through the two coils, and the angle of rotation observed by means of a precision system developed by Gauss for his magnetometer, consisting of a mirror and telescope. The effect of the Earth's magnetic force could be precisely determined, and thus eliminated, using the system already developed by Gauss. Hence the experimental

Courtesy of the Museum of Electricity at Poleymieux

André-Marie Ampère (1775-1836)

Lithograph by Siegfried Bendixen, courtesy of Historical Collection of the Göttingen University I. Physical Institute

Carl Friedrich Gauss (1777-1855)

E. Scott Barr Collection, American Institute of Physics Emilio Segrè Visual Archives

Wilhelm Eduard Weber (1804-1891)

data could be reduced to yield the exact rotational moment exerted between the two Ampère solenoids.

Ampère had already shown in his famous treatise (Ampère 1826), how to calculate the rotational moment exerted by a single circular current loop on a current element in any position in space. The force was dependent on the current strength, the distance of separation, and the area enclosed by the loop, all values which were determined in the Weber apparatus. By treating the helically wound coils as a compound of such current loops and integrating their effect, Weber was able to calculate with precision the angular rotation that should be imparted to the bifilar coil. His measurements, achieved under a variety of experimental conditions, conformed to the calculated values within one-third of a scale unit, or less than 6 seconds of arc.

Despite this complete agreement between theory and measurement, which Weber had already determined before 1845, there had remained the possibility that the Ampère law was not correct in all its specificity, and that a simpler generalization, discarding the longitudinal force, might suffice. After receipt of Gauss's 19 March letter, with full confidence in the master's judgment, Weber forged ahead into new territory.

The task he set himself was to find a generalization of Ampère's law that would encompass the phenomena of voltaic induction, discovered by the American, Joseph Henry, five years after Ampère had completed his work in electrodynamics. This included the following effects:

- the appearance of an electrical current in a closed circuit when there is relative motion between it and a current-carrying wire in its vicinity.
- the appearance of an electrical current in a closed circuit when there is a change in the intensity of current in a neighboring conductor.

Ampère's electrodynamic law applied only to moving currents in fixed conductors. Beside it, stood the separate law of electrostatic force. The existence of the phenomenon of induction suggested to Weber that a true, fundamental law of electricity would have to subsume the electrostatic and electrodynamic laws under a new, more general form. A conception developed by his colleague, Gustav Fechner, proved to be of crucial value.

Fechner had extended the Ampère conception of the current element by considering the flow of electricity as consisting of oppositely charged electrical particles moving through the conductor with equal velocity in opposite directions. (Today, we assume that the positive electrical particle is virtually stationary and that the negative particle moves, a modification first suggested by Wilhelm Weber.) In any small segment of the wire, a positive and a negative particle would be found speeding past one another. Thus, the interaction between two current elements involved four interactions among electrical particles. If the current elements are labeled e and e', there are the following four relationships:

(1) between $+e$ and $+e'$
(2) between $+e$ and $-e'$
(3) between $-e$ and $-e'$
(4) between $-e$ and $+e'$.

Since the particles, in these cases, are confined to their conductors, the forces between them are assumed to be transferred to the motion of the conducting wires themselves.

Weber now considers the situation where one current element follows the other along the same line, that is the situation described by Ampère's *longitudinal force* (Figure 6). If the electrostatic law alone applied, the two attractions of opposite particles (2 and 4) would exactly equal the two repulsions of like particles (1 and 3). But by the crucial *hypothesis* derived from Ampère's experiments, we know there will be an attraction or repulsion between the current elements, depending on the direction of current flow.

The question is, how must the electrostatic law be modified

in order to yield the longitudinal force as a result? Notice in Figure 6, Case 1, that the particles in relative motion are those of opposite charge (the like particles flow in the same direction and thus have no relative velocity). Now see, in Case 2, that it is the like particles that are in relative motion. In Case 1, the resultant force is repulsion; in Case 2, it is attraction. From this, Weber adduces the theorem *that the electrostatic force must be reduced when the electrical particles are in relative motion,* that is when they have a relative velocity.

The electrostatic law is a simple inverse square law. If e and e' are the charge of two stationary particles, and r their distance, the force between them is simply ee'/r^2. The *relative velocity* of two particles can be designated as dr/dt. Since the theorem of Weber applies both where the particles are approaching or receding from one another—that is, where the sign (direction) of the relative velocity is either positive or negative, Weber will use the *square,* dr^2/dt^2. He thus expresses his theorem for the force between two electrical particles in longitudinal motion:

$$\frac{ee'}{r^2}\left(1 - a^2\frac{dr^2}{dt^2}\right),$$

where a is a constant whose value must be determined.

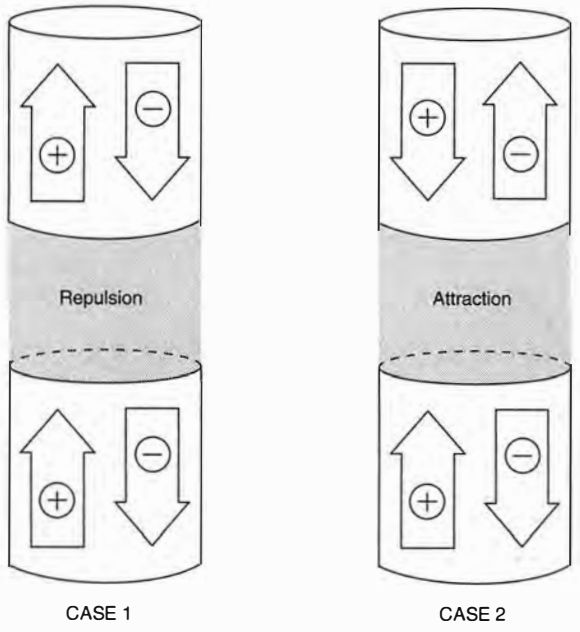


Figure 6
WEBER'S DEVELOPMENT OF AMPERE'S LAW: LONGITUDINAL ELEMENTS

To broaden Ampère's approach to include the new phenomena of induction, Weber used the hypothesis of Gustav Fechner that a current consists of the opposite flow of positive and negative electrical particles. In this view, a single current element contains a positive and a negative particle in opposite motion, depicted here by the contents of a single cylindrical section of the wire. The schematic, for each case, depicts two of these current elements, one following the other, in a straight line along the wire. In Case 1, where the current elements (positive and negative particles for Weber) are moving in the same direction, Ampère's theory deduced repulsion. For Case 2, where the positive particles and the negative particles have opposite motion, Ampère deduced attraction. From these experimental deductions of Ampère, Weber determined the velocity dependency of the law of force between electrical particles.

The Parallel Case

The same considerations must now be applied to the case of two parallel current elements which form a right angle with the line connecting their midpoints (Figure 7). In this case, the result (attraction or repulsion depending on whether the currents flow in the same or different directions), was known to Ampère through his earliest experiments. Their interaction will now be analyzed, as in the previous case, according to Fechner's hypothesis.

The first thing we notice is that at the very instant when the current elements are directly opposite each other, the *relative*

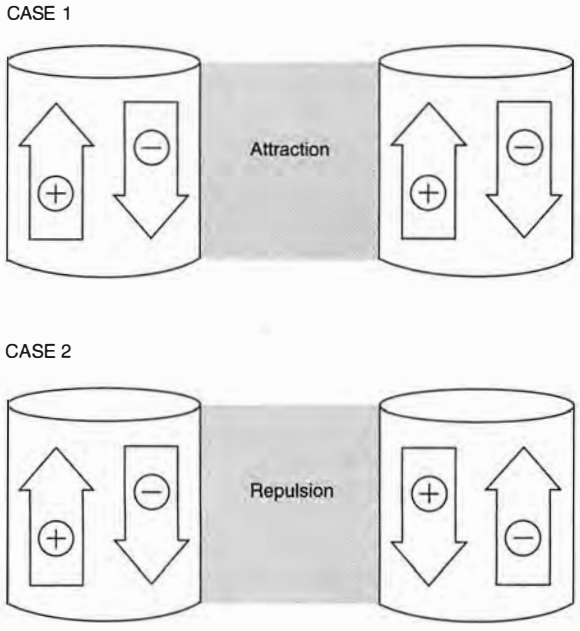


Figure 7
WEBER'S DEVELOPMENT OF AMPERE'S LAW: PARALLEL ELEMENTS

When the current elements are parallel, Ampère's theory describes attraction in Case 1, where both elements move in the same direction, and repulsion in Case 2, where the two elements move in opposite directions. Weber noted that like *electrical particles move in the same direction in Case 1, and in opposite directions in Case 2. In the longitudinal case, the same relative motions of the particles produced opposite results. Weber saw that in the parallel case, the relative velocity of the particles was zero, but that they had a relative acceleration. Thus came the acceleration term in his fundamental law of electricity.*

velocity of all the electrical particles is zero, and thus the law just deduced can have no bearing in explaining the resultant force. That is, two particles approaching each other, are said to have a negative relative velocity; as their paths cross, their relative velocity is zero; as they now recede from each other, their relative velocity becomes positive. At the point of crossing, the relative velocity is changing from negative to positive. A change in relative velocity is known as *relative acceleration.* Thus at the instant under consideration, when the current elements are directly opposite each other, they have a *relative acceleration,* but no *relative velocity.*

Now, in Case 1 of Figure 7, where the net effect according to Ampère's experiments is attraction, we observe that it is the *unlike* particles that are in relative motion between the two current elements. In Case 2, where the force between current elements is repulsive, we observe that it is the *like* particles which are in relative motion. Thus the situation is the opposite of that noted for longitudinal current elements, and, rather than diminishing, the electrostatic force must be increased by the presence of a relative acceleration between particles. Thus must Weber add a term to the expression derived just above, which yields:

$$\frac{ee'}{r^2}\left(1 - a^2\frac{dr^2}{dt^2} + b\frac{d^2r}{dt^2}\right), \qquad \textbf{Eq. 2}$$

where b is also a constant to be determined.

Now a more detailed consideration arises; namely, unlike the previous case, the particles in parallel current elements do not move along the same straight line. When the function of their distance of separation is determined (Weber 1846, §19), the result is that

$$\frac{d^2r}{dt^2} = \frac{1}{r}\frac{dr^2}{dt^2}.$$

Hence, Equation 2 becomes:

$$\frac{ee'}{r^2}\left(1 - a^2\frac{dr^2}{dt^2} + \frac{b}{r}\frac{dr^2}{dt^2}\right). \qquad \textbf{Eq. 2(a)}$$

To find the relationship between the coefficients a and b, Weber returns once more to Ampère's work, and specifically to the point referenced in Gauss's 19 March letter. The ratio of the coefficients in Equation 2(a) is nothing other than the ratio of the force between parallel current elements to the force between longitudinal elements; namely the same relationship which Ampère had determined to have the absolute value ½. Weber consequently sets:

$$a^2 = \frac{1}{2}\frac{b}{r}, \text{ or } b = 2a^2r,$$

from which the general expression for the force between two electrical particles becomes:

$$\frac{ee'}{r^2}\left(1 - a^2\frac{dr^2}{dt^2} + 2a^2 \cdot r\frac{d^2r}{dt^2}\right). \qquad \textbf{Eq. 3}$$

By consideration of the four interrelationships existing among the particles of each pair of current elements, Weber divides the constant a by 4, producing the finished 1846 form of his expression for the force between two electrical particles in motion:

$$\frac{ee'}{r^2}\left(1 - \frac{a^2}{16}\frac{dr^2}{dt^2} + \frac{a^2}{8}r\frac{d^2r}{dt^2}\right). \qquad \textbf{Eq. 4}$$

This is Weber's fundamental law of electrical action as presented in his famous 1846 memoir, in which he also shows its application to the phenomenon of induction and its complete compatibility with Ampère's law. Most of the features of atomic physics that Weber was later to discover are already implicit in the formulation stated in Equation 4.

4. The Final Steps

In 1855, Weber and Rudolf Kohlrausch carried out experiments which determined with fine precision the value of the constant so far designated as a. They found that $4/a = 4.395 \times 10^{11}$ mm/sec, and this value, thenceforth designated c, came to be known as the *Weber constant.*[2] Weber understood the constant c as "that relative velocity which electrical masses e and e' have and must retain, if they are not to act on each other at all" (Weber and Kohlrausch 1856, p. 20). His fundamental law was from now on to be written:

$$\frac{ee'}{r^2}\left(1 - \frac{1}{c^2}\frac{dr^2}{dt^2} + \frac{2r}{c^2}\frac{ddr}{dt^2}\right). \qquad \textbf{Eq. 5}$$

In a comment appended to the précis of the experiment, published jointly with Kohlrausch in 1856, Weber hints at the direction his thought was to take in coming years. Weber pointed out that the extremely small value of the coefficient $1/c^2$

> makes it possible to grasp, why the electrodynamic effect of electrical masses . . . compared with the electrostatic . . . always seems infinitesimally small, so that in general the former only remains significant, when as in galvanic currents, the electrostatic forces completely cancel each other in virtue of the neutralization of the positive and negative electricity [Weber and Kohlrausch 1856, p. 21].

It shall shortly become clear that Weber was already groping for a means to penetrate to the level of the forces among these tiny particles of electrical charge, those which we now call *atomic.* His comment reveals that he could not see an experimental path to that goal. The power of his subsequent work resides largely in his determined working through of the theoretical implications of his earlier work.

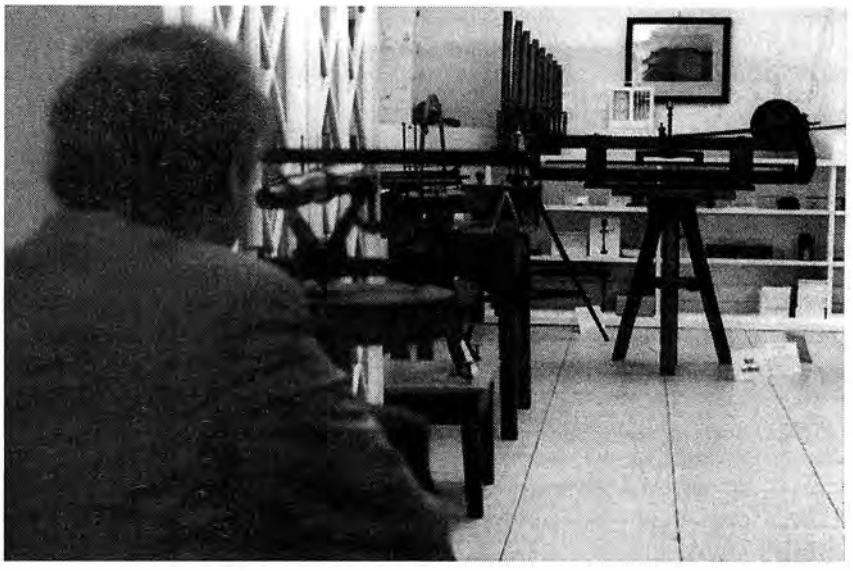
Catalytic Forces and a Fundamental Length

We jump now to 1870, when Weber is under a sustained attack by Helmholtz and Clausius in Germany and Thomson, Tait, and Maxwell in Britain. They are claiming that Weber's law must violate the principle of conservation of energy. Helmholtz has constructed a specific case where, he claims, Weber's law will produce an infinite *vis viva.*

In a treatise which appeared in January 1871, his sixth memoir under the series titled "Electrodynamic Determinations of

Measure" (Weber 1871), Weber not only offers a devastating reply to the criticisms, but also discovers, purely through a theoretical analysis of his fundamental electrical law, basic principles of atomic physics, which were not empirically determined until decades later. In the opening pages of the memoir is found perhaps the most astounding of these discoveries, Weber's determination of a minimal distance below which the Coulomb force, the repulsion of like particles, must reverse and become attractive.

First Weber notes that the positive and negative electrical particles, expressed as e and e', are not masses in the mechanical sense. Lacking our current use of the term, *charge,* they had been called at the time *electrical masses.* Weber draws the distinction, between charge and mechanical mass, expressing the former by e, and the latter by ϵ (epsilon). He then recognizes that while the amount of charge on positive and negative electrical particles is equal, though opposite, their masses need not be equal. He thus arrives for the first time, on page 3 of the *Sixth Memoir,* at the modern concepts of charge-to-mass ratio and proton-electron mass ratio.



Chris Lewis

Jonathan Tennenbaum observing the ultra-sensitive receiving apparatus of the Gauss-Weber telegraph, set up here to detect very weak magnetic forces. The telegraph, the world's first, was constructed in 1833, and ran from the Göttingen Observatory to the Physics Building.

Weber next examines an underlying assumption in his fundamental law of electrical action. Namely, that the expression for the force, which the particles, e and e', mutually exert upon each other, is dependent on a magnitude, that is, their relative acceleration, "which contains as a factor the very force that is to be determined." He makes this clear by the consideration that the relative acceleration must consist of two parts—one due to the mutual action of the two particles, and a second part due to other causes. The second part would include whatever velocity the particles may have in directions other than the line r connecting them, and whatever is due to the action on them by other bodies. He had already considered this aspect of the matter in the 1846 memoir (p. 212 ff.), where he employs the term *catalytic forces* to describe them, after the expression introduced by the chemist Berzelius. In that location, by considering separately the mathematical term for the force of acceleration which each one of the particles exerts on the other one, he was able to derive an expression for his fundamental law which is independent of the acceleration term caused by their mutual action, but which still must contain a term, f, which denotes the acceleration due to other causes. The expression thus derived is

$$\frac{ee'}{rr - \frac{2r}{cc}(e + e')}\left(1 - \frac{1}{cc}\frac{dr^2}{dt^2} + \frac{2rf}{cc}\right). \quad \textbf{Eq. 6(a)}$$

But when the distinction is made between the charge (e,e') and the mass (ϵ, ϵ') of the electrical particles, Weber shows in the *Sixth Memoir* (Weber 1871, pp. 2-6) that the expression then becomes:

$$\frac{ee'}{rr - \frac{2r}{cc}\frac{\epsilon + \epsilon'}{\epsilon\epsilon'}ee'}\left(1 - \frac{1}{cc}\frac{dr^2}{dt^2} + \frac{2rf}{cc}\right). \quad \textbf{Eq. 6(b)}$$

"From this it results," Weber remarks, "that the law of electrical force is by no means so simple as we expect a fundamental law to be; on the contrary, it appears in two respects to be particularly complex." The first complexity is the *catalytic forces* just referenced. The second is the appearance of a unique length, associated with reversal of the Coulomb force. As Weber describes that latter aspect of the discovery:

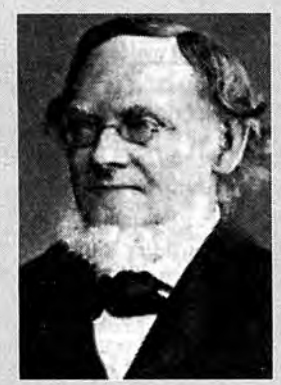
> In the second place, another noteworthy result follows from this expression for the force—namely, that when the particles e and e' are of the same kind, *they do not by any means always repel each other;* thus when $dr^2/dt^2 < cc + 2rf$, they repel only so long as
>
> $$r > \frac{2}{cc}\frac{\epsilon + \epsilon'}{\epsilon\epsilon'}ee',$$
>
> and, on the contrary, they attract when
>
> $$r < \frac{2}{cc}\frac{\epsilon + \epsilon'}{\epsilon\epsilon'}ee'.$$

This remarkable result is no more than a necessary, mathematical consequence of the expression for Weber's fundamental law just given above. It is easily seen that when e and e' represent two similar particles, the expression gives $4e^2/\epsilon c^2$. Recalling that the Weber constant is $\sqrt{2}\times$ the velocity of light, we have then in modern terms, where c expresses the velocity of light, and m_e the mass of the electron, the familiar expression

Critics of Ampère and Weber

Ampère's revolutionary hypothesis that magnetism arises from electrical orbits surrounding the particles of matter became the basis for the development of early atomic science by Gauss, Weber, and others. But many could not understand his hypothesis, nor deal with the fact that its mathematical development implied an overthrow of Newtonian mechanics.

Among the leading critics of Ampère and Weber's work were Hermann Grassmann, James C. Maxwell, and the English engineer Oliver Heaviside. Grassmann attacked the Ampère hypothesis as "improbable," but without giving a reason. Maxwell took the middle ground of allowing Ampère's hypothesis, but rejecting Weber's development of it. Heaviside's position is notable as an expression of the sort of gross empiricism so frequently encountered in science today. His suggestion, that Ampère's contribution be changed to what it was not, has been adopted by most modern textbooks.



Hermann Grassmann (1809-1877)

When I submitted the explanation offered by Ampère for the interaction of two infinitely small current-sections on one another to a more exacting analysis, this explanation seemed to me a highly improbable one. . . .

—Hermann Grassmann, *A New Theory of Electrodynamics,* 1845

There are also objections to making any ultimate forces in nature depend on the velocity of the bodies between which they act. If the forces in nature are to be reduced to forces acting between particles, the principle of the Conservation of Force requires that these forces should be in the line joining the particles and functions of the distance only.

—James Clerk Maxwell, *On Faraday's Lines of Force,* 1854

Millikan and Gale, A First Course in Physics (Boston: Ginn & Co. 1915)

James Clerk Maxwell (1831-1879)

It has been stated, on no less authority than that of the great Maxwell, that Ampère's law of force between a pair of current elements is the cardinal formula of electrodynamics. If so, should we not be always using it? Do we ever use it? *Did Maxwell in his* Treatise? *Surely there is some mistake. I do not in the least mean to rob Ampère of the credit of being the father of electrodynamics: I would only transfer the name of cardinal formula to another due to him, expressing the mechanical force on an element of a conductor supporting current in any magnetic field—the vector product of current and induction. There is something real about it; it is not like his force between a pair of unclosed elements; it is fundamental; and, as everybody knows, it is in continual use, either actually or virtually (through electromotive force), both by theorists and practicians.*

—Oliver Heaviside, in *The Electrician,* 1888

IEE Archives

Oliver Heaviside (1850-1925)

$$\frac{2e^2}{m_e c^2},$$

That is the distance below which two electrons may not approach, which, when divided by two, gives the classical electron radius of 2.8×10^{-13} cm. When the mass of the proton is inserted into the Weber expression, the value 3.06×10^{-16} cm results—perhaps some sort of lower bounding value for the strong force, in any case, a most interesting approximation for the year 1870!

Weber's 1871 paper progresses in richness. The laws of motion of an electron orbiting around a central nucleus are deduced, and the determination that two like particles cannot have such orbital motion, but that an oscillation along the same line (as if attached by a rubber band) is possible. (From this latter, Weber attempts to find the basis for the production of oscillations of the frequency of light.) Finally, Helmholtz's silly charge that the electrical particles will attain an *infinite energy* under Weber's formulation, is answered with the observation that Helmholtz assumes the possibility of the particles also attaining *infinite relative velocities.* Rather it is the case, Weber points out, that his constant, *c,* must represent a *limiting velocity* for the electrical particles.

These are some of the remarkable results produced by that singular intervention of Gauss in his letter of 19 March 1845. His recognition of the *real existence* of a mere *idea,* which had appeared in the mind of Ampère by no later than 1823, led to the discovery of some of the most crucial among the concepts of our modern physics. Thus did a scientific *idea,* a

colorless, odorless, and tasteless substance, change the course of history.

Yet, none of these remarkable accomplishments of the line of work from Ampère to Gauss to Weber, which we have just reviewed, is recognized in the standard histories, or textbooks today. Only when one delves into the remote corners of specialist sources can scant mention of these facts be found—always presented as isolated events, never with coherence. How can it be that the names of Ampère, Gauss, and Weber are never mentioned when the physics of the atom is taught? If the name of Ampère arises, it is in connection only with electricity and magnetism. The actual law of electrical force he discovered is almost impossible to find in any modern textbook; under Ampère's name appears something quite different. The name of Weber is rarely heard.

Today, students of physics and electrical engineering are taught that all of the laws of electrodynamics have been included under the ingenious formulations arrived at by James Clerk Maxwell and codified in his 1873 *Treatise on Electricity and Magnetism*. One need not study Ampère and Weber, they are told, because Maxwell already did that. He also did us the service of cleaning up any "errors" that might have been found there. And a very thorough job it was.[3]

But where, pray tell, did the method of discovery go? Or is that no longer of interest to students today? Is it that we know so much today, that it would only be confusing to teach how we know it? (Some might even be so foolish as to argue thusly.) Yet not just the method is missing. So too are its results. Where did the classical electron radius, the nuclear strong force, the limiting value of the velocity of light come from? Not from Ampère, Gauss, and Weber, according to today's textbooks and authorities. Did we in any way exaggerate when we used the term *a consumer fraud* to describe the university science education which commits such glaring omissions? Has a fraud been committed, a cover-up? Was it accidental or witting? We hope we have given the reader sufficient leads that he may investigate and decide for himself.

Laurence Hecht is an associate editor of 21st Century. *A co-thinker of Lyndon H. LaRouche, he is currently a political prisoner in the state of Virginia.*

Notes

1. The mathematical development of Ampère's hypothesis, of a force acting along the straight line conecting two elements, and certain uncritical references to Newton found in the opening pages of his 1826 Memoir, have emboldened some interpreters, Maxwell included, to falsely presume Ampère to be a Newtonian. They completely miss the point. Ampère's 1826 Memoir is rather a sort of Gödel's proof for experimental physics: working within the framework of Newtonian assumptions to demonstrate the absurdity of sticking to the Newtonian assumptions of point mass and a simply continuous, linear-extended space-time. Without referencing it explicitly, Ampère is raising precisely the same points of criticism of Newtonian assumptions addressed a century earlier by Gottfried W. Leibniz in his famous correspondence with Newton's proxy Samuel Clarke, and in his *Monadology*. Immediately following the completion of his 1826 Memoir on electrodynamics, Ampère turned his attention to these deeper implied issues of his experimental work, becoming a champion of Leibniz's method in science from that time until his death in 1836.

   The continuing hegemony within mathematical physics, even to the present moment, of Leonhard Euler's fraud respecting Leibniz's work, is the root of the failure of Maxwell and all subsequent specialists to recognize this essential aspect of Ampère's contribution. Where science must answer such questions by experimental measurement, Euler claims to refute Leibniz's insistence on the existence of atomic structure within the "hard, massy particles" of Newton's cosmology, by resorting in his *Letters to a German Princess*, to a blackboard trick. To defend the existence of a mere mathematical construct, his ever-present infinite series, Euler claims to prove the *physical existence* of a simply continuous space-time by successively subdividing a straight line into as many parts as the mind can imagine ("as near as you please" in Augustin Cauchy's more refined version of the ruse). Thus is reality stood on its head by a mathematician's trick, passed on from generation to credulous generation of university science undergraduates.

   See also, Lyndon H. LaRouche, Jr, "Riemann Refutes Euler," *21st Century Science & Technology*, (Winter 1995-1996) pp. 36-47.

2. The experiment actually determined the ratio of the mechanical measure of current intensity to the three other existing measures, that is, the electromagnetic, the electrodynamic, and the electrolytic. The value given above, the *Weber constant*, is the ratio of the mechanical to the electrodynamic measure. Weber first showed in 1846 that the ratio of the electrodynamic to the electromagnetic unit is as $\sqrt{2}$:1. Therefore, the experimentally derived ratio of the mechanical measure of current intensity to the electromagnetic measure was 3.1074×10^{11} mm/sec. Bernhard Riemann, who observed the Weber-Kohlrausch experiment, was the first to note that the value corresponded closely to Fizeau's experimental determination of the velocity of light. His theory of *retarded potential* proceeded from there. Here Riemann attempted the unsolved task of which Gauss had commented in the 19 March 1845 letter:

   > Without a doubt, I would have made my investigations public long ago, had it not been the case that at the point where I broke off, what I considered to be the actual keystone was lacking . . . namely, the *derivation* of the additional forces (which enter into the reciprocal action of electrical particles at rest, if they are in relative motion) from the action which is *not instantaneous*, but on the contrary (in a way comparable to light) propagates itself in time.

3. Maxwell was a capable mathematical analyst and possessed a creative gift for physical-geometrical insight. His utter ignorance of matters of method, which took the form of a slavish adherence to the method of empiricism, prevented his ever understanding the deeper issues posed by Gauss above (note 2). Maxwell stubbornly remarks on Gauss's challenge:

   > Now we are unable to conceive of a propagation in time, except either as the flight of a material substance through space, or as the propagation of a condition of motion or stress in a medium already existing in space [*Treatise*, p. 492].

   Maxwell's dismissal of what he did not understand, increasingly took on the character of ignorant prejudice. There was nothing original in his idea of an ether as the transmitting medium of electromagnetic action. Had Gauss seen a clear solution through such a mode of representation, he would have developed it. There was none, as the glaring failure of Maxwell's theory to even account for the existence of the electron ought to indicate.

References

André-Marie Ampère, 1826. "Memoire sur la théorie mathématique des phénomenes électrodynamiques uniquement déduite de l'expérience," in A.M. Ampère, *Electrodynamiques, uniquement déduite de l'expérience* (Paris: A. Hermann, 1883). A partial English translation appears in R.A.R. Tricker, *Early Electrodynamics: The First Law of Circulation* (New York: Pergamon, 1965) pp. 155-200.

James Clerk Maxwell, 1873. *A Treatise on Electricity and Magnetism*, Vols. 1 and 2 (New York: Dover, 1954) Unabridged Third Edition. Wilhelm Eduard Weber, 1846. "Elektrodynamische Maasbestimmungen über ein allgemeines Grundgesetz der elektrischen Wirkung," in *Wilhelm Webers Werke* (Berlin: Julius Springer, 1893) Vol. 3, pp. 25-214. Unpublished English translation by Susan P. Johnson.

Wilhelm Eduard Weber and R. Kohlrausch, 1856. "Über die Elektricitätsmenge, welche bei galvanischen Strömen durch den Querschnitt der Kette fliesst," *Annalen der Physik und Chemie, herausgegeben von J.C. Poggendorff*, Vol. 99, pp. 10-25. Unpublished English translation by Susan P. Johnson.

Wilhelm Eduard Weber, 1871. "Elektrodynamische Maasbestimmungen, insbesondere über das Princip der Erhaltung der Energie," *Abhandlungen der mathem.-phys. Classe der Koenigl. S´achsischen Gesellschaft der Wissenschaften*, Vol. X (Jan.). English translation in *Philosophical Magazine*, 4th Series. Vol. 43, No. 283, January 1872, pp. 1-20, 119-49 ("Electrodynamic Measurements—Sixth Memoir, relating specifically to the Principle of the Conservation of Energy").

Experimental Apparatus and Instrumentation

1. The Gauss Magnetometer

Carl Friedrich Gauss's 1832 determination of the absolute intensity of the Earth's magnetic force was the crucial prerequisite for Weber's electrodynamic studies. Prior to Gauss's work, measurements of the intensity of the Earth's magnetic force were carried out by observing the oscillations of compass needles at varying points on the Earth's surface. Based on the theory of the pendulum, the intensity was assumed to be equal to the square of the number of oscillations.

Observations of both the horizontal and vertical (inclination and dip) intensity had been carried out sporadically over the previous century and brought to a high state of refinement by the travels of Alexander von Humboldt. But all of these observations contained an inherent weakness: that the magnetic strength of the needles used had to be considered equal and unchanging. A more exact determination of the magnetic intensity at differing points on the Earth's surface had long been desired for a better understanding of geomagnetism, which would be useful in navigation, surveying, and the Earth sciences. It was soon to play a crucial role as well in the theoretical pursuit of electrodynamics and atomic theory.

The problem in all the observations carried out prior to Gauss's work, was that the strength, or *magnetic moment, M,* of the oscillating needle could not be separated from the strength of the Earth's magnetism, *T*. The number of oscillations observed is proportional to the product of the two, *MT*. Thus, it is impossible to tell whether variations measured at different points on the Earth's surface, or at different times in the same location, represent changes in the intensity of the Earth's magnetism, or are a result of a natural weakening of the needle's magnetism.

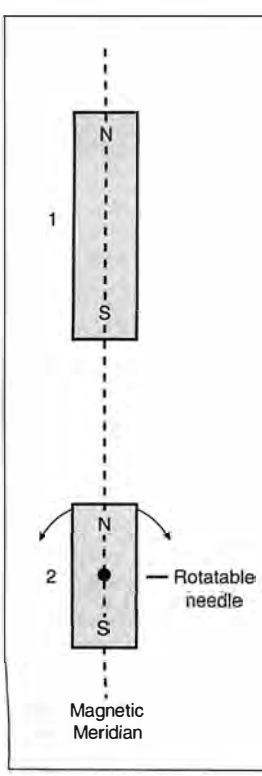


Figure 1.1
POISSON'S METHOD

The oscillations of the needle marked 2 *will be accelerated by the presence of the fixed, first needle in this configuration, where the opposite poles are turned toward each other. A comparison of the number of oscillations in this configuration, to the number of oscillations when the first needle is removed, gives the ratio* (M/T) of the magnetic strength of the first needle to the Earth's magnetic strength.

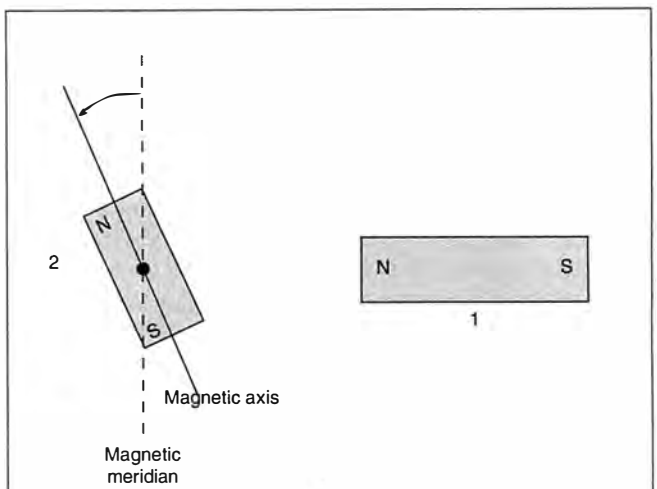


Figure 1.2
GAUSS'S METHOD

Observations carried out by Poisson's method either totally miscarried, or produced very approximate results. In this configuration, conceived by Gauss, needle 1 tends to produce an angular deflection in the second, oscillating needle, while the Earth's magnetism attempts to return the second needle into a line with the magnetic meridian. The resulting angular deflection is proportional to the sought-for ratio M/T. An additional apparatus devised by Gauss, known as the Spiegel und Fernrohr (mirror and telescope), allowed for the precise determination of the angular deflection to a hitherto unknown degree of accuracy. (See Figure 1.3).

Before Gauss, Poisson in France had suggested a means of overcoming this obstacle, by making a second set of observations on the compass needle whose oscillations, under the influence of the Earth's magnetic force, had already been observed. Poisson proposed to fix this needle in line with the magnetic meridian (that is, pointing to magnetic north). A second, rotatable or oscillating needle was then to be placed in the same line (Figure 1.1).

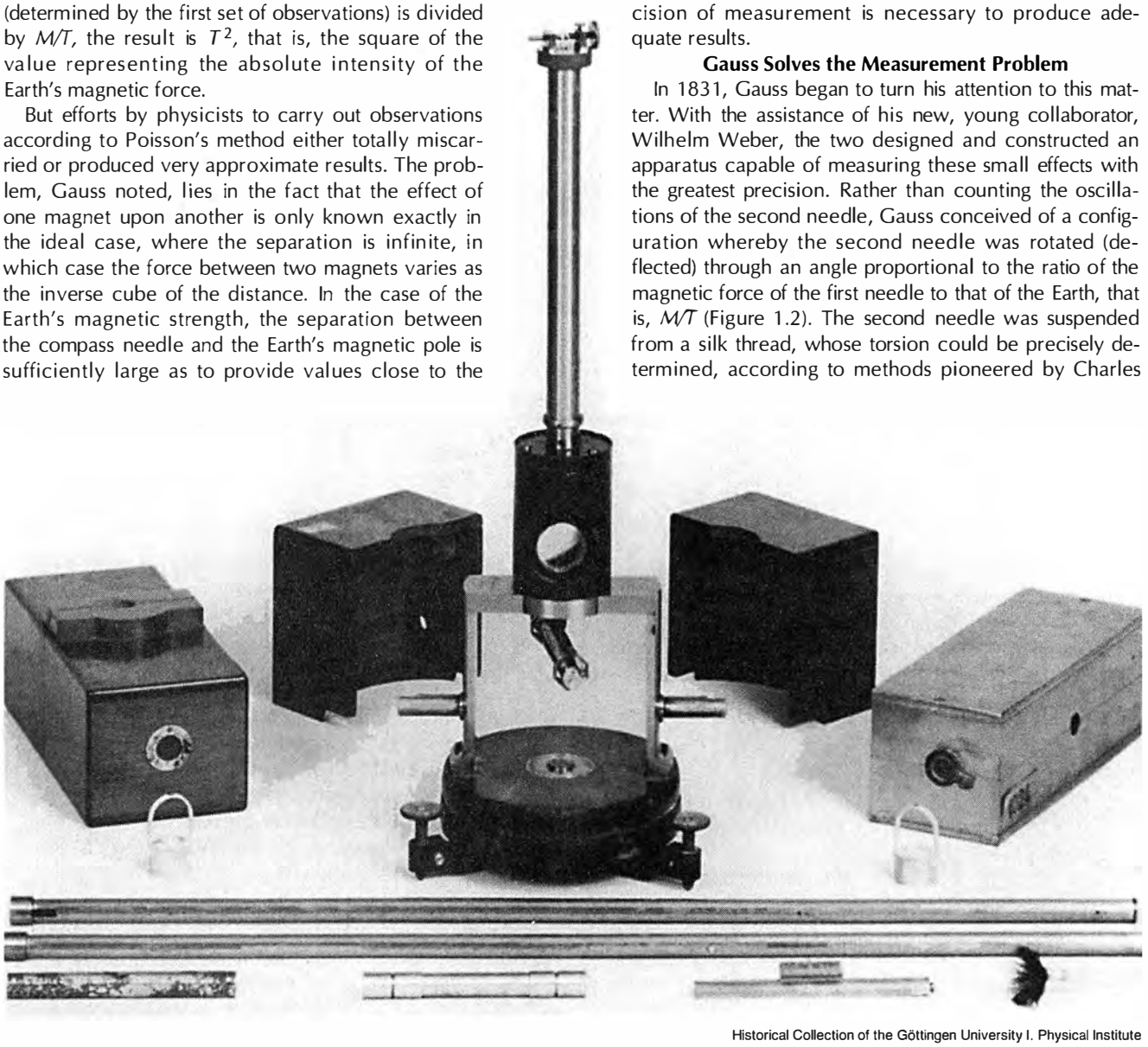
The oscillations of the second needle would be either retarded or accelerated by the presence of the first needle, according to whether like or unlike poles are turned toward

each other. By comparing the number of oscillations of the second needle when in the presence of the first one, to its oscillations when standing alone (that is, under the sole influence of the Earth's magnetic force), the ratio M/T, expressing the strength of the first needle to the magnetic strength of the Earth, could be determined. When the value of MT (determined by the first set of observations) is divided by M/T, the result is T^2, that is, the square of the value representing the absolute intensity of the Earth's magnetic force.

But efforts by physicists to carry out observations according to Poisson's method either totally miscarried or produced very approximate results. The problem, Gauss noted, lies in the fact that the effect of one magnet upon another is only known exactly in the ideal case, where the separation is infinite, in which case the force between two magnets varies as the inverse cube of the distance. In the case of the Earth's magnetic strength, the separation between the compass needle and the Earth's magnetic pole is sufficiently large as to provide values close to the ideal case. However, to carry out the second observation on two compass needles of finite separation—as suggested by Poisson—with any degree of accuracy, requires that the separation distance of the two needles be rather large in relation to the length of the second one. This means that the observable effect is very small, and therefore the greatest precision of measurement is necessary to produce adequate results.

Gauss Solves the Measurement Problem

In 1831, Gauss began to turn his attention to this matter. With the assistance of his new, young collaborator, Wilhelm Weber, the two designed and constructed an apparatus capable of measuring these small effects with the greatest precision. Rather than counting the oscillations of the second needle, Gauss conceived of a configuration whereby the second needle was rotated (deflected) through an angle proportional to the ratio of the magnetic force of the first needle to that of the Earth, that is, M/T (Figure 1.2). The second needle was suspended from a silk thread, whose torsion could be precisely determined, according to methods pioneered by Charles



Historical Collection of the Göttingen University I. Physical Institute

A transportable magnetometer built for Wilhelm Weber in 1839 by Meyerstein. The apparatus in the center is used to determine the absolute intensity of the Earth's magnetic force. In the first row, in foreground, are two bar magnets with cleaning brush and holder. Behind it are two brass bars which can be attached to the magnetometer housing at either of the two flanges seen protruding to the left and right. The bar magnet, which plays the role of needle 1 in the schematic of Figure 1.3, is slid along this non-magnetic brass support until the proper distance is achieved.

Suspended in the center of the magnetometer housing is a rotatable carrier holding the cylindrical magnetized needle, which plays the role of needle 2 in Figure 1.3. The rotatable carrier is suspended by two silk threads which run up the vertical column to the highest point of the apparatus (44 cm). Attached to the carrier is a plane mirror, which is observed through the porthole in the dark cylindrical casing above the rotatable magnet. A telescope and meter stick such as that pictured on page 23 would be aimed at the mirror.

The boxes, at far left and right, hold weights used to determine the gravitational moment of the magnet. In the background are a wooden housing to protect the apparatus from air currents and a copper one for damping the oscillations of the needle with electrical current.

Augustin Coulomb in France, several decades earlier. Then, through an ingenious apparatus conceived by Gauss, the angle of deflection could be measured with a degree of precision hitherto unknown.

Gauss's angle measurement apparatus, the *Spiegel und Fernrohr* (mirror and telescope), was integrated into many types of precision measuring instruments well into this century. Figure 1.3 schematically portrays one of the earliest versions of the apparatus. In later versions, the mirror was attached at the rotational axis of a carrier holding the second compass needle, or magnet (see photograph of 1839 device, page 36). Another important breakthrough, also incorporated into the pictured 1839 device, was the development of the *bifilar* (two-thread) suspension. By varying the distance of separation of the two parallel silk threads supporting the rotatable compass needle, their torsion could be adjusted with the greatest precision. Since the torsion provided a part of the restoring force, against which the angular rotation of the second needle by the first had to operate, its exact determination was essential for experimental accuracy.

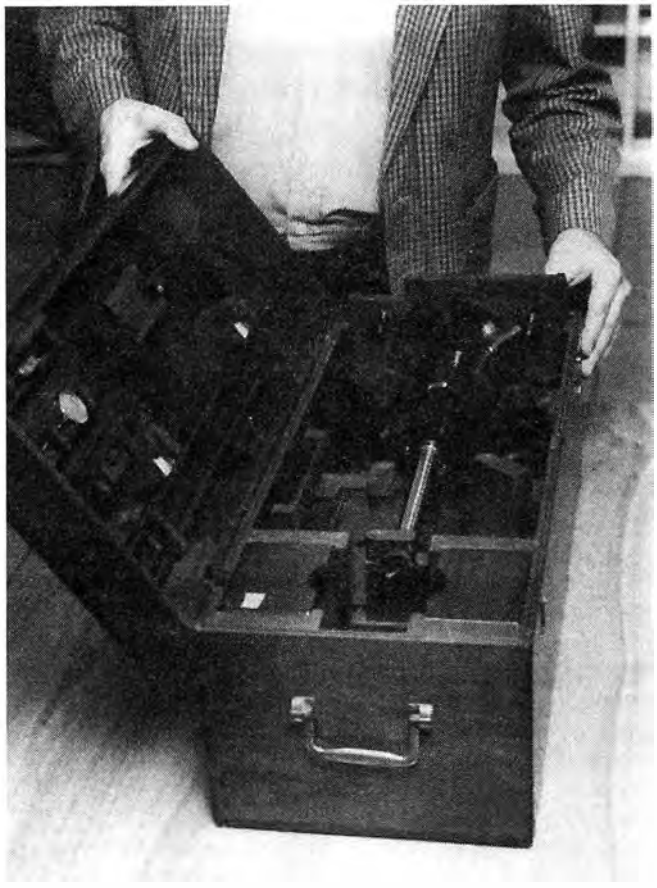
Gauss's 1831-1832 study of magnetism, reported in his paper "The Intensity of the Earth's Magnetic Force Reduced to Absolute Measure,"[1] became the model for all rigorous investigation thereafter. The study included the first introduction of the concept that the units of *mass, length,* and *time* could serve as the basis for all physical measurement.

Notes

1. "Intensitas vis magneticae terrestris ad mensuram absolutam revocata," read by Gauss at the Göttingen Gesellschaft der Wissenschaften on 15 December 1832, and printed in Volume 8 of the treatises of this society, pp. 3-44.

   German translation from the orginal Latin, by Dr. Kiel of Bonn, available as: *Die Intensität der Erdmagneti'schen Kraft auf absolutes Maass zurückgeführt* (Leipzig: Wilhelm Engelmann Verlag, 1894).

   English translation (unpublished) from the German, by Susan P. Johnson.



Chris Lewis

The boxed portable magnetometer, on display in the Historical Collection of the Göttingen University I. Physical Institute.

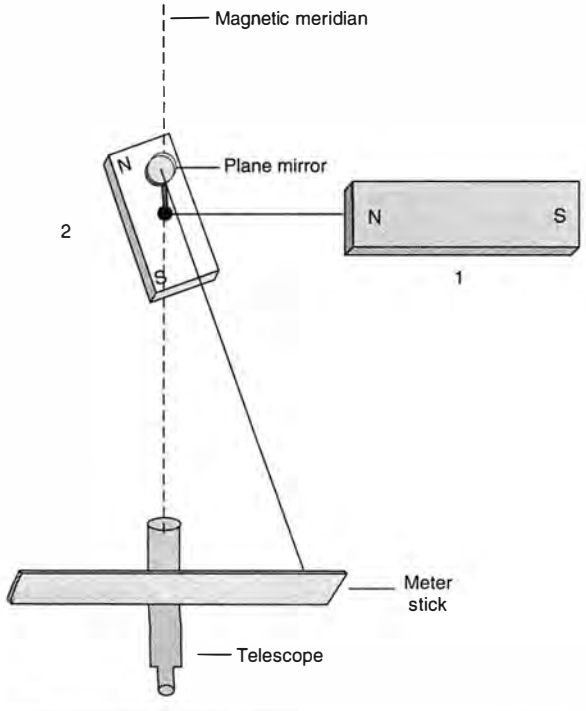


Figure 1.3
***SPIEGEL UND FERNROHR* APPARATUS**

The Spiegel und Fernrohr *(mirror and telescope) apparatus, devised by Gauss, permits the very precise determination of angular deflection. A plane mirror is attached to the axis of the rotatable compass needle (2). The face of the mirror is oriented perpendicular to the magnetic axis.*

A telescope is placed about 2 meters distant, its optical axis in a line with the magnetic meridian. A graduated meter stick is affixed to the telescope, perpendicular to its optical axis. In the rest position, when the axis of needle 2 is aligned with the magnetic meridian, the mirror reflects the mid- or zero-point of the meter stick into the barrel of the telescope, and to the viewer. When the presence of needle 1 causes an angular deflection of the second needle (pictured), the resulting rotation of the plane mirror causes it to reflect a more distant part of the meter stick into the telescope. In the 1841 apparatus used by Weber, each graduated marking on the meter stick represented about 18 seconds of arc, or 1/200 of a degree.

2. The Electrodynamometer and Weber's Proof of Ampère's Theory

Commenting in 1846, on the state of electrical science since the 1826 publication of Ampère's famous memoir on electrodynamics, Wilhelm Weber wrote:

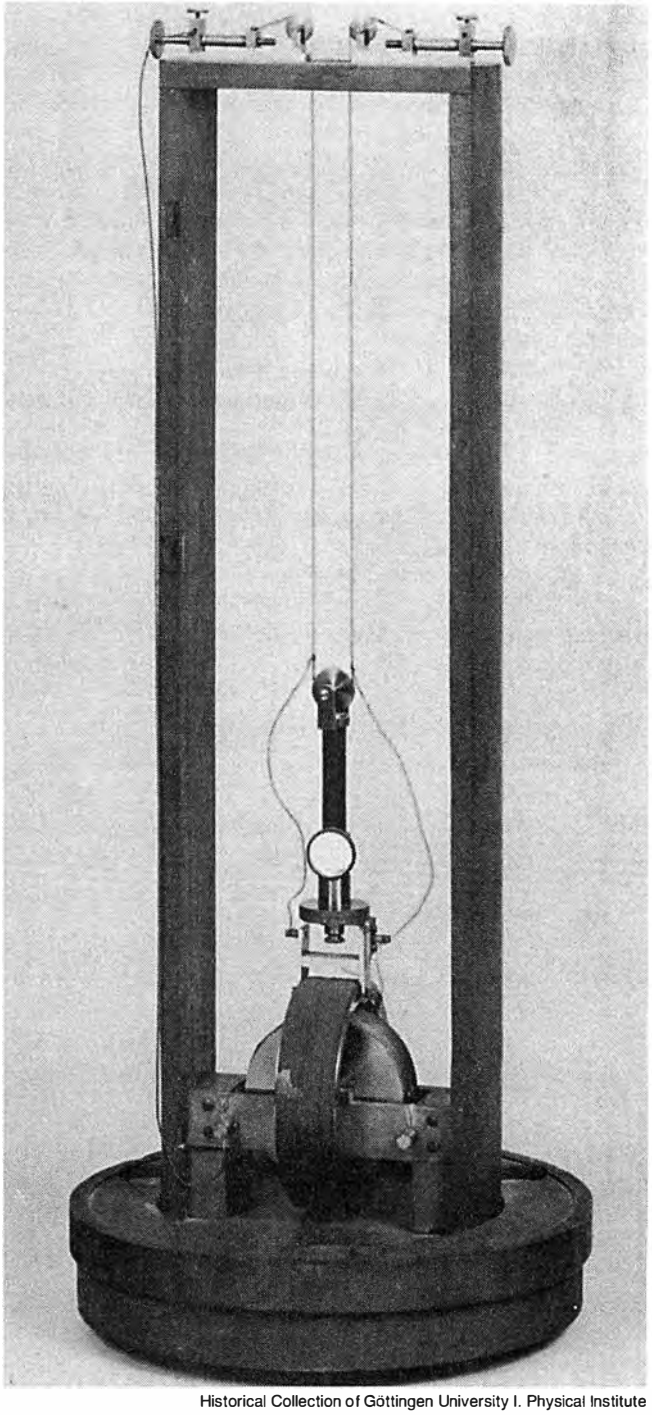
> Ampère did not continue these investigations, nor has anyone else published anything to date, from either the experimental or theoretical side, concerning further investigations. . . . This neglect of electrodynamics since Ampère is not to be considered a consequence of attributing less importance to the fundamental phenomenon discovered by Ampère . . . but rather it results from dread of the great difficulty of the experiments, which are very hard to carry out with present equipment. . . .[Weber 1846, Introduction]

The essential problem Weber saw with Ampère's apparatus was the possibility that the force of *friction* might be disguising subtle effects. In each of Ampère's equilibrium experiments, deductions are made from the lack of motion of a movable conductor, for example, the rectangular conductor CDGH in the second equilibrium experiment (Figure 4 in article text). If this lack of motion were the result, even in small part, of frictional resistance, then the entire set of deductions derived by Ampère would have to be re-evaluated.

To establish the validity of Ampère's theory with more exactness, it was necessary to devise an apparatus in which the electrodynamic forces were strengthened, such that friction would be only a negligible fraction of the force measured. This was the purpose of the instrument, known as the electrodynamometer, the first model of which Weber constructed in 1834.

The essential improvement over Ampère's various apparatuses was, that instead of single wires interacting with each other, a pair of multiply wound coils was used. This had the advantage that each successive winding would multiply the effect of the electrodynamic force between the two coils. Thus, even the smallest currents flowing through the coils could produce measurable effects. But the use of coils, rather than single lengths of wires, would require a completely different experimental geometry. And, rather than attempting experiments whose purpose was to produce zero motion, Weber intended to precisely measure the rotational force exerted by one coil on another. Then, by geometric analysis, he would reduce these results to the effect of a single circular loop on another, and, through further analysis, relate the strength of this effect to that predicted by Ampère's law.

The principal elements of Weber's apparatus were two cylindrical coils of wire, called solenoids by Ampère. One cylinder was suspended horizontally such that it could rotate around a vertical axis. The other was placed horizontally in a fixed position, usually either perpendicular (Figure 2.1) or longitudinal to the first coil. We know from Ampère's earliest experiments, that when current passes through a solenoid, it takes on the properties of a bar magnet, one end of the cylinder acting as north pole, and the other as south. Thus, as can be seen from Figure 2.1, the arrangement of the Weber electrodynamometer



Historical Collection of Göttingen University I. Physical Institute

This is the electrodynamometer, constructed in 1841, which Weber used to experimentally verify Ampère's electrodynamic theory. The larger outer ring is the bifilar coil, *so called because it is suspended from above by two wires, which also carry current to it. The inner ring, an electrical* coil known as *the* multiplier, *is affixed to a wooden frame with tripod base. During the experiment, the multiplier and frame are placed in various positions on the laboratory table to determine its rotational effect on the bifilar coil. The angle of rotation is measured by observing the mirror (affixed to the suspension apparatus) through a telescope with meter stick attached.*

Chris Lewis

Professor G. Beuermann (r.) of Göttingen University demonstrates the sending apparatus of the 1833 electromagnetic telegraph of Gauss and Weber to Jonathan Tennenbaum. In the background is displayed part of the historical collection of Weber's apparatus.

is quite analogous to that of the Gauss magnetometer.

Weber borrowed the use of the bifilar (two-thread) suspension from this earlier instrument, but instead of silk threads, he used the conducting wires themselves to suspend the coil. Thus, a hollow wooden cylinder wound with insulated copper wire, which came to be known as the *bifilar coil,* was suspended from above by its own two wire leads. The second cylindrical coil, known as the *multiplier,* was placed in the same horizontal plane, at right angles, or longitudinal to the first. A mirror was affixed to the bifilar coil, and its angle of rotation observed with a telescope and meter stick, just as in the magnetometer.

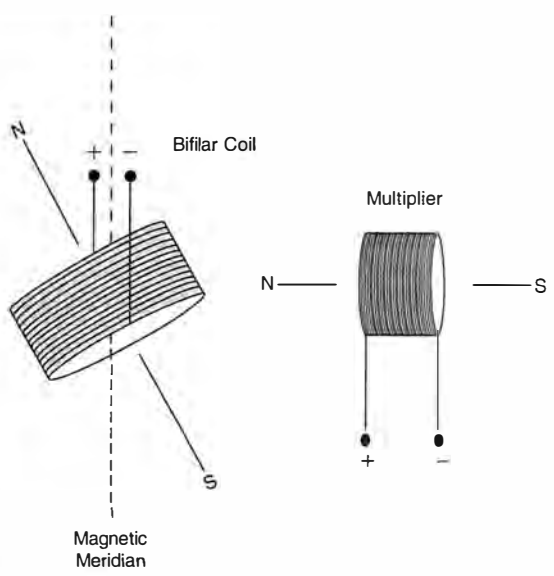


Figure 2.1
BASIC CONFIGURATION OF ELECTRODYNAMOMETER

In this topdown view of the Weber electrodynamometer, the rotatable bifilar coil is suspended by its two conducting wires. When current is passed through it, it will tend to behave just like a magnetic compass needle, aligning itself with the magnetic meridian. But the multiplier, placed at right angles to the bifilar coil, will also behave like a magnet when electrified, and will tend to rotate the bifilar coil out of the magnetic meridian, as depicted. If a plane mirror is attached to the bifilar coil and observed through a telescope and measuring stick apparatus, as in the Gauss magnetometer, the angle of rotation can be very precisely measured.

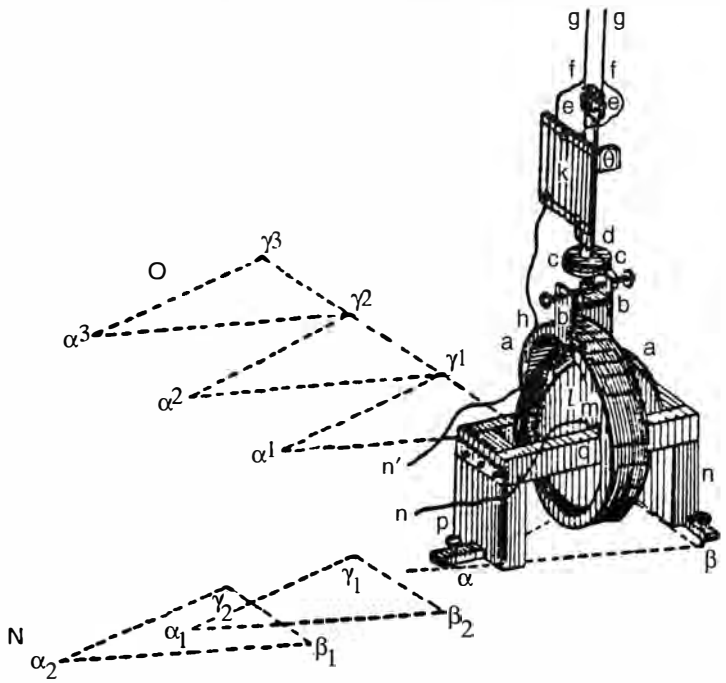


Figure 2.2
BIFILAR COIL AND MULTIPLIER

In this illustration from Weber's First Memoir, the multiplier coil is depicted in the unique position where it is inside *the bifilar coil. The bifilar coil is the outer ring, shown with the suspension apparatus leading up to the wire leads* gg. *A plane mirror,* k, *is attached to the suspension. The multiplier coil is affixed to the wooden base which is mounted on the three feet, α, β, and γ. The multiplier and base can be extracted from the position depicted and moved to any desired position. The dotted triangles indicate the premeasured positions on the laboratory table at which the multiplier will be placed during the experiment.*

After additional instrumentation was added to measure the precise current flow through each coil, observations were made with the multiplier positioned at varying, precisely measured distances to the east, west, north, and south of the bifilar coil (Figures 2.2, 2.3). A table of experimentally determined values was then arrived at, representing the torque, or rotational moment, exerted by the multiplier on the bifilar coil at the different distances. By knowing the number of turns in each coil, and by assuming from the symmetry of the windings, that the total effect could be considered as concentrated in the most central loop of each coil, Weber was then able to reduce these observed values to the mutual effect of a single pair of circular loops, acting at each measured position of the multiplier and bifilar coil.

In his mathematical theory of electrodynamics, Ampère had developed a formula that provided a theoretical determination of what the rotational moment of two such circular loops should be, dependent on their distance of separation, the area enclosed by each, their relative angles, and the strength of current flowing in them. Weber was now able to compare the predicted values, derived from Ampère's controversial theory of electrodynamics, to a set of experimentally determined values. The difference amounted to less than 1/3 of a scale unit (about 6 seconds of arc), of which Weber wrote in his First Memoir:

> This complete agreement between the values calculated according to Ampère's formula and the observed values (namely, the differences never exceed the possible amount contributed by unavoidable observational error) is, under such diverse conditions, a full proof of the truth of Ampère's law [Weber 1846, §8].

—Laurence Hecht

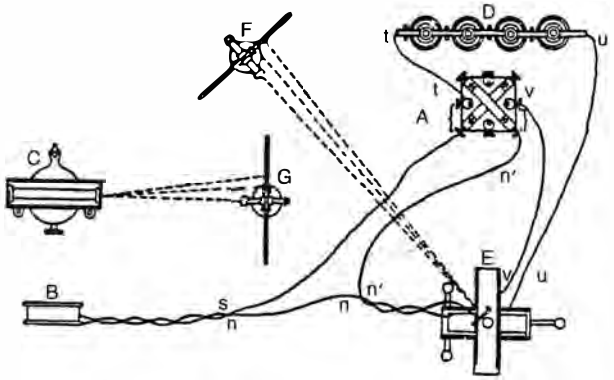
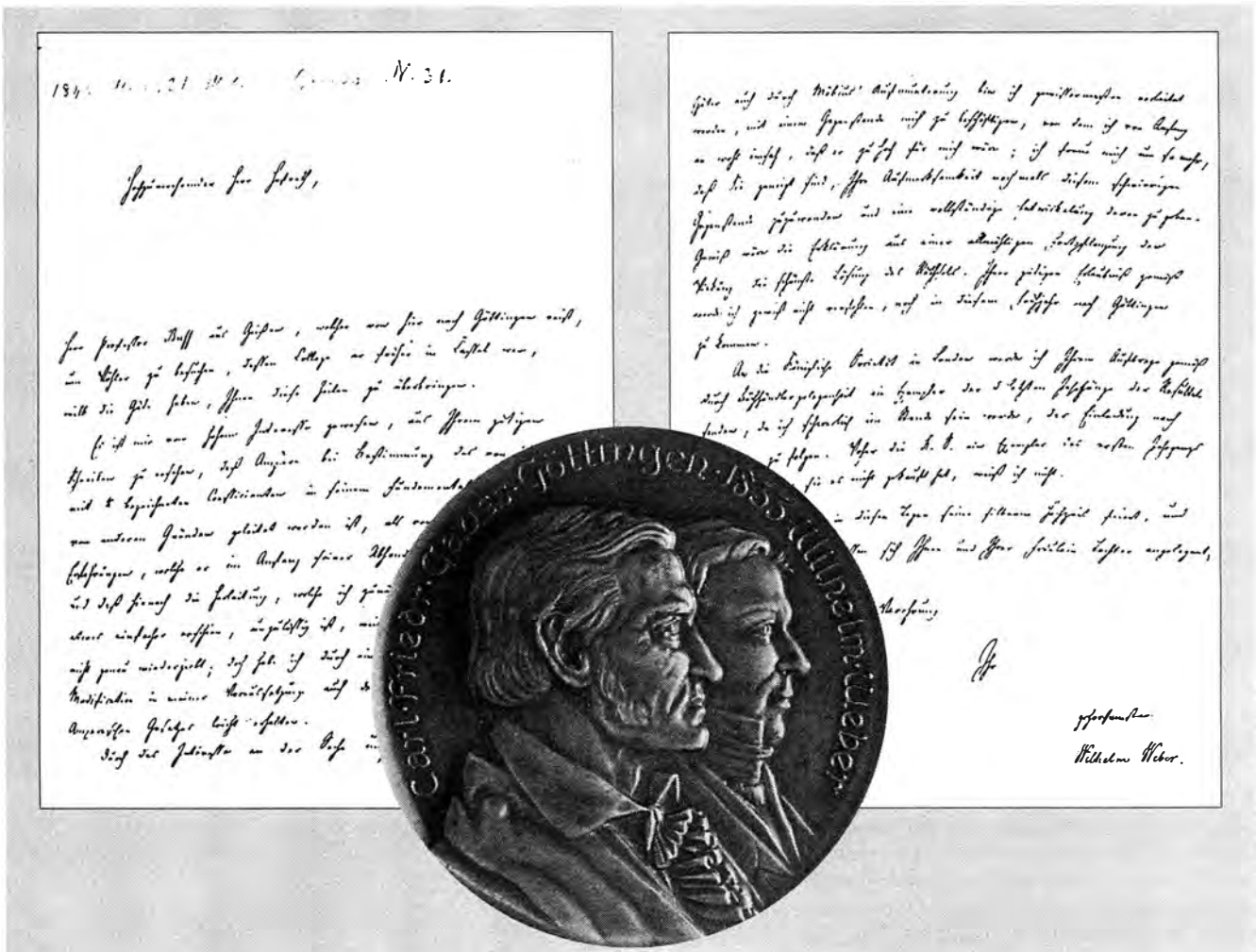


Figure 2.3
SCHEMATIC OF WEBER'S EXPERIMENT

In addition to the bifilar coil and multiplier, depicted in the closed position at E, *this schematic diagram from Weber's First Memoir shows the other instrumentation required for the verification of Ampère's electrodynamic theory.*

The telescope and meter stick for observing the rotation of the bifilar coil is shown at F. *The current supply (a four-cell battery) is depicted at* D *and a commutator for reversing the direction of current flow at* A. *The apparatus at* B, C, *and* G *measures the current in the circuit and takes the place of a modern ammeter. B is a second multiplier coil connected to the main circuit, and about 20 feet distant from the bifilar coil.* C *is a portable magnetometer whose deflections (measured by the telescope and meter stick at* G*) correspond to the current strength in B. Observers were required at both the scopes* F *and* G, *to take simultaneous readings of the deflection of the bifilar coil and the current strength, and a third operator to manipulate the current supply.*



Text of the Gauss-Weber 1845 Correspondence

Courtesy of the George August Physics Institute at Göttingen University

EDITOR'S NOTE

The letters from Weber to Gauss, numbered 29 to 31, come from the Gauss manuscripts in the Manuscripts and Rare Books Division of the State and University Library of Lower Saxony, in Göttingen. They were transcribed from the German script by Karl Krause and Alexander Hartmann. The letter from Gauss to Weber of 19 March appears in Carl Friedrich Gauss, Werke, *Vol. V, pages 627-629. All the letters were translated into English by Susan P. Johnson. The words in brackets are added by the translator; the footnotes are by the editor.*

Above: Commemorative medal honoring Carl Friedrich Gauss and Wilhelm Weber, issued in 1933. In background is a facsimile of Weber's 31 May 1845 letter to Gauss.

Weber to Gauss,
No. 29, 18 January 1845

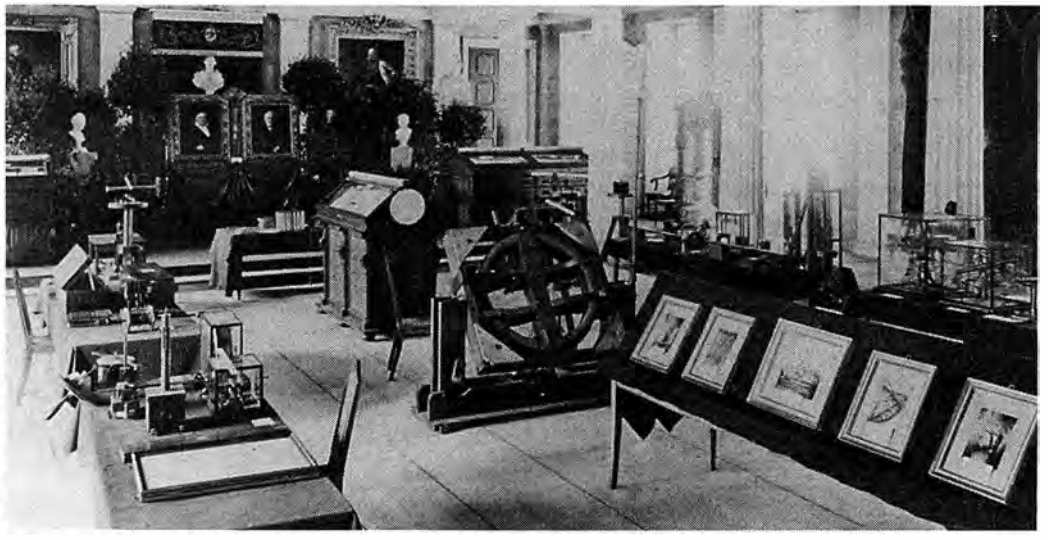
Highly honored Herr Hofrath:[1]

. . . For some time now, I have occupied myself with a treatise, which I would like to present to the Royal Society in Göttingen; now that I am finished, however, I do not dare to venture a sound judgment, either about its correctness in your eyes, or about whether it is worthy of being presented to the Society, and therefore I would by far prefer to leave both to your benevolent decision. Hence I submit them to you with the request, that you will be good enough to look at them at your convenience, when your time permits. . . .

With heartfelt affection and respect.

Leipzig, 1845, January 18

Your devoted,
Wilhelm Weber



Courtesy of the George August Physics Institute at Göttingen University

An exhibit honoring Gauss and Weber in June 1899 at Göttingen University. Portraits of the scientists are surrounded by their experimental apparatus and illustrations of their experiments. On the tables at left are various electrical and magnetic apparatus. The large coil in the center mounted on a wooden dolly is from the Earth inductor, which can still be seen today in the Gauss House at Göttingen.

* * *

Weber to Gauss,
No. 30, 1 February 1845

Highly honored Herr Hofrath:

I have just noticed, that in the manuscript I recently sent to you, there is apparently missing a note regarding Ampère's formula, which would be necessary in order to understand it. Namely, Ampère has given a more general expression, for the interaction of two current elements, than I introduce there, which I seek to justify, by means of the consideration that the empirically derived definition of the coefficient of the second term, which I have discarded, seems completely untrustworthy, because of the unreliability of the method, and hence that coefficient, so long as it lacks a more precise quantitative determination, by the same reasoning would have to be set = 0. If I am not in error, you yourself earlier expressed certain thoughts about discarding the negative value which Ampère assumed for that coefficient by means of which two current elements, one following the other, would have to mutually repel one another.

With heartfelt respect.

Leipzig, 1845, February 1

Your most devoted,
Wilhelm Weber

* * *

Gauss to Weber,
19 March 1845

Esteemed friend:

Since the beginning of this year, my time has been incessantly taken up and frittered away in so many ways, and on the other hand, the state of my health is so little favorable to sustained work, that up to now, I have not been in any position to go through the little treatise you were so good as to send me, and to which I just now have been able to give a first quick glance. This, however, has shown me that the subject belongs to the same investigations with which I very extensively occupied myself some 10 years ago (I mean especially in 1834-1836), and that in order to be able to express a thorough and exhaustive judgment upon your treatise, it does not suffice to read through *it,* but I would have to first plunge into study of my own work from that period, which would require all the more time, since, in the course of a preliminary survey of papers, I have found only some fragmentary snatches, although probably many more will be extant, even if not in completely ordered form.

However, if, having been removed from that subject for several years, I may permit myself to express a judgment based on recollection, I would think, to begin with, that, were Ampère still living, he would decidedly protest, when you express Ampère's law by means of the formula

$$-\frac{\alpha\alpha'}{rr} ii' \sin\theta \sin\theta' \cos\epsilon \qquad \textbf{(I)}$$

since that is contained in a wholly different formula, namely

$$-\frac{\alpha\alpha'}{rr} ii' \left(\tfrac{1}{2}\cos\theta \cos\theta' + \sin\theta \sin\theta' \cos\epsilon\right). \qquad \textbf{(II)}^2$$

Nor do I believe that Ampère would be satisfied by the appended note, which you mention in a later letter, namely, where you cast the difference in such a way, that Ampère's formula would be a *more general one,* just like

$$-\frac{\alpha\alpha'}{rr}(F\cos\theta \cos\theta' + G\sin\theta \sin\theta' \cos\epsilon)$$

where Ampère experimentally derived $F = {}^1/_2\, G$, while, because Ampère's experiments may not be very exact, you think that with equal correctness, you can claim that $F = 0$. In any other case than the present one, I would concede that in this discordance between you and Ampère, a third party would perhaps clarify the matter as follows, that:

whether one (with you) views this as merely a modification of Ampère's law, or

whether (as, in my estimation, Ampère would have to view the matter), this is nothing less than a complete overturning of Ampère's formula, and the introduction of an essentially different one,

is at bottom little more than idle word-play. As I said, in any other case I would gladly grant this, since no one can be *in*

verbis facilior [more easy-going in matters of verbal formulation] than I. However, in the present case the difference is a vital question, for Ampère's entire theory of the interchangeability of magnetism with galvanic currents depends absolutely on the correctness of Formula II and is wholly lost, if another is chosen in its place.

I cannot contradict you, when you pronounce Ampère's experiments to be not very conclusive, while, since I do not have Ampère's classic treatise at hand, nor do I recall the manner of his experiments at all, nonetheless I do not believe that Ampère, even if he himself were to admit the incompleteness of his experiments, would authorize the adoption of an entirely different formula (I), whereby his entire theory would fall to pieces, so long as this other formula were not reinforced by *completely decisive* experiments. You must have misunderstood the reservations which, according to your second letter, I myself have expressed. Early on I was convinced, and continued to be so, that the above-mentioned interchangeability *necessarily* requires the Ampère formula, and allows no other which is not identical with that one for a closed current, *if the effect is to occur in the direction of the straight lines connecting the two current elements;* that, however, if one relinquishes the just-expressed condition, one can choose countless other forms, which for a closed current, must always give the same end result as Ampère's formula. Furthermore, one can also add that, since for this purpose it is always a matter of effects at measurable distances, nothing would prevent us from presupposing that other components might possibly enter into the formula, which are only effective at immeasurably small distances (as molecular attraction takes the place of gravitation), and that thereby, the difficulty of the repulsion of two successive elements of the same current could be removed.

In order to avert misunderstanding, I will further remark, that the Formula II above can also be written

$$-\frac{\alpha\alpha'}{rr} ii' \left(-\tfrac{1}{2}\cos\theta\cos\theta' + \sin\theta\sin\theta'\cos\epsilon\right)$$

and that I do not know, whether Ampère (whose memoire, as I said, I do not have at hand) used the first or the second notation. Both of them signify the same thing, and one uses the first form, when one measures the angle θ, θ' with the same delimited straight line; thus, this line determines the side of the second angle in the opposite way, but determines the other form, when one is considering a straight line of indeterminate length, and, for the measurement of angle θ, θ', one resorts to that line twice, in one sense or another. And, likewise, one can place a + sign in front of the whole formula instead of the − sign, if one is considering as a positive effect, not repulsion, but attraction.

Perhaps I am in a position to again delve somewhat further into this subject, which has now grown so remote from me, by the time that you delight me with a visit, as you have given me hope that you will do at the end of April or the beginning of May. Without a doubt, I would have made my investigations public long ago, had it not been the case that at the point where I broke off, what I considered to be the actual keystone was lacking

Nil actum reputans si quid superesset agendum

[Discussions accomplish nothing, if work remains to be done]

namely, the *derivation* of the additional forces (which enter into the reciprocal action of electrical particles at rest, if they are in relative motion) from the action which is *not instantaneous,* but on the contrary (in a way comparable to light) propagates itself in time. At the time, I did not succeed; however, I recall enough of the investigation at the time, not to remain wholly without hope, that success could perhaps be attained later, although—if I remember correctly—with the subjective conviction, that it would first be necessary to make a constructible representation of the *way* in which the propagation occurs.

With hearty greetings to your brothers and sister and to Professor Möbius.

Göttingen, 19 March 1845

Ever yours,
C.F. Gauss

* * *

Weber to Gauss,
No. 31, 31 March 1845

Highly honored Herr Hofrath:

Professor Buff from Giessen, who is travelling from here to Göttingen, in order to visit Woehler, his former colleague in Cassel, will have the goodness to bring you these pages. It has been of great interest to me to learn from what you were kind enough to write, that Ampère, in the definition of the coefficient he calls *k* in his fundamental law, was guided by other reasons, than the ones from immediate empirical experience which he cites at the beginning of his treatise, and that hence the derivation, which I first gave, because it seemed somewhat simpler, is inadmissible, because it does not reproduce Ampère's law with exactness; yet, by means of what seems to me to be a slight modification in my premise, I have easily obtained the exact expression of Ampère's law.

Through the interest taken in the matter, and through the encouragement of Fechner and later Möbius, I have been induced to occupy myself up to a point, with a subject which I conceived from the start might well be beyond me; I am all the happier that you are inclined to turn your attention once more to this arduous subject, and to give a complete development of it. Certainly, the explanation derived from a gradual propagation of the effect would be the most beautiful solution of the riddle. In response to your kind invitation, I will certainly not fail to come to Göttingen by the end of this spring.

In conformity with your instructions, I will send to the Royal Society in London a copy of the five last annual summaries of the *Resultate,* by way of the book dealer, since it will be difficult for me to pursue the invitation to Cambridge. Whence the Royal Society has obtained a copy of the first annual summary, I do not know, since they did not buy it.

Möbius, who is now celebrating his silver wedding anniversary, and my sister, remember themselves to you and your daughter with the greatest regard.

With the most heartfelt respect.

Leipzig, 1845, March 31

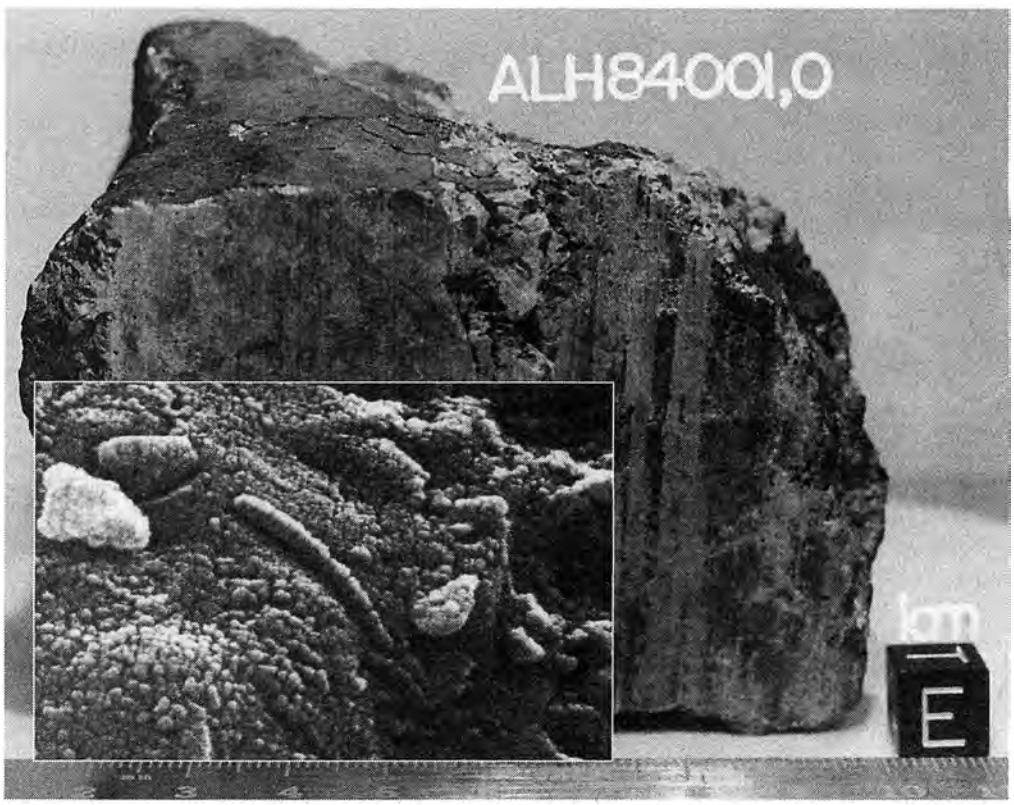
Your most devoted,
Wilhelm Weber

Notes

1. The title by which Weber addressed Gauss is approximately translated as "Mr. Court Councillor."
2. This seems to be Gauss's only error of memory: The epsilon should be an omega.

Discovery of Life on Mars To Redefine Future Missions

by Marsha Freeman



NASA

Of the dozen meteorites from Mars found so far in Antarctica, 4.2 pound ALH84001 is the oldest. Scientists believe that primitive life developed there more than 3 billion years ago. Inside the meteorite's cracks and fissures, a team of scientists has found indirect, but provocative evidence, that primitive life existed on Mars. One worm-like feature, seen here (inset), which is one hundredth the width of a human hair, looks like the fossil remains of an early form of life.

At an Aug. 7 press conference at NASA Headquarters in Washington, four scientists announced their discovery that a meteorite from Mars very likely contains fossil remains of a primitive form of life that developed there billions of years ago.

The scientists were well aware that their conclusion was a profound one, and could provide substantiation to the idea that "life is a natural product of planetary evolution," as Dr. John Rummel of the Marine Biology Laboratory at Woods Hole had remarked three weeks *before* the scientists made their announcement. Rummel had counseled scientists at an international meeting in England "to be ready for surprises."

The four scientists, led by David McKay from the NASA Johnson Space Center, had presented their surprising results to the NASA leadership before going public. After "grilling" the scientists for more than two hours, NASA Administrator Dan Goldin set up a meeting at the White House, and briefed President Clinton on the development.

On Aug. 7, at the same moment that the scientists were explaining the results of their investigations to the media, the President held a brief press conference and announced that he had asked Vice President Al Gore to convene a bipartisan space summit at the White House before the end of this year. The summit will take place in November.

"If this discovery is confirmed," the President said, "it will surely be one of the most stunning insights into our universe that science has ever uncovered. Its implications are as far-reaching and awe-inspiring as can be imagined." The space summit, he instructed, will "discuss how America should pursue answers to the scientific questions raised by this finding."

Tell-Tale Signs of Life on Mars

The evidence for life on Mars, presented by the scientists, is indirect but very provocative. The 4.2-pound Antarctic meteorite, ALH84001 (the first one found in 1984 in the Allan Hills region of the continent), was identified in 1993 as one of a dozen that has come to the Earth from Mars. That is established by matching gases trapped inside the meteorite with what we know is the unique Martian atmosphere. At an estimated age of 4.5 billion years, it is, by far, the oldest meteorite from Mars.

Scientists at the NASA press conference explained that at the time this meteorite was formed, Mars, and all of the planets of the inner solar system, were undergoing an intense bombardment by small bodies. Mars, wetter and warmer than it is today, apparently had its surface fractured by such impacts, and liquid water, then on the surface, infiltrated cracks in the rocks. The scientists propose that the primitive life they have found in the meteorite formed inside

these cracks and fractures.

About 16 million years ago, they estimate, a large object hit the surface, ejecting material into space, including ALH84001. Approximately 13,000 years ago, this rock found its way to Antarctica.

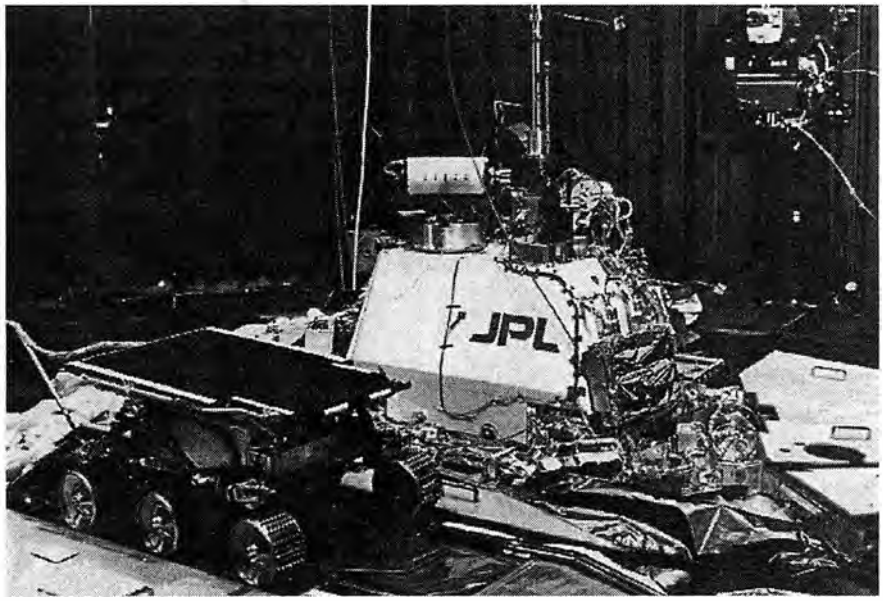
As David McKay explained at the press briefing, there are four main lines of evidence upon which the scientific team concluded that life existed on Mars. Each line of evidence could be explained by processes other than the biological, he said, but all four, occurring in such close physical proximity to each other, led the scientists to conclude a primitive form of life was involved.

The first clue was the presence of calcium carbonate, which formed into globules in the cracks inside the rock. The globules, it is estimated, were formed about 3.6 billion years ago, when the carbon dioxide from Mars's atmosphere combined with infiltrating water. Dr. Everett Gibson, a geochemist, also from the NASA Johnson Space Center, explained that it is inside these tiny globules that the unusual features have been found.

The carbonate globules contained detectable amounts of polycyclic aromatic hydrocarbons (PAHs). As the four scientists explain in an article in *Science* magazine Aug. 16, PAHs are abundant on Earth as fossil molecules in ancient sedimentary rocks, coal, and petroleum. When microorganisms die, the complex organic molecules they contain frequently degrade into PAHs.

Dr. Kathie Thomas-Keprta, of Lockheed Martin, presented mineralogical evidence that primitive bacteria lived inside this Martian meteorite. Magnetite particles in ALH84001 are similar chemically, structurally, and morphologically to terrestrial magnetite particles known as magnetofossils, which are fossil remains of bacterial magnetosomes.

Associated with the globules is the most intriguing evidence of all—ovoid features similar in size and shape to nanobacteria found on Earth, and elongated forms that resemble fossilized forms of filamentary bacteria. The scientists point out that, in general, terrestrial bacteria are an order of magnitude larger than the 20- to 100-nanometer forms seen in the meteorite carbonates. The largest of the structures is one-100th the width of a human hair.



NASA

The Mars Pathfinder mission will be launched this December, and will place the first rover on the planet. Here the 25-pound, six-wheeled rover, Sojourner, is tested in a vacuum chamber, alongside the lander that will carry it to the surface of Mars.

Each member of the team that developed the evidence for this discovery is anxious to continue the research, to see if it is possible to find the "smoking gun" that will prove, beyond a shadow of a doubt, that it was living organisms which produced the evidence preserved in the meteorite. The scientists hope to find remains of membranes of cells inside the tiny structures in the carbonate globules.

They will also be reexamining some of the other Martian meteorites, with such tools as a scanning electron microscope, and a high-resolution transmission electron microscope, which were used to investigate ALH84001.

The Future Mars Missions

When scientists analyzed the data the two Viking landers sent back from the surface of Mars starting in the summer of 1976, they were disappointed that the spacecraft did not find what was considered to be convincing evidence of life on Mars. But as David McKay recently pointed out, Viking had no ability to look for fossils.

Missions to Mars that followed Viking were not designed to look for life, because very few scientists maintained that the results from Viking were not conclusive. The Mars Observer, launched in 1992, had as its primary task the remote sensing of Mars from orbit. Its goal was to enhance our understanding of the global climate, topography, and mineral distribution on the planet. But the spacecraft lost contact with Earth in August 1993, three days before its insertion into Mars orbit.

In order to accomplish the science objectives of the Mars Observer, but within a very limited budget, NASA has scheduled a series of small Mars Surveyor missions, which will fly Mars Observer instrument spares, or equivalent equipment, in a series of spacecraft.

The first launch will be in November 1996, and is the Mars Global Surveyor. The science objectives involve high resolution imaging of the surface, studies of the topography and variations in gravity, the role of water and dust on the surface and in the atmosphere, the weather and climate, the composition of the surface and atmosphere, and the existence and evolution of the Martian magnetic field.

The Mars Global Surveyor will arrive at Mars in September 1997 after a 10-month cruise phase. The spacecraft will be in a polar, Sun-synchronous orbit, so that each image will be taken with the Sun at the same mid-afternoon azimuth, similar to some Earth-orbiting remote-sensing spacecraft. Data will be acquired for one Martian year, or approximately two Earth years. The spacecraft will also be used as a data relay for later U.S. and international missions over the following three years.

Less than a month after the Mars

Global Surveyor is launched, the Mars Pathfinder will be on its way, taking a shorter path, and arriving before its orbital partner. The Pathfinder will be the first spacecraft to land on Mars in 20 years, and the first to deploy a rover there.

Because of budget constraints on the space agency, the cap on the cost of the mission is $150 million, and it is primarily an engineering demonstration of key new technologies and concepts, for use in future unmanned rover missions to Mars.

Within an hour of landing on the surface of Mars, the Pathfinder lander will open its three metallic petals, and stand itself right side up, if necessary. Engineers will then instruct the rover to drive off and begin exploring the immediate surroundings.

The diminutive rover is named Sojourner, meaning traveler, after African-American Isabella Van Wagner, who, as Sojourner Truth, traveled around the United States in the Civil War period, advocating the abolition of slavery, and women's rights. Sojourner, which weighs a mere 25 pounds, will be deployed to roam across an ancient Martian flood plain, using an autonomous navigation system. The communications range of the rover is about 1,640 feet (500 meters), a distance it would take it a few weeks to achieve.

Sojourner has cameras fore and aft, and an Alpha-Proton X-Ray Spectrometer, or APXS. The APXS will be capable of determining the elemental composition of rocks it encounters. One thing scientists hope to find are aqueous deposits, or minerals that were deposited by standing bodies of water, to tell them about the history of water on Mars.

The lander will make atmospheric and meteorological observations during its descent through Mars's atmosphere, and will function as a weather station on the surface of the planet. It will also relay data to Earth from Sojourner. Cameras on the lander, which will see at about eye level above the surface, have filters to aid in geologic studies. The cameras can be rotated, to provide a nearly complete view of the lander and the Martian surface.

Moving Up the Agenda

NASA currently has plans for two spacecraft for each 26-month window of opportunity for launches from the Earth to Mars, with increasing sophistication and difficulty of tasks.

NASA

In order to test the outer limits of the conditions that can sustain life, scientists like Chris McKay have gone to the ends of the Earth in search of terrestrial analogues to the conditions on Mars. Here, McKay peers down a hole carved out of the Antarctic ice, during one of his many trips to the South Pole.

To the surprise of scientists on the mission, they found that under the 13 to 16 feet of ice that cover the Antarctic dry valleys, there are algae, diatoms, and other microbial forms of life. If there is water under the surface of Mars, could similar creatures be found there also?

However, the first mission that is crucial in the search for evidence of life on Mars, is not planned to take place until the year 2005, at the earliest. Such a sample return mission will bring pieces of Mars, from regions that would be clearly identified, back to Earth for close investigation. Manned missions to Mars, which will provide the final word on this crucial question, have not even been on the agenda.

Within hours of the announcement on Aug. 7 that a team of well-seasoned and well-respected scientists believed they had found evidence of early life on Mars, an ad hoc group of more than 30 planetary scientists began discussions on how future Mars missions might be designed to aid the search for life. They have taken up President Clinton's challenge to provide policy direction for this area of the nation's space program.

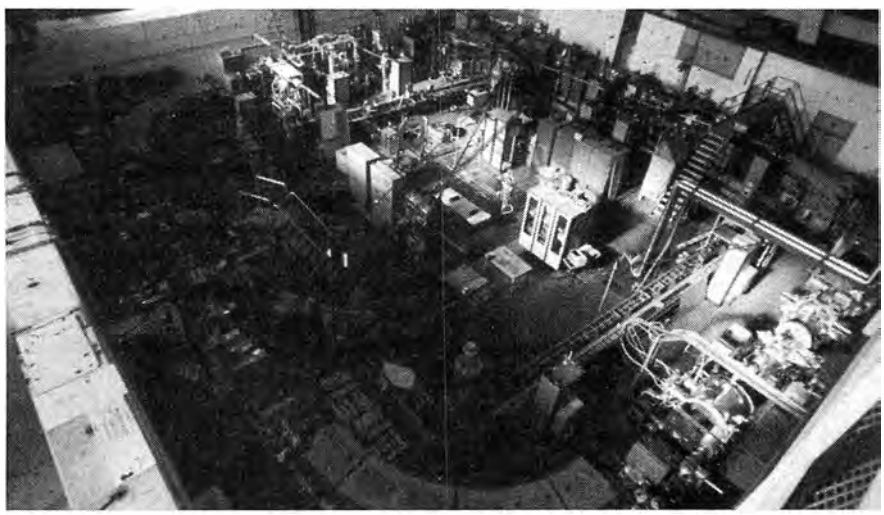
At the space summit in November, it will be up to the President and the leadership of NASA to go forward from that challenge, and formulate a space program that will answer as many questions as possible with robotic precursor missions, which will lay the basis for the missions that will eventually take men to Mars.

The Gate to the Antimatter Universe

by Charles B. Stevens

More than 60 of the world's leading experts in the field of antimatter gathered from May 19 to 25 in a remote region of Italy's Apennine Mountains to review the status of their research and prospects for the future. The occasion was the International Workshop on Antimatter Gravity and Antihydrogen Spectroscopy, sponsored by the Istituto per la Ricerca di Base (IRB, Institute for Fundamental Research).

Despite the often trivial representation in popular works of science fiction, it is true that the generation and science of antimatter is the next stage of technology, beyond that of nuclear fission and fusion. And, as in the case of learning a new language, R&D in antimatter promises to greatly expand our mastery of ordinary energy and matter processes by giving us entirely new insights.



CERN

The birthplace of the first man-made antimatter hydrogen: The Low-Energy Antiproton Ring, LEAR, the main experimental facility for antimatter research, is being forced to shut down next year because of budget cuts. LEAR is located at the CERN laboratory in Switzerland.

This was a most auspicious time for such a workshop. German, Italian, and Swiss scientists working in the CERN European Laboratory for Particle Physics and using the Low-Energy Antiproton Ring (LEAR), had just announced a few weeks before that they had succeeded in generating the first atoms of antihydrogen, by combining an antimatter electron—a positron—with an antimatter proton—the antiproton. And, while the antihydrogen atoms lived for less than 40 billionths of a second, their existence was nevertheless documented with a high degree of certainty.

In the case of ordinary hydrogen, too, there came an announcement, about the same time, that scientists in the United States, at the Lawrence Livermore National Laboratory had—unexpectedly and contrary to current theories—produced the first metallic hydrogen.

What Is Antimatter?

Most descriptions of antimatter appear somewhat strange or mysterious: electrons and protons going backwards in time, mirror-matter, the double solution to the relativistic Schrödinger Ψ function for the electron. To understand it, it is best to look at how antimatter is generated.

As we increase the frequency of electromagnetic waves, there are singular frequencies at which the light wave is transformed into material particles. The energy of a photon—a quantum of light—is directly proportional to its frequency. And mass, according to the Theory of Special Relativity, is related to energy by the famous "Energy equals mass times the speed of light squared" ($e = mc^2$). When the photon energy—or corresponding frequency—reaches a level where it is twice the energy equivalent of the mass of an electron, the photon can be transformed into an electron and positron—the antimatter electron with a positive electric charge. If the photon energy is twice that of the proton, a proton-antiproton pair can be generated. This process is termed pair production.

The high-energy photons for pair production can be generated either by nuclear reactions, or by high-energy particle accelerators, where electron or proton beams travelling near the speed of light are collided with themselves or with solid targets to produce the high-energy photons. Particle accelerators appear at present to be the only way to generate any significant numbers of antimatter particles.

In general, the conditions of pair production in accelerators mean that the antimatter that is generated is already travelling at near the speed of light, and as elementary charged particles—not as atoms. Therefore, to generate electrically neutral atoms, either the high-velocity positrons or antiprotons must be slowed down and trapped in some manner, or a process must be found for combining the particles at high velocities.

Antimatter is difficult to trap because, if it comes into contact with ordinary matter, it and an equal amount of the ordinary matter are transformed into high-energy photons. (Indeed, the fact that antimatter is present, is determined by the signature of self-destruction: high-energy

photons.) Antimatter charged-particle beams can in principle be confined, like plasmas, by magnetic fields. For trapping of neutral atoms of antihydrogen, the atoms must be brought to very low velocities—very low temperatures—and trapped in magnetic and electrostatic bottles (Penning Traps), possibly with the help of lasers.

Overall, work in antimatter represents the frontiers of science in terms of the generation of singularities. In general, it is not possible to simply keep increasing the frequency of electromagnetic waves—pair production interrupts the process.

Near-term Objectives

Despite what some newspaper articles say, there are slim near-term prospects of constructing antimatter-powered rocket engines. Antimatter could be used in small amounts to catalyze other processes, but the cost ratio of energy input to antimatter energy produced is currently about 1 million trillion.

The main focus of antimatter research is currently on fundamental scientific questions. For example, will antimatter respond to gravity in the same way that ordinary matter does? Does antimatter go up instead of down? Do antimatter atoms produce the same spectrum of light as their matter counterparts? Is the light generated by antimatter atoms the same as ordinary light?

It is already known that antiprotons, when combined with helium atoms, are producing entirely new chemical states and bonds—an entirely new chemistry. These differences, and ones that could be demonstrated in the near future, promise to revolutionize our understanding of the universe.

Renaissance Spirit Lives

The May workshop in Italy came just at the right time. Budget cutbacks at CERN are forcing the shutdown next year of the Low-Energy Antiproton Ring (LEAR). LEAR is the only facility of its kind, and the chief experimental facility for antimatter research. So the Antimatter Workshop had to map out, not only the theoretical future of this research field in the wake of the production of the first antimatter hydrogen atoms on the LEAR, but also its practical future, in terms of what will replace LEAR.

In this connection, the workshop heard near-term proposals by Dr. G. Jackson of Fermilab in the United States, and Drs. Dieter Moehl and Stephan Maury of CERN, for new antimatter facilities to replace LEAR.

Ironically, while throughout the advanced world, science budgets are being slashed across the board, the critical margin of support to keep world antimatter research alive comes from the public and private institutions of Molise, the southern Italian district in which the workshop was held. During one evening session of the conference, more than three score of the religious, business, and public officials of the district met with the scientists to discuss why the Molise district considers support of such basic research so important.

The philosophy they expressed is succinctly summarized by one statement made by the director of the Isernia archaeological site—a paleolithic hominid "village" more than 750,000 years old. "Significant human progress only appears when scientists are free to soar like Icarus, although, in this day and age, we will provide parachutes in case of mishaps along the way."

Isodual Representation

Antimatter actually represents a new level of singularity generation in science and technology. We should, therefore, not expect to see a simple mirror reflection of the ordinary laws of matter with the formation of antimatter atoms and antimatter chemistry and spectroscopy. Dr. Ruggiero Santilli, director of the IRB, has in fact developed a theoretical overview—the isodual representation of antimatter—which forecasts a number of startling characteristics. For example, antimatter may actually rise in a gravitational field, instead of falling.

Santilli also projects significant differences in the spectroscopy of antimatter hydrogen. In fact, even the light generated by antimatter may be of a fundamentally different character.

Among the proposals for experiments to test the gravity response of antimatter were those presented by Dr. Meshkov of the Russian Joint Institute for Nuclear Research at Dubna: "Antihydrogen Generation and Studies in Storage Rings"; by Dr. A.P. Mills of Bell Labs in New Jersey: "Possibilities for Measuring the Passive Gravitational Mass of Electrons and Positrons in Free Horizontal Flight"; by Dr. G. Testera of Genoa, Italy: "Possible Measurements of Gravity in the Presence of Electric Stray Fields (Patch Effect)."

Antimatter Applications

Although we are a long way from realizing antimatter rocket engines for interstellar spaceflight, a session on antimatter applications was held during the conference. Dr. G. Smith of Pennsylvania State University presented a paper on "Portable Traps for Antiprotons and Medical Applications." Positron tomography is already a significant medical diagnostic using antimatter. As Smith detailed, antiprotons could be another important diagnostic and medical tool in the near future.

Dr. F. Huber of the University of Stuttgart in Germany presented a paper on the prospects for using antiprotons to heat the plasma exhaust of rocket engines: "Antiprotons for Plasma Heating."

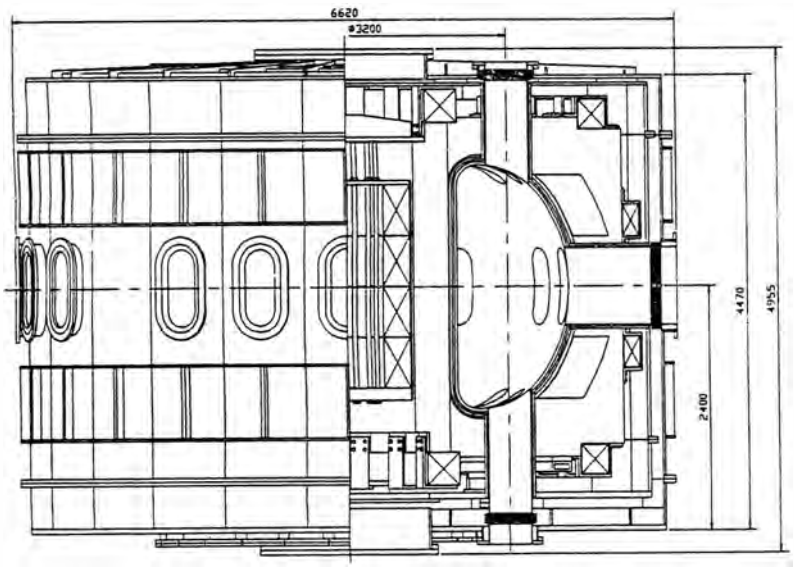
Among the most interesting developments reviewed at the antimatter workshop were those combining the most advanced theoretical implications of antimatter and near-term applications, such as the observation of antiprotons combining to form molecules with helium atoms. These metastable states of antiprotons in helium represent an opportunity to examine the chemistry of antimatter and its most advanced theoretical implications. They also represent the opportunity to develop an entirely new chemistry, which could have immediate and far-reaching applications.

For example, it has been found that when beams of antiprotons are shot through a container of helium, some of the antiprotons—which have a negative electric charge like that of the electron—replace one of the two electrons in the helium atom. There is evidence that this new configuration undergoes a further evolution, combining with a second helium atom to form a molecule. Because the antiproton has 2,000 times the mass of the electron which it replaces in the helium, the atomic structure of this new type of atom—and, later, molecule—is of a totally new variety that offers vast insights into the existing models of atomic structure and chemistry.

Before LEAR is shut down, scientists from Harvard University plan to use it in new experiments to generate and trap antihydrogen atoms. Prof. Gerald Gabrielse, who heads this effort, reports that "if we're lucky, we'll make low-energy antihydrogen. But our chances of doing interesting measurements by the end of the year are not very high."

China and Korea Plan World-class Nuclear Fusion Projects

by Mark Wilsey



◀*The Chinese are calling in U.S. scientists to help with the HT-7U, a machine similar to the cancelled U.S. TPX Tokamak. The hydrogen fuel is magnetically confined in the torus seen in cross section on the left.*

China and Korea are each planning to enter the 21st century with new world-class nuclear fusion research facilities. Although fusion research in these countries has been limited in the past, it is hoped that these ambitious projects will now allow each to play a major role in world fusion research.

The push for fusion research in these countries comes at a time when the U.S. magnetic fusion program has been scaled back by budget cuts (see box). Last year, the U.S. next-generation advanced fusion experiment was cancelled. Now, the Chinese and Koreans are putting forward new fusion devices similar to the cancelled U.S. machine, which should come on line early in the next decade. Furthermore, to help design these new machines, they have enlisted the aid of scientists in the U.S. fusion community who worked on the cancelled U.S. machine.

Fusion energy is what powers the Sun and stars. Under tremendous temperatures and pressures, atoms of hydrogen fuse to form helium, and in so doing release bursts of energy. One way to confine hydrogen at high temperature and pressure is to hold it inside powerful magnetic fields. One of the devices for doing this is called a tokamak, a torus-shaped chamber surrounded by magnets.

The flagship U.S. fusion facility is the Tokamak Fusion Test Reactor, TFTR, at the Princeton Plasma Physics Laboratory (PPPL) in New Jersey. The TFTR has been in operation for more than two decades and is now nearing the end of its useful life. TFTR's successor was to have been the now-cancelled Tokamak Physics Experiment, TPX. Much of its design work had been completed before its funds were cut.

TPX was to have been an advanced fusion reactor that would make use of superconducting magnets. Because superconducting magnetic coils conduct electricity without resistance, and are therefore very efficient, TPX would have been able to sustain fusion reactions for several minutes, instead of the few sec-

MAIN PARAMETERS OF HT-7U, KSTAR, AND TPX

	HT-7U	KSTAR	TPX
Major radius	1.6 m	1.6 m	2.25 m
Minor radius	.35 m	0.5 m	0.5 m
Toroidal field	4.5 T	4 T	4 T
Plasma current	1 MA	3 MA	2 MA

The planned Chinese and Korean machines are similar in basic parameters to the cancelled TPX. The major radius of a tokamak torus is the "bicycle wheel" radius, while the minor radius is the "inner tube cross-section" radius. Toroidal field strength—strength along the "bicycle wheel" circumference—is given in tesla, plasma current in millions of amperes.

onds achieved by conventional tokamaks. TPX was designed to examine the behavior of burning plasmas under steady-state conditions.

China's HT-7U

Several years ago, China acquired a tokamak from Russia, the HT-7, the predecessor to the T-15 tokamak, Russia's largest fusion machine. Although China's work on this secondhand tokamak has not been of particular interest to the rest of the fusion community, Chinese scientists, having gained experience on it, are now preparing to move forward with the new HT-7U. If successful, it would be the world's first fully superconducting tokamak.

While the U in HT-7U stands for "upgrade," there will be little of the machine that is not new, save perhaps the power systems. The vacuum chamber and most of the machine's support structure will be new. Official approval for the project from the Chinese government is expected in the next couple of months.

For the HT-7U, the Chinese Academy of Sciences has sought the expertise of the U.S. fusion community, specifically the assistance of the Fusion Research Center at the University of Texas, in Austin. Last July, Alan Wootton, the director of the Center, visited China to discuss the collaboration.

Wootton reports that the role the Fusion Research Center will play is twofold: First, to assist in acquiring the superconducting cable to be used in the coils. (It will be the same cable that was to be used in the now defunct Superconducting Super Collider.) Second, the Center will lend the Chinese diagnostic equipment from its tokamak that is no longer in use. The Texas Tokamak in Austin, TEXT, was shut down at the end of 1995, a victim of congressional budget cuts. Also, the Fusion Research Center will help the Chinese in developing the physics experiments to meet the objectives of the machine.

KSTAR

Even before the demise of TPX in the U.S. last summer, the Korea Basic Science Institute, KBSI, had proposed a similar advanced superconducting tokamak as the centerpiece of a Korean National Fusion Project, KNFP. KNFP can be seen in the broader context of Korea's expanded efforts to develop other advanced technologies in energy and space.

Recently, PPPL and KBSI announced a collaborative research agreement in which Princeton would receive $540,000 this year from Korea to assist in the planning and design of the Korean Superconducting Tokamak Advanced Research facility: KSTAR. This was part of a cooperative research pact signed in June by U.S. Secretary of Energy, Hazel O'Leary, and Korean Minister of Science and Technology, Dr. Kun Mo Chung.

Several Korean researchers are expected to come to Princeton over the next six months to begin the design of KSTAR, a process that will also help to develop Korean expertise in tokamak design. The collaboration could continue into the operation of KSTAR, which is scheduled to come on line in the year 2002. The capital cost is projected to be approximately $200 million.

KSTAR and HT-7U will be similar in design to the TPX, and therefore will investigate advanced tokamak operating modes and performance parameters in steady-state operation. Such research will help to build a solid foundation for future economical and safe tokamak fusion power plants. China and Korea have taken a bold initiative, not only to fill the gap in fusion research that opened up when TPX fell by the wayside, but to advance their own countries' research and energy prospectives into the next century.

U.S Fusion Funding Shrinks

In late July, the House Appropriations Committee recommended $225 million for the Department of Energy's magnetic fusion program in 1997, a cut of $31 million from the administration's request. The Senate committee has approved $240 million. The difference is to be resolved in conference.

Fusion research funding has taken some hard knocks in recent years. The biggest jolt came last year when funding shrank to $244 million in 1996 from $349 million in 1995. This forced the Department of Energy to "restructure" its fusion program to focus more on science issues and less on technology development, and to abandon any target date for a future demonstration power plant.

The House bill would fund the three main U.S. fusion facilities, DIII-D at General Atomics in San Diego, Alcator C-Mod at the Massachusetts Institute of Technology, and TFTR at Princeton, which in all likelihood will be its last year of operation. The bill also provides $5 million for a new small-scale machine, the National Spherical Tokamak Experiment (NSTX) at Princeton.

ITER's Troubles

Again this year the budget will allot only $55 million of an $80 million commitment from the United States to the International Thermonuclear Experimental Reactor (ITER)—a shortfall sure to cause concerns among our international partners in the ITER program.

ITER, a joint project of the United States, Japan, Russia, and the European Union, will be a huge, multi-billion-dollar machine to test large-scale plasmas under near power-reactor conditions. Currently ITER is in the engineering design phase, which is scheduled to run until 1998. The site for ITER has yet to be agreed.

French Secretary of State for Research, François d'Aubert, and the German Research Minister, Jürgen Rüttgers, announced this summer that "France and Germany cannot and do not wish to be candidates" for hosting ITER. The statement was made in light of the prospect that whoever gives the reactor a home may have to contribute up to 70 percent of the cost, amounting to several billion dollars. The announcement may mean that no member of the European Union will offer a site for ITER.

However, for the past several months, Japan has expressed increased interest in hosting ITER and in contributing the lion's share of the cost if ITER is sited there. Japan has not yet formally made such an offer, but it is being seriously considered.

—Mark Wilsey

Victor Ambartsumian, 1908-1996

Victor Amazaspovich Ambartsumian, a giant of 20th century astrophysics, died August 11 at age 87, in Byurakan, Armenia, home of the Byurakan Astrophysical Observatory he founded in 1946. He was accorded a state funeral in Yerevan, the capital.

Several years ago, the director of Pulkovo Observatory, V.A. Krat, said of him, "Ambartsumian's predictions were truly amazing. Everything that he had written about in the 1930s has become central to astrophysics."[1]

Ambartsumian studied astronomy at Pulkovo Observatory (Leningrad) and in 1935 took his doctorate in physics and mathematics at Leningrad State University. Not much later, while a professor there, he founded the chair of astrophysics. In 1941, he was named prorector of the university in charge of scientific affairs.

In 1946, Ambartsumian founded the Byurakan Astrophysical Observatory, and remained its director until 1988. From 1947 until 1993, he was president of the Armenian Academy of Sciences, and from 1950, a deputy of the Supreme Soviet of the USSR. He chaired the USSR Academy of Sciences' commission to oversee all research on cosmogony, set up in 1952. He was president of the International Astronomical Union from 1961-1964.

Creativity Driven by Love

Ambartsumian professed to know nothing scientific about agapic love, only that it was central to human existence. As he once told the Armenian poet Aramis Saakyan, "I only know that human warmth is as necessary to us as the vital warmth radiated by the Sun." No one came into contact with Ambartsumian without being touched by his own love. It also guided his intellectual life: he dismissed Norbert Wiener for pursuing merely "knowledge, not victory."

A poetic or compositional method of thought was the key to Ambartsumian's startling creativity. It is no wonder that he loved poetry and knew a number of Pushkin's poems by heart, some of Heine, and others, including the Armenian poets.

Since a poetic approach is the necessary basis for generating new hypotheses about nature, it follows that mathematics cannot generate them, even though mathematics is needed to describe the natural phenomena we observe. Ambartsumian was keenly aware of this. What a pity, he once commented, "that so many mathematicians-idealists proceed from mathematics to natural phenomena and life, and not from life to mathematics." His polemics were especially focussed on what he called the Cambridge School, referring to Cambridge University's Sir James Jeans, Sir Arthur Eddington, E.A. Milne, and many others.

With these strengths, Ambartsumian readily recognized that the universe continues to develop, and the falsity of the Cambridge School dogma that it is running down to a state of thermal equilibrium or heat death. He also rejected the alternative notion, also crafted by the Cambridge School, that the universe maintained a steady state. He discarded, along with these, the related idea that the universe must be homogeneous.

Since the universe continues to develop, it must favor life. Poet Saakyan asked Ambartsumian, "Are we alone in the universe?" Ambartsumian replied, "I am certain that we are not. The universe is a vast organism, and it is naive to think that life exists only in . . . Earth. . . . We still know very little about the universe. . . . [M]an himself is a micro-universe within the universe. This is both poetic and scientifically accurate."

Thus in important respects, Ambartsumian shared the outlook of Leibniz, and stood out sharply in a century dominated by his adversaries. Yet his adversaries felt obliged to honor him. He was elected to membership in the Royal Astronomical Society in 1953, and received its Gold Medal in 1960.

The same honor was never given his ideas. In 1961 in Berkeley, for example, Ambartsumian announced, in an invited discourse before the 11th General Assembly of the International Astronomical Union, that "the activity of the [galactic] nuclei determines the most important processes in the life of large galaxies." This was received by most of his hearers with shock and disbelief.

The subject came up years later, when Saakyan asked Ambartsumian whether he had any opponents. He answered, "Many. When a new idea is born, it has at first only one supporter—its author. When the theory on the activity of galactic nuclei was formulated at Byurakan, many scientists around the world rejected it. Recognition came later. In short, he who has no opponents in science has no individuality."

Recognition, however, always came in the form of fitting the new idea, somehow, into the dominant Cambridge School framework that was too sterile to have produced it. Ambartsumian's method remained anathema.

Ambartsumian's writings are a treasure. For students of astrophysics, they are the best point of departure, because his superior method can be read and recovered from between their lines.[2]

—David Cherry

Notes

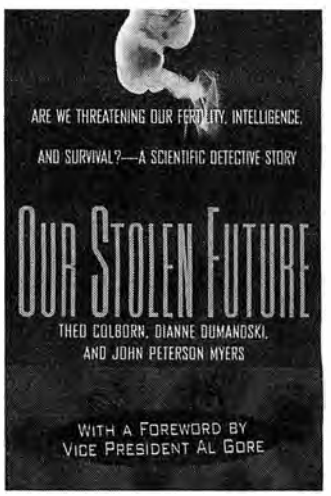
1. This and the quotations from Ambartsumian come from a popular biography in English translation, *Envoy of the Stars*, by Ashot Arzumanyan (Moscow: Progress Publishers, 1987).
2. A synthesis of the work of the Byurakan school is *Problems of Modern Cosmogony* (1968), edited by Ambartsumian. It appeared in Russian, French, German, and other languages, but not in English, the international language of science. It appears that Ambartsumian later rejected the view of solar system origins found in this work.

   Works by Ludwig Mirzoyan, one of his students, bringing the findings of the Byurakan school down to recent date, have also been rejected by English-language publishers (*Instability and the Evolution of Stars*, in Russian, Yerevan, 1981; *Early Stages in the Evolution of Stars*, in Russian, Yerevan, 1991; and *Problems of Stellar Evolution*, unpublished English-language manuscript, 1992).

   Mirzoyan summarized Ambartsumian's most important ideas in two articles in *21st Century* (Winter 1991, Fall 1994). They include references to important papers by Ambartsumian in English. See also this author's "Hubble's Quasar Images: A Moment of Truth" (*21st Century*, Summer, 1995).

   Ambartsumian's most important papers have appeared in a Russian edition titled *Scientific Works* (Yerevan, 3 vols.).

The Long and Short of It



by Dr. J. Gordon Edwards

Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival?—A Scientific Detective Story
Theo Colborn, Dianne Dumanoski, and John Peterson Myers
New York: Dutton (Penguin Books USA), 1996
Hardcover, 306 pages, $24.95

The authors of *Our Stolen Future* imply that almost every man-made chemical threatens endocrine (hormonal) systems and functions, but they fail to provide any data that could corroborate their frightening hypotheses. They allege that "synthetic compounds found in pesticides and industrial chemicals may be wreaking havoc with endocrine systems, decreasing fertility and compromising immune systems in humans, as well as in wildlife."

"[T]he cause is probably environmental," we are told on page 174. But the evidence consists only of anecdotes, questionable stories, and unsupportable hypotheses, which the authors evidently hope will terrify the general public.

The book has gathered the predictable green support for such scare stories, such as that of Jessica Mathews of the Council on Foreign Relations. Mathews wrote in her *Washington Post* column March 11, 1996:

"We have been too obsessed with the obvious risks of toxic chemicals, cancer and birth defects. Immune suppression and hormone disruption, if proved, could be more dangerous. . . . Hormone disrupters can do their damage in infinitesimal doses, concentrations of one part per trillion. . . . There are many thousands of persistent organic pollutants on the market, of which 50 are so far known to be hormone disrupters."

Mathews contends that these charges "will make earlier struggles—over nitrates, saccharin, formaldehyde, Times Beach, Love Canal, cholesterol, alar, and even tobacco, look like kids' stuff."

Who are the authors of *Our Stolen Future?* Dianne Dumanoski is the environmentalist writer for the *Boston Globe,* and is notorious for her statement that "There is no such thing as objective reporting, and I've become even more crafty about finding the voices to say the things I think are true. That's my subversive mission."

Another author is Theo Colborn, a senior fellow with the World Wildlife Fund and W. Alton Jones Foundation, who attacks not only pesticides, but all other synthetic chemicals used in modern industry, transportation, recreation, food and drink containers, and equipment in normal offices and households.

The third author, John Peterson Myers, is director of the W. Alton Jones Foundation, one of the largest providers of environmentalist grants in the United States, with assets of $173 million.

Vice President Al Gore added an enthusiastic introduction to the book, calling it a "sequel" to Rachel Carson's *Silent Spring.* This may be so: Carson's book helped ban DDT, causing millions of human deaths to result from uncontrolled malaria.

Shrinking Penises

The authors discuss the case of the alligators in Lake Apopka, Fla. where male alligators "have elevated levels of estrogen and greatly reduced levels of testosterone in their blood, ony one fourth the level found in males from the relatively uncontaminated Lake Woodruff." Relying upon the work of University of Florida reproductive biologist Louis Guillette, the authors report that the alligators' penises are "one-third to one-half normal size."

Guillette "knew" that these abnormalities had to be the result of a major spill of the miticide dicofol, on the shore in 1980, and he focussed the blame on one or more of the DDE-like breakdown products of dicofol. DDE is a breakdown product of DDT, and the authors report that DDE-like compounds, as a group, are the contaminant found in the highest concentrations in the lake's alligator eggs.

(What they don't say, is that the concentrations are not much higher in Apopka than in other lakes.)

Lake Apopka was already a cesspool in the 1950s, "due to an overdose of citrus processing wastes and sewage effluents" (*Wilderness* magazine, Winter 1986). In September 1971, *Audubon* magazine reported the "first known die-off of alligators in Florida's badly polluted Lake Apopka," when thousands of turtles and fish also died. That great die-off was found to be caused by a bacterium, *Aeromonas liquefaciens,* that dissolves the internal organs of aquatic animals.

The *National Observer* reported on June 21, 1971: "Today, Apopka is a fetid, shallow body of water, nearly unfit for human use. Human waste is dumped into the lake from Winter Garden's sewage treatment plant. Effluent from a citrus processing plant still goes into the lake."

In the years of sewage treatment plant effluents being poured into the lake, it was inevitable that the birth control chemical, ethynylestradiol, which is excreted in urine into Winter Garden's sewage, was entering the lake. Ethynylestradiol is hormonally effective in humans at concentrations as low as 0.1 nanogram (a nanogram is a billionth of a gram). It should be expected to have estrogenic effects on alligators as well as humans.

(Since *Our Stolen Future* was published, John Sumpter, studying English

Behind the DDT Ban: Population Control

Alexander King, founder of the Malthusian Club of Rome, wrote frankly about DDT in a 1990 biographical essay: "[M]y chief quarrel with DDT in hindsight is that it has greatly added to the population problem."

The fact that DDT saved millions of lives, and that it was banned in 1972 not on the basis of the scientific evidence, but for political reasons, highlights the ideological agenda of *Our Stolen Future* and other campaigns to ban life-prolonging chemicals on the basis of bad science—or no science at all.

Environmental Protection Agency (EPA) administrator William Ruckelshaus chose to ban DDT, despite the fact that after the EPA had held seven months of hearings on DDT, the EPA hearing examiner had ruled on the basis of the scientific evidence presented that DDT should *not* be banned.

Hearing Examiner Edmund Sweeney stated: "DDT is not carcinogenic, mutagenic, or teratogenic to man [and] these uses of DDT do not have a deleterious effect on fish, birds, wildlife, or estuarine organisms." The major scientific organizations testified on behalf of continuing the use of DDT.

But EPA head Ruckelshaus never read the 9,000 pages of testimony, and he admitted later that he made the decision to ban DDT for political reasons.

A Life-saving Record

Speaking at a press conference on the 20th anniversary of the ban on DDT, May 21, 1992, in Washington, D.C., Gordon Edwards summarized DDT's life-saving record:

"DDT saved millions of human lives during the past 25 years, by controlling the insects that transmit disease to people—the mosquitoes that give us malaria, yellow fever, encephalitis and elephantiasis, the lice that transmit typhus, the flea vectors of plague, and the tsetse flies that spread African sleeping sickness and nagana. . . .

"DDT has eliminated much of the illness that formerly prevented millions of inhabitants of tropical lands from performing a good day's work. DDT permitted people to occupy and produce food in large areas of Africa, India, and Asia that were formerly uninhabitable. . . .

"DDT and other pesticides contributed heavily to the spectacular agricultural success in the United States and abroad, boosting farm productivity, raising farm income and keeping food costs low. . . .

Stuart Lewis

Gordon Edwards addressing a May 21, 1992 press conference on DDT in Washington D.C.

". . .[T]he so-called environmental groups devoted millions of dollars to the campaign *against* DDT. Their activities doomed . . . hundreds of millions of people to death from insect-borne disease, malnutrition, and starvation.

"Their lack of concern for human life was exemplified by the Sierra Club president in 1971 when he told reporters: 'The Sierra Club wants a ban on DDT, even in tropical countries where it has kept malaria under control.' Similar statements have been made by leaders of most other so-called environmental organizations. . . . The major goals of those groups [include] the decimation of humans in the Third World countries by any means possible."

rivers, has come close to identifying ethynylestradiol as an environmental estrogen affecting the fish there.)

It is remarkable that the authors of *Our Stolen Future* seek to blame traces of DDE-like compounds for "feminizing" alligators in the lake, while ignoring more likely causes.

Chlorine a Villain

A major fixation of the authors appears to be that chlorine is a villainous chemical. To the contrary, Dr. Gordon W. Gribble points out that chlorine is as natural to our world as carbon, hydrogen, or oxygen. Writing in the *American Journal of Public Health* (1994), Gribble explained that nearly 2,000 chlorinated compounds were already shown to be produced in natural environments. That includes 5 million tons of chloromethane produced annually by sources such as decaying wood, and 400,000 tons of chlorinated phenols arising from Swedish peat bogs. Such "pollution" obviously dwarfs the 26,000 tons emitted by human activities!

Gribble comments that "to conclude [as the book does] that a chemical will be toxic, just because it contains chlorine, is equivalent to believing that milk will be as toxic as nerve gas, since both contain phosphorus."

A Preference for Anecdotes

The main argument of the book rests on a stringing together of anecdotal materials like the case of super-polluted Lake Apopka. Extrapolating to the nation and the planet, the authors suggest that humanity is facing the prospect of major endocrine disruptions, as witnessed by decades of "plummeting human sperm counts" and an epidemic of undescended testicles and shrinking penises.

What ever happened to the so-called "population explosion"? Which way is the environmental extremist to turn? Are human beings too riotously fertile, or is their fertility in danger because of traces of synthetic chemicals in the environment?

The allegation of "plummeting sperm counts" is refuted by the experts:

- Macleod and Wang (1979), wrote that there was "no evidence for a decline in sperm count or semen quality in U. S. between 1938 and 1977."
- R.J. Sherins (1995), after a 30-year study, concluded "the available data show no decline in male fertility."
- Olson et al. (1995) detected "no decline in sperm counts or semen quality over the period 1970 through 1994."
- Fisch et al. (1996) found that

"sperm counts have actually increased in the last 25 years."

• Heindel et al. (1994) reported that "mixtures of fertilizers and pesticides that have been suggested to be hormone disrupting" were administered in drinking water to rodents, and "even at doses up to 100 times the average level in contaminated ground water, there were no adverse reproductive or developmental effects including no reduction in the sperm counts or male offspring."

• Dr. Alice Ottoboni, California State Toxicologist, carried out feeding experiments on rats and dogs for years and reported that "DDT makes animals much more fertile than those without DDT" (*California Health,* May 1972).

Selective Reporting

An article by Niels Skakkebaek is gleefully reported in the book as showing that "human sperm counts declined by almost 50 percent between 1938 and 1990." Three years later, Olsen et al. revealed that Skakkebaek's treatment of statistical data had been in error, and that the data for 1970 to 1990, when reanalyzed, indicated that "sperm counts have not declined, and may have increased slightly."

Sinking lower, the authors say that "British researchers report a doubling in the numbers of cases of undescended testicles in England and Wales between 1962 and 1981, and similar increases have been reported in Sweden and Hungary," but they fail to mention the finding of Berkowitz et al. (1993), that "Hospital records indicate there has been no increase in the prevalence of this disorder in the United States."

The book proposes that "As human exposure to synthetic estrogens has increased over the past half century, so has the incidence of prostate cancer," but Helzlouser et al. (1995) reported that their results "contradicted the hypothesis that exposure to DDT or PCBs causes prostate cancer." Potosky et al. pointed out in 1995 that "The data indicate the recent dramatic increase in prostate cancer is the result of increased screening," and Miller et al. concluded in 1993 that "The increase in prostate cancer death rates seems to be due to greater survival to old age, where the disease is more prevalent."

Colborn and her associates seem eager to believe that all organochlorine compounds can mimic environmental hormones, but they present no proof to support such beliefs. Dr. Stephen Safe (1995) tested the effects of organochlorine compounds in the average human diet, and concluded that "the total estrogenic activity of those compounds is 40-million-fold lower than that from the *natural* components of vegetables and other foods consumed daily."

An excellent review by Dr. Robert Golden of Environmental Risk Sciences in Washington, D.C., (1995) summed up research by numerous toxicologists and physiologists, showing that DDT, DDE, heptachlor, chlordane, and many types of PCBs have no significant estrogenic activity. He included data on *natural* environmental substances that *do* mimic normal hormones or affect natural hormones in animals.

Golden evaluated the accuracy of claims made by environmental activists such as Theo Colborn and her colleagues. He points out that estrogens exert their effects via interactions with specific receptors, and that "only a small fraction of organochlorine compounds have the necessary chemical structure to bind them even weakly with the estrogen receptors."

Golden reported that more than 300 plants, in 16 common families, contain estrogens that may bind with the receptors of humans or wildlife. Naturally occurring estrogens abound in many cereals, legumes, fruits, and tubers. The 1996 National Academy of Sciences report on *Endocrine Disrupters in the Natural Environment* lists 36 categories of natural foodstuffs that contain endocrine disrupters. The authors of *Our Stolen Future* could probably have developed more frightening endocrine disruption scenarios based on healthy human diets containing cereals, fruits, and vegetables!

How do the authors respond to these professional studies and reports? They say, "Some skeptics dismiss such concerns, arguing that the hormone effects of synthetic chemicals are far weaker than those of natural hormones and that humans are not being exposed to enough to pose a hazard." They admit to readers that "Often the needed information simply does not exist or it is unavailable." They dismiss any evidence that does not support their agenda, regardless of the potential terrible cost to society of pursuing that agenda.

The *real* "stolen future" is more likely to be represented by the millions of human lives that will be blighted as a result of books like this that rely on bad science and revel in scare-mongering rhetoric.

J. Gordon Edwards, Emeritus Professor of Entomology at San Jose State University in California, has taught biology and entomology there for nearly 50 years. He is a long-time member of the Sierra Club and the Audubon Society and is a fellow of the California Academy of Sciences.

References

G.S. Berkowitz, R.H. Lapinski, S.E. Dolgin, et al., 1993. "Prevalence and natural history of cryptorchidism," *Pediatrics,* Vol. 92, pp. 44-49.

H. Fisch, 1996. *Fertility and Sterility* (in press).

R. Golden, 1995. A review paper in the *Proceedings of the International Environmental Conference,* Book I (Atlanta: TAPPI), p. 387.

G.W. Gribble, 1994. "Natural Organohalogens," *J. Chemical Education,* Vol. 17, p. 907.

J.J. Heindel, R.E. Chapin, D.K. Gulati, et al., 1994. *Fundamental and Applied Toxicology,* Vol. 22, pp. 605-621.

K.J. Helzlouser, G.W. Comstock, A.L. Alberg, et al., 1995. "Molecular epidemiology of prostate cancer." Cancer Workshop, 1995.

J. Macleod and Y. Wang, 1979. "Male fertility potential in terms of semen quality, a review of the past, a study of the present," *Fertility and Sterility,* Vol. 31, pp. 103-116.

B.A. Miller, L.A. Ries, B.F. Hankey, et al., 1993. *SEER Cancer Statistics Review* (National Cancer Institute Publication No. 93-2789).

G.W. Olsen, K.M. Bodner, J.M. Ramlow, et al., 1995. "Have sperm counts reduced 50 percent in 50 years? A statistic model revisited." *Fertility and Sterility,* Vol. 63, pp. 887-893.

J.H. Olson, R. Birnbaum, M.N. Roseville, et al., 1995. "Semen analysis in 632 men over a 25 year period: no change in quality," *Journal of Urology,* Vol. 153, Supplement, p. 323.

A.L. Potosky, B.A. Miller, P.C. Albertsen and B.S. Kramer, 1995. "The role of increasing detection in the rising incidence of prostate cancer." *Journal of American Medical Association,* Vol. 273, pp. 548-552.

Stephen H. Safe, 1995. "Environmental estrogens and human health: Is there a problem?" *Environmental Health Perspectives,* Vol. 103, pp. 346-351.

R.J. Sherins, 1995. "Are semen quality and male fertility changing?" *New England Journal of Medicine,* Vol. 332, pp. 327-328.

William Herschel's Heavenly Music-making

by David Shavin

Sir William Herschel: Music by the Father of Modern Astronomy: First recording of orchestral chamber works by the celebrated 18th-century composer/astronomer
The Mozart Orchestra, Davis Jerome, conductor; Richard Woodhams, oboe soloist
Newport Classic, 1995, $16.99

I approached this unique CD with both delight—for the long-overdue opportunity to hear William Herschel's compositions—and trepidation, in the fear that his music would be an embarrassing letdown, compared to his scientific work.

The reader should definitely seek out this CD with both delight and confidence. Herschel's two oboe concerti here (C and E-flat major) reveal that the man must have been both an excellent oboist, and a composer with a specially fine ear for the use of woodwind color against a string chamber group—in a manner shared and perfected by Mozart within the next decade or two.

William Herschel composed these works in the 1760s, having come to England from Hanover, escaping the turmoil of the Seven Years' War. His discovery of the planet Uranus in 1781, and his lifelong scientific endeavors, reflected his conviction that the soul of man was to investigate God's creation, to come to know his Maker better, and to share in God's love in that way.

Early on, William could contrast the lacunae of Newton's theories with the more mature approach of Leibniz. Later, William ripened his education by comparing John Locke's *An Essay Concerning Human Understanding* with Leibniz's critique thereof. The influence of Schiller and Leibniz in the Herschel household is reflected in his rearing of his astronomer son, John, who:

- led the fight in England in the 1810s, to restore Leibniz's calculus (and dump the stultifying Newtonian imposition);
- translated some works of Schiller into English, not being satisfied with what was on the market; and
- fought for a proper, scientific tuning of the musical pitch of middle C at 256 cycles per second.

The musicality, grace, and humor, reflected in the third Herschel offering on the CD, his "Chamber Symphony in F," confirms in music, what I had suspected from anecdotes of his life. Even though he ground lenses and observed the heavens for hours upon hours, laboriously toiling for his genius, his musical product seems to be an effortless outflowing of the man's humanity.

One anecdote has Herschel wanting to direct the city of Bath's musical culture, instead of merely participating as a performing oboist or violinist. He decided to win the required organ competition, though having only a few weeks to learn. He persuaded a local organist in the town to allow him access to the organ. A few weeks of applied effort tuned his powerful and well-prepared mind and personality to the task, and he won the competition over those who had spent more time with fewer results.

Again, having won the position, and needing assistance, he recruited a sister, Caroline, from Hanover, who had been left without any formal education, and destined to keep house. As a child, Caroline had helped their father with the logistics of his violin concerts. She claimed that, from listening to his violin, "I had gained a tolerable execution [in singing] before I knew how to sing." She quickly became the leading solo singer at Bath, and assimilated running the chorus.

Before long, Caroline Herschel also shared with her brother the grinding of lenses, the extensive calculations, and the exploration of the heavens. Leibniz's "least action" was more than a principle for the Herschels.

This CD concludes with a fourth offering, Joseph Haydn's Symphony No. 23, which was chosen for comparison, having been written in 1764. It makes the point. As of the 1760s, Herschel is near the top of his class. One could certainly wish that Herschel could have participated in the revolutionary developments engineered by Haydn and Mozart in the next two decades. And in his own extramusical way, he did.

As it happens, Herschel and Haydn meet in 1792, during Haydn's visit to England. Haydn is insistent that he must peer through Herschel's amazing machine, the large telescope that he constructed to explore the shape and construction of the heavens. It is hard to imagine that this experience for Haydn did not shape his late work, "The Creation."

Dr. Davis Jerome, professor of music at Rutgers University, Camden, N.J., has done the world a favor in finally recording these three works of William Herschel. Jerome draws a tasteful and enlivened sound from this modest ensemble. The oboe soloist, Richard Woodhams, has found for his listeners a good deal of music-making in Herschel's manuscript. One must believe that he has come pretty close to how William Herschel heard and performed his own works.

A Nuclear Film Worth Seeing

Atoms for Peace
The New Explorers Series
Chicago: Public Media Education, 1996
(800) 323-4222
Videotape, 57 minutes, $19.95

So few films even attempt a fair portrayal of nuclear energy, that a film like "Atoms for Peace" bowls you over, despite its imperfections. Narrated by Bill Kurtis, the host of the New Explorers Series, the film begins with the idea that after 50 years, the atomic age is finally

ready to begin. The example given is the use of a radioactive weapon—to destroy a cancerous tumor.

The film recaps the Manhattan Project and the dream of scientists to use atomic power for peace: a dream to save the world. The main theme centers on the second generation of nuclear scientists, like Charles Till at Argonne National Laboratory in Illinois, who have pursued a quest for a perfect reactor for the past three decades. Interwoven with the story of the breakthroughs in the development of the Integral Fast Reactor (IFR), a breeder reactor developed at Argonne, is the news of how the IFR was killed politically and is now shut down, despite its promise.

There is some fascinating historical film footage. You see Mamie Eisenhower launch the *Nautilus,* the first nuclear-powered submarine, in June 1952. You see President Eisenhower speaking at the United Nations in 1953 to launch the Atoms for Peace program. President Kennedy is shown at the Hanford Nuclear Reservation in 1963, making a stirring call for use of low-cost atomic power to "strike a blow for peace . . . and a better life for all citizens."

The film discusses in a lively fashion the technical problems that were solved in the course of the Argonne work on the IFR. Then it documents the betrayal of the Atoms for Peace dream. It is in the explanation of why things went wrong that the film is flawed. Author Richard Rhodes, for example, treats nuclear as a "classic tech fad," and attributes its demise to "old-fashioned economics."

In all, "Atoms for Peace" is worth seeing, and is a good film to put in local libraries and schools.

—Marjorie Mazel Hecht

A Timely Guide to Mars

Strategies for Mars: A Guide to Human Exploration
Carol R. Stoker and Carter Emmart, editors
San Diego: Univelt Inc., 1996
Paperback, 619 pages, $33.75

The American Astronautical Society's newly published compilation of papers about the human exporation of Mars could not come at a better time: The Aug. 7 announcement that scientists have discovered what they believe are fossil remains of early life on Mars, has spurred increased interest in the red planet.

The book is dedicated to the late Dr. Tom Paine, who was the administrator of NASA when the United States landed men on the Moon, and who continued throughout his life to organize public support for sending human beings to Mars. The book is illustrated by co-editor Carter Emmart, who painted the illustration of a fusion-propelled manned mission to Mars for the premier issue of *21st Century* in 1988.

Chapters include discussions of why we should go to Mars, and the transportation, life support, and biomedical issues involved in getting and staying there. One section of the book presents concepts for using Martian resources, and another, the scientific objectives of manned exploration. The book includes a 1992 presentation by Dr. Paine on Mars colonization.

—Marsha Freeman

Catch Up with 21st CENTURY SCIENCE & TECHNOLOGY

Back issues of *21st Century* are available at $5 each ($6 foreign)—while copies last. Send check or money order (U.S. currency only) with date of issues requested to *21st Century,* P.O. Box 16285, Washington, D.C. 20041.

1989

September-October

"How Space Technology Makes Us Healthier" *Marsha Freeman*

"Environmental Pollution and the Causes of Human Cancer" *Bruce N. Ames*

Despite all the scare stories about carcinogens, Americans are healthier than they ever have been. An expert on cancer causation sets the record straight on six of the most frequent errors about pollution and cancer.

"Gaia: Ecologists Embrace the Earth Goddess" *Rogelio A. Maduro*

1990

Summer

"Mining Helium on the Moon to Power the Earth" *Marsha Freeman*

As the world approaches the 21st century, vast increases in total energy production and consumption per capita are required. Helium-3, sitting on the surface of the Moon, can fuel the greatest period of economic development in mankind's history.

"'Mind Bombs': Putting Greenpeace in Perspective" *Ellen Chance*

"We fire images rather than missiles—mind bombs delivered by the world media." Think about this self-description of Greenpeace the next time you get a "save the dolphins" mailing from this $87-million-a-year environmentalist multinational, whose propaganda campaigns stab at the heart of Western civilization.

"Don't Bury Nuclear Waste: Recycle and Reprocess It!" *An interview with nuclear scientist Michael Fox*

1991

Spring

"Fission and the Breakthrough of Women in Fundamental Scientific Research" *Jonathan Tennenbaum*

Radical feminists and others who fear nuclear energy, and technology in general, should take a lesson from the women who founded nuclear science.

"How Nuclear Fission Was Really Discovered" *Jonathan Tennenbaum*

For years, students had been taught that the fission of uranium was physically impossible. Nuclear chemist Ida Noddack objected, but her voice was ignored for 5 years—until Hahn and Strassmann's "discovery" of 1938-1939.

"LaRouche's 'Oasis Plan': The Only Real Basis for Mideast Peace"

Economist Lyndon LaRouche's Grand Design for regional infrastructure development, first proposed 15 years ago, is still the only way to build a stable peace in the Mideast.

"Hyperbolic Functions, the Catenary, and the Human Mind" *Carol White*

"A New Look at Negative Curvature: Applying Beltrami's Geometry to Astrophysics" *Charles B. Stevens*

1993

Spring

"Ole Romer and the Discovery of the Speed of Light" *Poul Rasmussen*

"Are Soap Bubbles Smarter Than You Are?" *Raynald Rouleau*

"Nuclear Report: 50 Years of Fission" *Marjorie Mazel Hecht*

"Hanford Workers' Health and the Decline of Scientific Debate" *Michael Fox*

"Food Irradiation and Biotechnology Necessary to 'Protect People' " *An Interview with Julia Child*

"The Third International Cold Fusion Conference: Solid State Fusion Comes of Age" *Carol White*

Fall

"Hermann Oberth: The Father of Space Travel" *Marsha Freeman*

"Reviving de Broglie's Wave-Particle Synthesis" *Philippe Guéret*

"What's Wrong with Hawking's Theory of Time and Space?" *B.A. Soldano, Ph.D.*

"Virginia Political Vendetta to Jail *21st Century* Editor" *Interview with Laurence and Marjorie Hecht*

1994

Summer

"Recapturing the Promise of Apollo" *Marsha Freeman*

"Plutonium As a Resource Now and in the Future" *Dr. Dixy Lee Ray*

"An Economist's View of Gauss's 'Pentagramma Mirificum' " *Lyndon H. LaRouche, Jr.*

The last 600 years of scientific and cultural development would not have been possible had the great thinkers of the 15th century used the methods that dominate economics today.

1995

Spring

"It's Time to Bury Darwin and Get On With Real Science" *Carol Huginin*

"The Breeder Reactor—Affordable Energy Forever" *Bernard L. Cohen*

"Great Projects Are the Path to Global Economic Recovery" *Lyndon H. LaRouche, Jr.*

Summer

"A Tragedy of Science: The Life of Max Planck" *Caroline Hartmann*

"Hubble's Quasar Images: A Moment of Truth" *David Cherry*

"From Hot to Cold Fusion: A Look at the Life of Yoshiaka Arata" *Carol White*

"Special Report: A Warning on the 'Wise Use' Movement"

Fall

"Eureka! Rediscovering the Method of Archimedes" *Bob Robinson*

"Kenneth Arrow Runs Out of Ideas, But Not Words" *Lyndon H. LaRouche, Jr.*

An exposé of *Science* magazine's promotion of environmentalist mumbo-jumbo as peer-reviewed objective science.

"The 5th International Cold Fusion Conference: Slow, Steady Progress and Some Fast Talk" *Carol White*

"Court Affirms Greenpeace Ties to Earth First! Terrorists"

Winter

"Johannes Kepler's *Mysterium Cosmographicum:* A Guide to the Harmony of the Mind and the Universe" *Ralf Schauerhammer*

"Riemann Refutes Euler" *Lyndon H. LaRouche, Jr.*

"Philosophical Fragments" *Bernhard Riemann* (First English Translation)

The Darwin Debate:

"In Defense of Darwin" *Karol Sabath*

"Bury Darwin—It's Overdue" *Carol Hugunin*

"A Master Polyhedra Builder Demonstrates His Art" *Charles Stevens*

In This Issue:

THE REAL ROOTS OF ATOMIC SCIENCE

In an 1845 letter, Carl Friedrich Gauss advised his collaborator, Wilhelm Weber, not to reject Ampère's hypothesis of a tiny electrical force acting between invisible atomic particles. The subsequent electrodynamic researches of Gauss, Weber, and Bernhard Riemann defined the precise relationships for such modern atomic concepts as classical electron radius and proton-electron mass ratio, half a century before their empirical determination. The suppression of the Gauss-Weber tradition, in favor of the conceptually inferior Faraday-Maxwell electrical theories, buried this knowledge along with its discoverers.

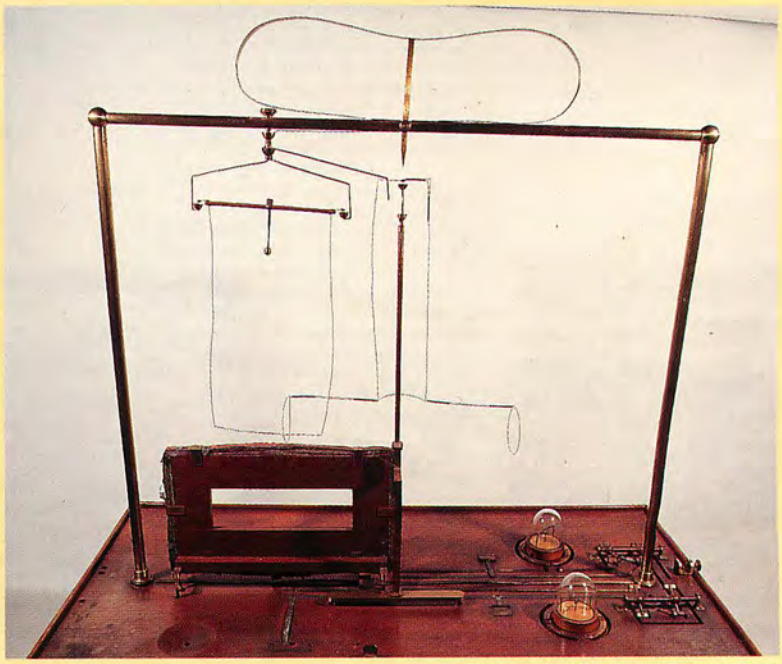
Here, for the first time, Laurence Hecht reveals the true early history of atomic science. And, in a special editorial commentary, Jonathan Tennenbaum shows how the Gauss-Weber research collaboration uniquely embodies the nearly forgotten method underlying all of science.

Chris Lewis

At the back of the statue of Gauss and Weber (see front cover) Weber's hand rests on a telegraph sending unit, which he and Gauss built in 1833. This electromagnetic telegraph, the world's first, transmitted messages over a distance of about 1 kilometer, from the Göttingen University Observatory to the Physics Building.

Chris Lewis

Jonathan Tennenbaum with two of Weber's electrodynamometers, kept in working order at the Historical Collection of Göttingen University's I. Physical Institute. Tennenbaum, who heads the Fusion Energy Foundation in Europe, visited Göttingen University in July 1996.



Courtesy of the Deutsches Museum, Munich

An apparatus designed by H. Pixii in 1824, for the purpose of replicating many of Ampère's electrodynamic experiments. It is on display at the Deutsches Museum in Munich.