EIR Science & Technology

How Fresnel and Ampère launched a scientific revolution

This presentation by Jonathan Tennenbaum on "The Drama of Cognition," was given to the Schiller Institute's summer seminar in Oberwesel, Germany on July 24.

This presentation was composed on the basis of research by Laurence Hecht in the United States, Jacques Cheminade, Pierre Bonnefoy, and Christine Bierre in France, and Dino de Paoli and Jonathan Tennenbaum in Germany. Original quotes were read by different speakers, heightening the dramatic effect of the presentation. The importance of the Fresnel-Ampère collaboration, which is the immediate subject of the presentation, first came to light thanks to the groundbreaking work of Laurence Hecht,[1] carried out during his long incarceration as a political prisoner in Virginia. In a recent article,[2] Lyndon LaRouche had called attention to the broader significance of the matters addressed here, to the situation of the world today.

I. A French overture

We are in France, after 1815. The ruling powers of Europe, sponsored by London and Venice, have smashed and bled the French armies to death. The monsters of the Revolution have devoured their sons. Following the self-destructive rage of the Jacobins rallied behind the outcry "the Republic does not need scientists," and the murderous Bonapartist revival of the Roman legions, the monarchist Restoration is now falling upon the defeated country. The scene is filled with aristocrats running after their lost privileges and bourgeois financiers seeking to keep their new ones. Legitimists, Orléanists and rallied Bonapartists play the game of the purse and the coat of arms, while the living dead dance at the Congress of Vienna, the hand of vice patting the head of crime.

A romantic lust for pleasure and pain and, worse, the unpleasant habit of talking endlessly about it, have replaced the joy of acting, discovering and creating. Lazare Carnot and Gilbert de Lafayette have lost their battle to create humanist republics over the world, following the example of the American Revolution, and the British system rules over world trade and finances.

Science is being willfully destroyed, because for such oligarchical regimes, the very existence of truth and human reason is a threat. Napoleon had sponsored a "science" without God: when he asked Marquis de Laplace, why Laplace did not mention God in his monumental work, *Méchanique Célèste,* Laplace told him, "Sire, je n'avais pas besoin de cette hypothèse" ("Sir, I didn't need that hypothesis"). But the aristocrats now dreamt of a God without science. It amounts, of course, to the same: no God and no science altogether.

After Napoleon had let the scientific elite from the Ecole Polytechnique be butchered on his battlefields, now the Restoration was organizing a drastic cleansing of what was left at the Ecole, shutting it down temporarily to eliminate all scientists suspected of republicanism, leaving inside only the Newtonians and the Cartesians.

Your "choice" is either to pretend to make no hypotheses at all, like Newton, and be an empiricist in a void and endlessly abstract space-time filled with balls, or to be a Cartesian filling space with inert fluids and pretending that such constructs are obvious truths.

In both cases, so-called "science" is limited to measuring the known within an established system. Therefore you don't need the hypothesis of God or any hypothesis at all, because you limit yourself, under that name of "science," to do what

1. Laurence Hecht, et al., "The Significance of the 1845 Gauss-Weber Correspondence," *21st Century Science & Technology,* Fall 1996; and Hecht, "Optical Theory in the 19th Century, and the Truth about Michelson-Morley-Miller," *21st Century Science & Technology,* Spring 1998.

2. Lyndon H. LaRouche, Jr., "How to Save a Dying U.S.A.," *EIR,* July 16, 1999.



"Ampère, together with Fresnel," says Tennenbaum, "contributed decisively to breaking the authority of the Laplacian neo-Newtonianism and loosening the oligarchical grip on European science sufficiently, to make possible the 19th-century revolution in physical science. To do this, they exploited a key flank: the stupidity the 'standard methods' imposed by Laplace, which made the Laplacians highly vulnerable to attack." Left to right: Augustin Fresnel, André-Marie Ampère, Pierre Simon Laplace.

you are supposed to do: to find only what is consistent with the system, which means discovering nothing. If you want to go beyond and understand the *raison d'être* of your universe, you do need a God; but now it becomes an arbitrary God, like a despot on Earth. So in France, it is the no-God of the Newtonian Laplace put together with the arbitrary God of the Cartesian oligarchs, a marriage of convenience like that of an aristocrat's son and a financier's daughter.

So, the scientists are condemned to be learned donkeys. And indeed, if you listen to the discussions of those then leading the Académie des Sciences, the Institut, or the Ecole in those years—the Laplaces, Biots, Bertholléts, Charles, Maurices, or Poissons—you see a degeneration of science into endless calculations, synoptic charts and equations, where nobody has the "bad taste" to question an axiom. These gentlemen are too serious to indulge in such things as poetry or music, and make a point not to do so: They are objective and emotionless, like perfect oligarchical servants, Kantian robots.

This is France after 1815: The rules of the game are set; dualism and British "science" rule, and creativity is killed for good. At least, that is what the world looks like *inside* the system.

Fortunately, human beings cannot all be held in a mental cage for very long; the power of people for receiving and imparting profound and impassioned conceptions respecting man and nature cannot be killed. So in 1815 France, we find a man in his thirties, who has been educated a bit wildly, but outside the system, a genius who sees science and poetry as an inseparable unity. We find another man, in his twenties, writing outrageously to his younger brother: "I like to do research, but studies bore me."

Both are looking for a flank to smash the Newtonian-Cartesian oligarchy. The older one is perhaps more thoughtful, he looks more into his own mental processes, while the younger one is audacious, a dreamer who looks to the stars. It is a good pair. They are ready to plunge joyfully in the unknown. Light and electromagnetism: They meet and work together, with a few others, to make hypotheses and break the rules of the game.

So now the curtain opens.

II. Newton's 'Opticks'

Isaac Newton: "I frame no hypotheses; for whatever is not deduced from the phenomena is to be called a hypothesis, and hypotheses, whether metaphysical or physical, whether occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena and afterwards rendered general by induction."

This is the famous dictum of Newton, written in his *Opticks,* published in 1704. In no country, not even England, is the cult of Newton so extreme and so fanatical as in France, thanks to the influence of the evil Voltaire and the Venetianrun salons, codified in the mathematics of Euler and Lagrange, and now enforced by the pompous Marquis de Laplace, the politically dominant figure in French science since Napoleon's 1799 militarization of the Ecole Polytechnique.

And yet, Newton's claim of laws "deduced from the phenomena" is a fraud. Newton's entire scheme of physics, like that of Descartes, was based on the most simplistic sort of unproven hypothesis concerning the nature of matter and space. Newton assumed as self-evident, that the universe is composed of discrete mass-points or inert, hard particles moving around in an infinite, empty Euclidean three-dimensional space, and assumed the latter to be a perfectly continuous, infinitely divisible entity in which the most elementary forms of existence are the point and straight line. All a hypothesis, completely unproved and by no means "deduced from the phenomena," yet more or less believed by most people even today.

Superficially the Newtonian system seemed opposed to Descartes. While Newton emphasized point-like particles in an otherwise empty space. Descartes considered space as filled with or even constituted by a continuous sort of matter or fluid. But both, in essence, rested upon the same *kind* of fixed, aprioristic assumptions about the nature of matter and space.

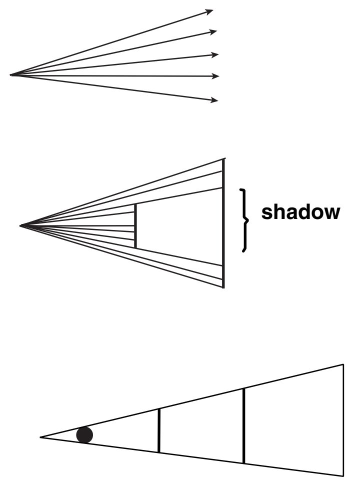
At the turn of the 19th century, Descartes and Newton's ideas were mixed in a very confused way: Many "fluids" were invented, sometimes considered continuous, sometimes considered as composed of particles: a heat fluid (caloric), electric fluids, magnetic fluids; plus electric particles, chemical particles, light particles etc., etc. with various sorts of "forces" acting between them.

Pierre Simon Laplace and Jean-Baptiste Biot, like Louis de Lagrange and Leonhard Euler before them, were not much concerned with whether all or any of these particles, fluids, or forces really existed; the essential thing was the establishment of a "standard procedure" for the elaboration of science based on the mathematical formalism provided by Euler and Lagrange. In fact, the whole manner of presentation in science textbooks today, the whole image of science and of "standard, accepted theory," was established in large part through the influence of Laplace and his gang, including Denis Poisson (Laplace's mathematical lackey, who was made into a baron by Napoleon) and Biot (a notorious plagiarist who acted as Laplace's dirty-tricks agent). We shall meet these two in short order.

But there was resistance to this Laplacian program. After the banishing of Monge and Carnot, one of its key rally-points became the brilliant André-Marie Ampère, who, more than any other contemporary French scientist, aspired to be a universal thinker, contributing to philosophy, physics, chemistry, biology, mathematics, and other fields. He, together with Fresnel, contributed decisively to breaking the authority of the Laplacian neo-Newtonianism and loosening the oligarchical grip on European science sufficiently, to make possible the 19th-century revolution in physical science.

FIGURE 1

Newton's concept of the propagation of light: Straight-line light rays—what could be simpler?



According to Newton, the shadow changes only in size, linearly, with distance.

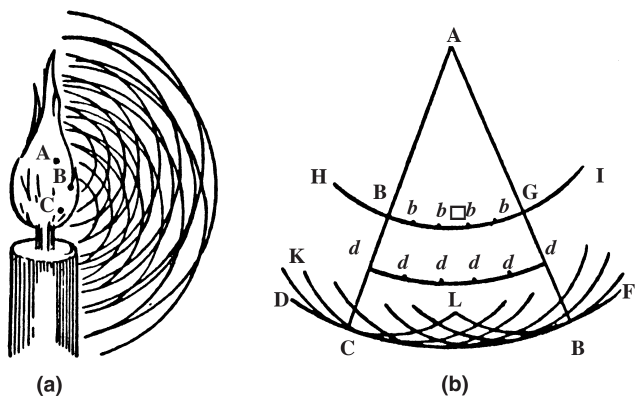
To do this, they exploited a key flank: the stupidity the "standard methods" imposed by Laplace, which made the Laplacians highly vulnerable to attack.

The most exposed flank, in experimental physics, was optics. Voltaire had made Newton's *Opticks* the key to his promotion of Newtonianism as a kind of popular religion in France, as had Algarotti in his famous salon popularization *Newton for Ladies*. Nothing appealed more to banal popular taste. First of all, light propagates in lines called rays—what can be more obvious and self-evident? (See **Figure 1.**) And very plausible, the idea that such rays are streams of tiny particles emitted by the luminous bodies (the sources of light), and travelling very fast in straight lines through space. Newton tried to explain the diffraction, i.e., the fact that light rays are bent in passing between different media—for example between air and water—by ascribing such bending to attractive and repulsive forces acting between the light particles and the particles of the media. This, in essence, is Newton's "emission theory."

Very significantly, Newton developed this scheme *after* a much more advanced theory of light had been elaborated and published by Leibniz's friend and collaborator Christian Huygens, building on the work of Roemer and Bernoulli, and the conceptions of Leonardo da Vinci.

According to Huygens's *Traité de la Lumière* (*Treatise on Light*), written in 1678, light is a form of action which reproduces itself in the act of propagating (**Figure 2**). Huy-

FIGURE 2
Huygens's envelope construction for light



In Huygens's conception, light setting out from any point forms wave fronts which are like expanding concentric spheres. In Figure 2(a), taken from his Treatise on Light, *the wave fronts from points A, B, and C of a candle flame are pictured. In Figure 2(b) he shows how these waves can cooperate to form an "envelope" along the wave front DF, and how, along a radial line such as AC, they could have the appearance of a straight ray.*

gens proposed that the "reproductive cycle"—if I might use that term—takes essentially the following form: At any given stage the action is concentrated on a surface in space, a wave-front. In the immediate next stage, a spherical wavelet (tiny secondary wave) is generated at each point on the wave-front. The *envelope* of those myriad secondary waves, forms the new wave-front. And then this process repeats in a new cycle of wavelet generation and envelope-formation.

Newton's *Opticks* was, from beginning to end, a violent attack on the Leibnizian conception of science and on Huygens's work in particular. Among other things, he put forward experiments and arguments by which he claimed to refute Huygens conception and put forward what appeared to be a much simpler explanation of the phenomena.

Among Newton's objections to Huygens, two were most influential. First, everyone knows that light is composed of rays, and we can form very narrow beams of light moving only straight ahead. So, it doesn't seem at all like a wave which naturally spreads out in all directions. And secondly, more specifically, Newton argued that if Huygens's conception were true, there could be no true shadows; because once a wave-front passes an object, the edges of the wave-front, "cut off" by the objects, would begin to generate spherical wavelets, and the next wave-fronts would propagate more and more into the space behind the object. But everyone knows that it is dark in a shadow!

Although Newton's *Opticks* had numerous glaring errors, the enormous authority given to Newton by the Venetian salons, which made him almost into a god, resulted in virtually burying Huygens's work. In fact, the spread of Newtonianism effectively blocked all progress in optics for one hundred years. Those who raised objections, such as Thomas Young, in England itself, at the beginning of the 19th century, were ruthlessly suppressed. In France, Laplace and Biot, particularly, insisted on Newton against Huygens. Even Ampère, who was inwardly opposed to the fanatical Newtonianism, publicly supported the emission theory.

II. Augustin Fresnel

Augustin Fresnel was born in Broglie in 1788. Fresnel's father was closely allied with the leading anti-British military leader of France [see the contribution of Jacques Cheminade, in this section]. Augustin Fresnel entered the famous Ecole Polytechnique in 1804. His uncle Léonor Mérimée, a well-known painter and teacher of drawing at the Ecole—which featured the study of Leonardo da Vinci's drawings—as well as permanent secretary of the Ecole des Beaux Arts, introduced him to François Arago and Ampère. In 1806 Fresnel entered the civilian engineering corps of the Ecole des Ponts et Chaussées, and then was assigned to manage infrastructure projects in the provinces. But the demands of his profession as an engineer did not dampen Fresnel's passion for scientific research, which he had acquired especially during his studies at the Ecole Polytechnique. In his notebooks of the time, we find on each page, beside calculations and drawings for construction projects, all sorts of objections to the optical theories of Newton, hypotheses and calculations on wave motion, on heat and light, and the molecular constitution of bodies.

In a letter to his brother Léonor on July 5, 1814, Fresnel writes:

"I permit myself certain doubts about the theory of the caloric (heat fluid) and light. . . . According to Newton's system, the molecules of light arrive to us from luminous bodies by being emitted radially. But is it not probable that, in the body which emits light, the light molecules would be emitted with different, greater or lesser speeds, since they are emitted under different circumstances, some with greater force than others? But light rays of a given color all bend in the same way, and it follows from that, that the differences in color come from differences in speed. But from this it would follow, that the first rays which would arrive to us after an eclipse of the Sun, would be the red ones. . . . But we know from experience that this does not happen.

"Try to get yourself out of that one, or extricate me. You are in the society of scientists; if you can't answer by yourself, you can get them to help you smash my objections.

"In the meantime, I must say that I am very tempted to believe that light and heat are transmitted by the vibrations of some fluid. That would explain the uniformity of the speed of light in the same way as that of sound; and in the disturbances of equilibrium of that fluid one may perhaps find the cause of electric phenomena. We will be able to understand easily why a body can lose so much heat without losing weight, and

The author (left), with Lyndon H. LaRouche, Jr. Tennenbaum told his audience at Oberwesel that, through the work of LaRouche, "the revolution launched by Fresnel and Ampère's brilliant flanking operation, leads all the way into this room, to you, dear listeners."

why the Sun can illuminate us for so long without becoming smaller, etc."

Now, although Fresnel speaks about a vibrating fluid, and the analogy of light and sound waves, his thinking is already invigorated by a sense that these phenomena are not so *simple* as naive imagination imagines a water wave, for example, to be. For this reason he is especially fascinated by the phenomenon of "polarization," which had been discovered a few years earlier by Etienne Louis Malus. Writing again to his brother Léonor on July 11, 1814, Fresnel says:

"Please keep me informed about what is known concerning the polarization of light. You cannot imagine how curious I am to know what it is. . . ."

In the winter of 1814, Fresnel wrote down his speculations about the propagation of light in a lengthy memorandum that he called his "reveries" or dreams. He asked his uncle, Léonor Mérimée, to transmit the memorandum to Ampère. For a long time there was no response, and the anxious young scientist wrote to his brother on Nov. 3, 1814:

"My dear friend, tell me now what has become of my uncle. It now more than a month since I sent him a big memorandum with my reveries, and he has still not answered. I begged him to ask Ampère what he had to answer the various questions and objections which I raised. Ampère and my uncle are usually so obliging, that their silence surprises me."

Mérimée wrote back implying that Ampère was in a delicate position, just about to be admitted as a member of the Institut National des Sciences. Also, at that time Ampère himself, at least publicly, adhered to Newton's emission theory.

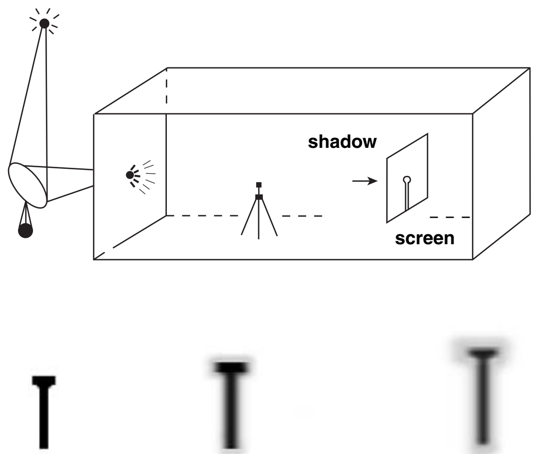
In April 1815, at the time of Napoleon's famous One Hundred Days, Fresnel, whose anti-Napoleon political background was well known, was suspended from his responsibilities in Nyons and placed under police surveillance. He immediately made use of the new, forced leisure to intensify his researches on light, and for the first time he was able to carry out experiments to test the hypotheses he had developed entirely on his own. Now he concentrated all his efforts on developing a decisive experimental refutation of Newton. With some relatively simple instruments which he had had made by the village machinist, he went to work.

Soon he found what he was looking for—a new whole set of anomalies, phenomena which could not happen, if Newton's doctrine of linear emission of light were true. At the same time, Fresnel was developing his own hypothesis, a new physical principle.

Fresnel chose as the subject of his experiments the apparently most simple thing of all, from a Newtonian standpoint—the way light casts *shadows*. Imagine the simplest source of light—a tiny luminous point sending light particles out in straight-line rays. We put an object in front of this source and a white screen behind it. The rays that strike the object, are either absorbed or bounce back, but do not arrive at the screen. The particles which do not hit the object, continue their straight-line motion until they strike the screen, illuminating those areas. So, the object will project a perfectly dark, perfectly sharp shadow on the screen. So says Newton.

Now everyone has noticed that in real life, the shadows cast by objects are not perfectly dark, nor are the boundaries

FIGURE 3
Schematic representation of a Fresnel experiment



completely sharp. This blurring of shadows is mainly caused by the fact that light normally comes from many directions; the source of light is not a simple point, and light is reflected into the shadow by other objects. To eliminate these disturbing factors, Fresnel did his experiments in a well-darkened room and worked with a very tiny, almost point-like source of light (**Figure 3**). His source of light for the experiments was a tiny hole, only about a tenth of a millimeter in radius, through which light from the Sun was admitted into the room. To make the tiny point of light as bright as possible, Fresnel used a mirror and lens to focus the sunlight onto the hole from the outside. Sometimes he used the sunlight directly, but sometimes he put a filter in between, in order to obtain light of a single color. Inside the dark room, at a certain distance from the hole, he set up various objects, and examined the shadows cast by those objects onto a white cardboard screen. He also moved the screen back and forth, closer or farther away from the objects, to see how the shadow changed.

Now, already Grimaldi in 1665 and later Newton had done very similar experiments with shadows cast by sunlight passing through a tiny hole. Grimaldi had noted an anomaly: The outlines of the shadow are not perfectly sharp, but there appear some faint, but otherwise unmistakable light-and-dark bands near the edges of the shadow. Newton, on the other hand, did not seem to notice this phenomenon; instead, he made a big point of emphasizing, that although some rays of light might be bent outward when passing very near the object no light rays go into the shadow. Newton wrote, in fact, in Question 29 of his *Opticks:*

"Are not the rays of light very small bodies emitted from luminous substances? For such bodies will pass through uniform media in straight lines without bending into the shadow, which is the nature of rays of light."

Now let us hear Fresnel describe his early experiments:

"In order to make the phenomenon as simple as possible, I have reduced the size of the luminous point as far as possible; and yet, nevertheless, I have observed that the shadows cast never end sharply, as they should, if light only propagates in its originally given direction. One sees that light spreads into the shadow, and it is difficult to identify a point where it stops. . . . Using a powerful magnifying glass I have seen light as far as in the middle of the shadow of a ruler two centimeters wide."

So, Newton's statement, that light rays never bend into a shadow, is *wrong!* The boundaries of the shadow are not simple lines, but *regions,* which can extend all the way into the middle of the shadow. But there is much more. Examining the shadows of various objects, especially of a piece of thick wire, Fresnel observed *light and dark colored bands*—fringes!—in the shadow as well as outside the shadow. Fresnel remarks, ironically:

"It is hard to conceive how the inflexion of light into the interior of shadows could have escaped notice by such a capable observer as Newton, especially when one remembers that Newton had done experiments with very narrow objects, since he even used strands of hair. One is tempted to believe that his theoretical taboos contributed to a certain extent to close his eyes against these important phenomena, which greatly weaken the main objection upon which he based the superiority of his system.

"According to the emission theory, nothing could be simpler than the phenomenon of shadows cast by objects, above all when the source of light is reduced to a luminous point; and yet, *nothing is so complicated!* Supposing that the surfaces of bodies possess a repulsive force capable of changing the direction of the light rays which passed nearby, one would expect just to see the shadows grow in size and to merge their outlines a bit with the light part. On the contrary, the shadows are surrounded by three very distinct colored fringes, and by an even much larger number of dark and light bands when we use essentially homogeneous (monochromatic) light."

Now, as I mentioned, Fresnel was not the first to discover those bands or fringes around shadows; Grimaldi had described them clearly in 1665, and given the name "diffraction" to this new phenomenon of propagation of light. Newton overlooked or ignored them. A century later, in 1801 the Englishman Thomas Young, who became interested in the question of light while studying sound and the generation of the human voice at Göttigen University, had also observed the fringes in shadows in various experiments, and concluded that Newton's emission theory was wrong. Although Young did not go as far as Fresnel and his wave hypothesis was much less rigorous, he was viciously attacked in England and his work was virtually suppressed.

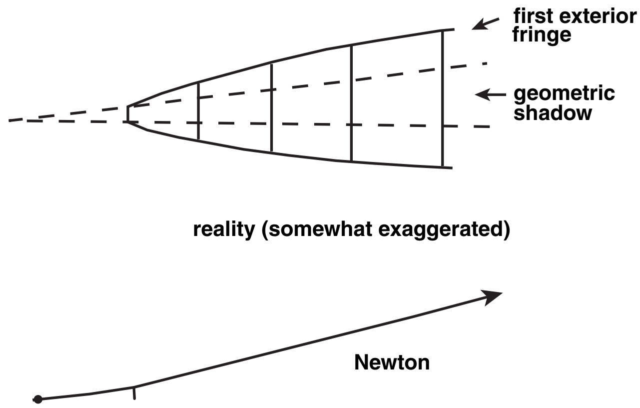
Now, just empirical evidence by itself never decides scientific disputes. And the neo-Newtonians will answer—as Laplace and Biot actually did, subsequently, with very elaborate mathematical arguments—that the appearance of the bands and the apparent bending of some light into the shadow, are due to deflection of some of the rays passing close to the surface of the object, as a result of attractive and repulsive forces between the particles of light and the atoms of the object. But now Fresnel made a decisive observation, which was one of those very small things, which others would have overlooked, but whose fundamental significance Fresnel immediately seized upon, as reflecting a new physical principle.

Fresnel concentrated his attention on the first band just outside the edge of the shadow, and watched how it changed its width and position as he moved the cardboard screen back away from the object. If the bands were caused by a deflection of some of the rays passing near the object, and if—as the Newtonians insist—the rays continue on in straight lines, then the bands themselves must propagate in straight lines, and the spacing and width of the bands must grow linearly as we move the screen backward. Fresnel writes:

"Having assured myself that the first fringe originally starts from the edges of the wire [the object used to cast the shadow—JBT], and believing that the fringe propagated in a straight line, [I tried to] estimate the angle of diffraction. . . . I noticed that the angle of diffraction, after having progressively diminished up to a certain point, began to grow afterwards. . . . I attributed this [at first] to the imprecision of my observations.

"However, since I had already noted a similar anomaly in another series of experiments, I suspected that the distance at which I placed the screen had an influence on the angle of diffraction; or in other words that the first fringe does not propagate in a straight line [**Figure 4**]. This is what I later became sure of, on the basis of observations that were so precise, that they left no room for any doubt on this point."

FIGURE 4
Propagation of fringes in Fresnel's experiment



Fresnel demonstrated that the exterior fringes propagate in parabolic curves, which is inexplicable from the standpoint of any Newtonian notion that fringes might be due to the bending of light rays at the edges of the object.

Very strange! If the bands are not caused by bending of the rays, then how are they created? Now Fresnel makes a key step which, as he said, led him to "the true theory of diffraction." Not concealing his excitement and suspense, he writes:

Fresnel: "For a long time I restricted myself to the exterior fringes, which are the easiest to observe, without paying attention to the interior ones. It is these, however, which finally led me to the explanation of the phenomenon.

"Already a few times before, I had pasted a small square of black paper to one side of the iron wire which I used for my experiments, and I always saw the fringes in the interior of the shadow disappear on account of the paper; but at that time, I was only paying attention to the effect on the external fringes, and thereby in a sense deprived myself of the remarkable insight which this phenomenon was leading me toward.

"It only struck me when I turned to the interior fringes, and at that moment I immediately had the following thought: If intercepting the light on *one* side of the wire made the interior fringes disappear, then the combination of rays arriving from both sides of the wire at the same time, must be necessary to the production of those fringes.

"They could not arise from a simple mixture of the rays, since each side of the wire, taken separately, only casts a continuous light into the shadow; it is therefore the encounter, the *intersection* itself of the rays which produces the fringes. This conclusion is completely opposed to the hypothesis of Newton, and confirms the theory of vibrations. We can easily imagine how the vibrations of the two rays, coming together at a small angle, can cancel each other, when the crests of the one coincide with the valleys of the other. . . . A very remarkable consequence of this theory of diffraction is, that a given fringe does not propagate in a straight line, but according to a hyperbola. . . ."

What Fresnel is saying, is that the bands are not caused by bending of rays of light. In fact, he is implying that light does not propagate in rays at all, light rays don't exist, except as a gross effect on the macroscopic scale. On the *microscopic* scale there are no light rays! What happens, is that the fringes are *generated* behind the object, by a complex process of multiply-connected rotational action.

Later, Louis de Broglie, a descendant of the anti-British de Broglie family to which Fresnel's father was closely attached, asserted the same thing for so-called particles. The supposed trajectory of an electron, for example, in the sense Newton pictured such a supposedly elementary particle, does not really exist any more than a ray of light does. All the effects associated with so-called elementary particles are "holographic," just as Fresnel demonstrated this to be the case for light.

What was Fresnel's theory? Fresnel started with the conception which Christian Huygens had developed, what Fresnel called the Huygens principle, and added an important correction and a new dimension.

Huygens indicated that he conceived of the generation of the spherical wavelets as a kind of shock process, in which a shock, like a little explosion, is communicated by any given location to the surrounding ones.

Fresnel added the following idea:

"We don't conceive of the vibrations of an elastic fluid in the same way as geometers have ordinarily done, namely in considering only a single shock. In nature vibrations are never isolated; they always repeat many times, as one can see in the oscillations of a pendulum or the vibrations of sonorous bodies. . . .

"It follows from the principle of coexistence of tiny motions, that the vibrations produced by many shocks in an arbitrary point of an elastic fluid are the *resultant of all the agitations communicated at the same moment to this point from the various centers of vibration,* no matter how many they are, no matter what the nature and original moment of those various disturbances."

This conception allowed Fresnel to make intelligible, the otherwise very anomalous and paradoxical phenomenon, that the combination of light, coming from different directions can sometimes produce *dark areas*. We just saw this with the shadow of a thin wire or nail: When we block off one side of the nail, the light from the other side casts a continuous, dim light into the shadow. When we remove the paper square blocking the light, we are adding *more light,* so to speak, and yet the result is, that in the shadow both bright and *very dark* bands are produced! So, we have the strange equation: light + light = darkness.

But such a result is easily understandable, if we imagine light as a *rotational* process. If the light waves, coming from different sources to a given point, arrive in such a way that the peaks of the one wave arrive at the same time as the valleys of the other (nowadays, we say they are in opposite phase), then the two actions cancel each other out, and we get darkness. That is the principle of what has become known as "interference" of light.

Figure 5 is Fresnel's own diagram to show how the curved propagation of external and internal fringes is generated as a result of interference. **Figure 6** illustrates more clearly how the "internal" interference fringes are produced in the region behind the object, by the interference of waves originating to the immediate left and right of the object (from regions "A" and "B" in the diagram). In the diagram, the waves from A and B are shown at a certain instant in time, with the "crests" drawn in blue and "valleys" in red. The black lines represent the locus of dark fringes that are generated where the two waves cancel out. That locus includes the points

FIGURE 5
Fresnel's diagram of curved propagation of fringes

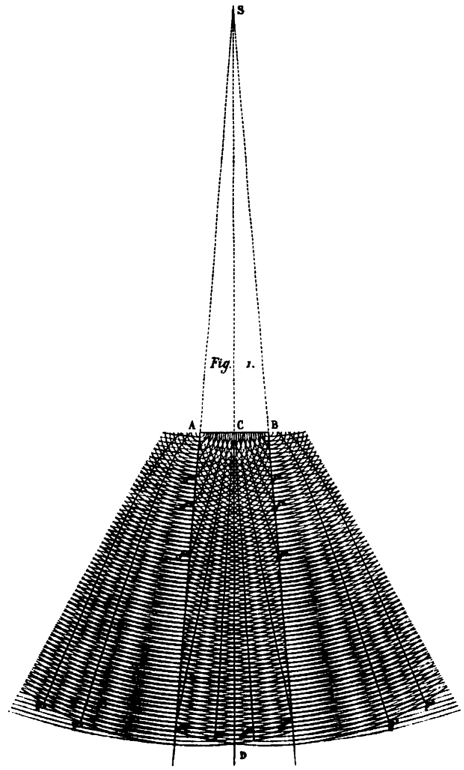
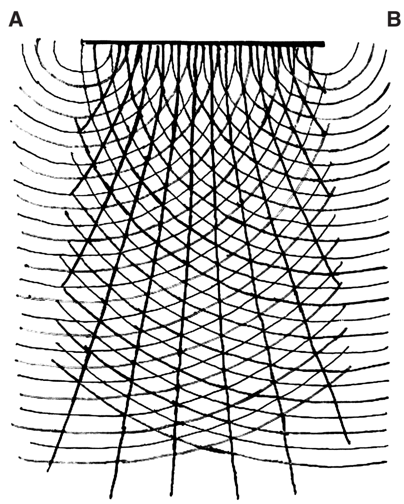


FIGURE 6
Interference fringes in the region behind the object



at which the "crests" of one wave intersect the "valleys" of the other. From the construction, it is clear that the internal fringes will not lie on straight lines, but actually form hyperbolas.

You see, that although the idea is very simple, the phenomena are very complicated. Even this drawing is highly simplified; only the oscillations starting *near* the edges of the object are taken into account; whereas in fact, according to Fresnel's conception, oscillations are coming from the positions farther away, from the *entire region* illuminated by the light source. To determine the actual net result (which is a good deal more complicated than we have indicated here), is a subtle matter, which calls for a distinctly Leibnizian mathematics. Indeed, Fresnel's conception of the propagation of light coheres with Leibniz's principle, that each portion of the universe reflects everything happening at every other point in the universe, and that every macroscopically visible effect is the result of a "sum" or accumulation of vastly many, "infinitesimal" impulses or influences acting at a given location.

What we now heard so far is just Fresnel's idea in its first, original form, not yet elaborated. But it was enough to cause an uproar in the Academy of Sciences. Marquis Laplace himself arose to criticize the young engineer's ideas.

Laplace: "In view of the success of Newton's emission theory, I greatly regret that anyone would presume to substitute for it another, purely hypothetical one, and which, so to speak, can be manipulated at will: that of Huygens's undulations. One must limit oneself to repeating and varying experiments and deducing laws from them, that is, coordinating facts, and avoid any undemonstrated hypothesis."

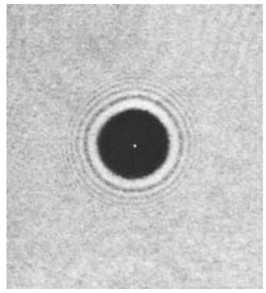
But Ampère defended Fresnel, noting that although he, Ampère, had always supported the theory of emission, the conclusions of Fresnel's report seemed sound. At the same time, the politically powerful François Arago, who was Alexander von Humboldt's closest collaborator in France, acted as Fresnel's protector as well as his original collaborator in the light experiments. Fresnel's position improved.

In a letter to Léonor on July 19, 1816, Fresnel reported:

"So you see that the vibrations party is becoming stronger every day. I think I have announced to you the conversion of Ampère. A revolution is being made in optics. "

Now the brilliant Ampère was fully behind Fresnel, and subsequently they worked closely together to elaborate Fresnel's initial discovery into a universal physical principle. Immediately these efforts focussed on the remarkable anomalies connected with the *polarization of light* (see box).

The Poisson spot



In 1818, on the occasion of Fresnel's defense of his thesis submitted for the Academy prize, a celebrated showdown occurred between Fresnel and the Laplacians. Poisson got up to raise a seemingly devastating objection to Fresnel's construction: If that construction were valid, a *bright spot* would have to appear in the middle of the shadow cast by a spherical or disk-shaped object, when illuminated by a suitable light source. But such a result is completely absurd and unimaginable. Therefore Fresnel's theory must be wrong!

Soon after the tumultuous meeting, however, one of the judges, François Arago, actually conducted the experiment. And there it was—the "impossible" bright spot in the middle of the shadow! Much to the dismay of Laplace, Biot, and Poisson, Fresnel was awarded the prize in the competition. The subsequent work of Fresnel and Ampère sealed the fate of Laplace's neo-Newtonian program once and for all. The phenomenon confirmed by Arago goes down in history with the name "Poisson's spot," like a curse.—*Bruce Director*

III. The transverse nature of light

It had been discovered by Malus, that light passing through certain crystals, takes on a new characteristic which was called *polarization*. This polarization, it was found, depends on the angular orientation of the crystal in space. If we let light pass through a polarizing crystal, and then take an identical crystal, but rotated 90° around the axis of the light beam, then the light is stopped! It does not pass through the second crystal. If we rotate the second crystal further, beyond 90°, the light begins to come through and finally becomes fully transparent.

Now long before, Huygens in his famous *Traité d'Optique* (*Treatise on Optics*), had investigated the anomaly of so-called double refraction. These are crystals, such as the so-called Iceland Spar, which actually split light coming in two directions, two beams. It was discovered, that the two beams are polarized in different ways.

Now Fresnel reports an anomaly in a memorandum of August 30, 1816:

"I have tried without success to produce fringes using the two images of a luminous point in front of which I placed a doubly-refracting crystal. . . . I begin to suspect that it could be possible that the two systems of waves, produced by light in the crystals possessing double refraction, do not have any influence upon each other. I have searched in vain for an explanation. For this it would be necessary to know what this singular modification of light really is, which constitutes its polarization."

Already in 1816, Ampère suggested to Fresnel the hypothesis, that the action propagated by the light "wave" is not longitudinal, i.e., not along the direction of the propagation itself, as most imagine a sound wave to be, but rather *perpendicular* to it, or *transverse*. Simple polarization amounts to orienting the main axis of that action—whatever it is—in a certain direction in that transverse plane. The circumstance, that waves with different directions of polarization would not cancel each other completely at any given point, made Fresnel's anomaly intelligible. Between 1816 and 1823, Fresnel and Ampère elaborated and demonstrated the transverse hypothesis, and made a new beautiful discovery of *circular and elliptical polarization:* light whose characteristic transverse action is *rotation* around the axis of the light beam.

This work was a starting-point for many further discoveries, including the later work of Louis Pasteur on the optical asymmetry of living material. But at the same time, it raised a powerful new paradox: These experimentally demonstrated characteristics of light, seem to contradict any attempt to interpret light as some sort of vibration within a material fluid or "ether." Indeed, Ampère wrote:

"The experiments of Fresnel have proved that light is produced by the vibrations of a fluid and that these vibrations are transversal, that is, perpendicular to the direction of the light rays; and that, besides this, calculation shows that this sort of vibration would be impossible in a continuous fluid, where the vibrations would become longitudinal, while transverse forces might occur if the fluid were composed of atoms held at a distance from each other by repulsive forces. . . .

"[But,] is matter made up of atoms that only occupy a portion of fixed, infinite space, where they are separated by absolutely empty intervals and in which they move by successively occupying different parts of this space?"

Ampère is raising up the fantasy of Newton, but, watch out! Then Ampère says:

"We must admit an immaterial, motive substance everywhere where there is spontaneous motion. We then discover that it is in this substance that *thought* is to be found, since words obey it. . . . The cause of all causes, the creative and all-powerful substance is, on the contrary, only known to us indirectly, through its works."

In his sequel to my presentation, Jacques Cheminade will give some insight into the origins of this seemingly confused concept which Ampère is trying to communicate, ideas which Ampère and his circle were groping toward.

Meanwhile, the battle with Laplace escalated. Laplace and Biot savagely attacked Fresnel's conception of the propagation of light, on the grounds that it was allegedly "too complicated" mathematically. Indeed, compared to Newton's impoverished mathematics of isolated particles moving through empty space, Fresnel's principle requires a Leibnizian mathematics of multiply-connected action in which all processes, at all points in space, are connected with each other. After a bitter fight in which Laplace and Biot had to back down to Ampère and Arago, the Academy of Sciences awarded its prize to Fresnel's *Mémoire*. In it, Fresnel refutes Laplace's argument about "simplicity," citing the real meaning of Leibniz's principle of least action:

"In the choice of theory, one should only pay attention to the simplicity of the hypotheses; that of the calculations should play no role. . . . Nature is not bothered by difficult calculations; she only avoids the complication of means. She seems to have proposed to herself, to do much with little; this is a principle for which the progress of science incessantly provides new demonstrations. . . ."

Pointing his finger at the disastrous failures of the Newton-Laplace-Biot optics, Fresnel commented:

"Such a hypothesis, which seems very simple as long as one only considers a single class of phenomena, requires adding many more hypotheses as soon as you want to depart from the narrow circle in which it was originally applied. If Nature proposed to produce the *maximum* of effects with the *minimum* of causes, then it is only in the totality of its laws that she has had to solve this great problem.

"Thus, the emission theory is so little suited to explaining the phenomena, that each new phenomenon requires a new hypothesis. You can convince yourself of this all the more in reading the 'Treatise on Experimental and Mathematical Physics' by Monsieur Biot, in which the principal consequences of Newton's theory are developed with a great deal of detail and clarity. One will see there how, in order to take account of the phenomena, it is necessary to load down each particle with a large number of different modifications, often very difficult to reconcile among each other. . . ."

Laplace was not pleased. In a letter to Léonor on Sept. 5, 1818, Fresnel retold with humorous irony an unpleasant encounter with Laplace himself:

"During a recent visit I made, together with Arago, to Monsieur de Laplace at his country home, I suffered an assault. . . . Monsieur Becquey had repeated to Laplace a discussion I had with him on the subject of physical theories, in the course of which I blurted out that *nature does not bother about complications of calculations,* and the difficult calculations of the theory of vibrations are not at all an argument against it. Apparently, Monsieur Becquey changed some of my expressions a bit, because Laplace concluded from his account that I did not believe in the usefulness of mathematical analysis. I responded that, on the contrary, I felt very strongly that analysis is indispensable in order to provide mathematical rigor to physical theories; but that it seemed to me that the complexity of the calculations should not be taken into account in judging between two theories. Laplace told me he did not agree with me on this point, and tried to quarrel with me about the principle of Huygens, which is the basis of my new theory of diffraction, and which, in my opinion, Laplace does not understand in the same way as I. Somewhat irritated by the way the attack had started, and finding myself in a disadvantageous situation on the defensive, I took the offensive; and, without transition, I presented to him the objection to the emission theory which I had used to hit Biot. Laplace could not answer it, or at least he only made some vague responses. Immediately the discussion changed subject, and Monsieur le Marquis turned his aggressive mood against the good Monsieur Berthollet, who was with us, and tried to blame him for the inconsistencies in chemical terminology. . . . I was thus relieved of this rude adversary, and I began to breathe freely, promising to myself, in a very low voice, never again to speak so much with Monsieur Becquey."

In a later, 1822 memorandum on the phenomenon of double refraction, Fresnel spoke out even more explicitly against the sterility and bankruptcy of Laplace's physics. Implicitly, Fresnel is not merely attacking Laplace, but also (and more importantly) the predecessor of Laplace, Lagrange, whose "analytical mechanics" has been the model and inspiration for Laplace's and other modern attempts to reduce physics to mathematical formalism.

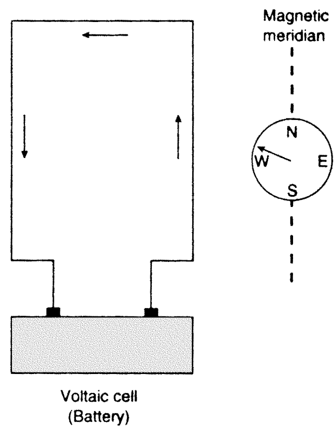
"The theory that we are combatting here . . . has led to not a single discovery. The scholarly calculations of Monsieur Laplace, however remarkable for their elegant application of the principles of mechanics, teach us nothing new about the laws of double refraction. But we do not think that a good theory should be limited to calculating the forces when the laws of the phenomena are known; such a theory would contribute too little to the progress of science. There are some laws so complicated and strange, that they could never be discovered by observation and analogy alone. To unlock such enigmas we need to be guided by theoretical *ideas* based on *a true hypothesis*. The theory of light vibrations presents this character and these precious advantages. . . ."

IV. Ampère's revolution

The real issue is thus not light per se, but the drive to demonstrate a new, universal physical principle, one which requires a radically different, Leibnizian form of mathematics. Having hit the Laplacians on the flank of optics, the battlefield shifted to electricity and magnetism. Soon, Ampère and Fresnel were able to decisively refute the Newtonian-Laplacian "standard theory" which had been elaborated by Charles de Coulomb.

Coulomb treated electricity and magnetism as absolutely separate categories of phenomena. For each one, he developed a separate mathematical theory modelled on Newton's treatment of gravitation. He tried to reduce the phenomena of static electricity to interactions of two types of electric particles (positive and negatively charged), attracting and repelling each other according to the now-famous "Coulomb's law." Likewise, he sought to explain all phenomena of magnetism in terms of the distribution of two types of magnetic particles; we might call them north pole particles and south pole particles. From the Coulomb-Laplace standpoint, electricity and magnetism had no essential connection. Both Fresnel and Ampère were utterly opposed to this, and looked about for a way to refute it.

FIGURE 7
The Oersted experiment



Source: 21st Century Science & Technology, Fall 1996.

In 1819, Hans Christian Oersted discovered a relationship between electricity and magnetism. He found that an electrical current in a wire causes a magnetic compass needle to turn. The wire is aligned in the direction of the Earth's magnetic force. When the current is turned on, the compass needle is deflected toward the perpendicular to the wire.

First, however, an event had to occur which supplied Ampère and Fresnel with the opportunity they were waiting for. In 1820, the Danish physicist Hans Oersted demonstrated that an electric current, flowing through a wire, causes the needle of a magnetic compass to rotate in a direction *transverse* to the current (**Figure 7**).

Oersted himself insisted that this experimental discovery, which in principle could have been made 20 years earlier, was no accident, but that he was guided to it by a notion that both electrical and magnetic phenomena are governed by rotational action:

"Electricity does not flow through conductors like a liquid through a pipe. It is propagated by a kind of continual decomposition and recomposition. . . . One might describe this series of opposing forces which exist in the transmission of electricity by saying that electricity is always propagating in an undulatory manner."

At the same time, Oersted clearly pointed to the *transverse nature* of electromagnetic action:

"It appears, according to the reported facts, that the electrical conflict is not restricted to the conducting wire, but that it has a rather extended sphere of activity around it . . . the nature of the circular action is such that the movements it produces take place in directions precisely contrary to the two extremities of the given diameter. Furthermore it seems that the circular movement . . . should form a mode of action which is exerted in a helix around this wire as an axis."

Creative discovery does not proceed in a smooth and routine manner, but like earthquakes. And often a seemingly small thing can initiate a chain reaction of developments. Within weeks, working night and day, together with the help of his friend Fresnel, Ampère virtually single-handedly created a new branch of physics: *electrodynamics*. First, Ampère replaced the compass needle in Oersted's experiment with a second loop of wire carrying a current, and demonstrated the action of one current on another. Grasping the complex geometry of that action between currents, Ampère immediately developed a whole new species of designs for all kinds of apparatus and instruments, including the prototype of all electromagnets, the magnetic coil or solenoid, and the first electromotors. Ampère became the Leonardo da Vinci of electricity.

With the artificial barrier between so-called "electric" and so-called "magnetic" categories of phenomena broken down, Ampère threw Coulomb's "magnetic particles" or "magnetic fluids" out the window. Ampère insisted: All magnetism—including that of the Earth itself—is connected with the presence of electric currents, a form of *rotational action*.

Now, in order to demonstrate magnetic effects of currents, Oersted and Ampère had to use batteries to create electric currents in wires. What about a permanent magnet, like the lodestone or the magnetized needle of a compass? Assisted by Fresnel, Ampère developed the hypothesis of so-called *molecular currents*—the existence of natural, constantly sustained electric currents on the microscopic scale. A material becomes magnetic, according to Ampère, when some action causes the microscopic currents to orient coherently. Ampère hypothesized that the microscopic currents were connected with the molecular constitution of matter in the small, creating the hypothesis of "magnetic atoms." Gone are the dead, inert particles of Newtonian physics. Ampère's magnetic atoms are characterized by constant *activity!*

Ampère's basic ideas were brilliantly confirmed by the entire ensuing development of modern physics. But Ampère himself emphasized that the breakthroughs in electrodynamics had been long delayed by Coulomb and Laplace's artificial imposition of neo-Newtonianism on scientific research:

Ampère: "It is indeed unbelievable that for 20 years [up to Oersted's work] the action of the voltaic pile on a magnet had not been tested. I think we can assign a reason for it: It lies in the hypothesis of Coulomb on the nature of magnetic action. This hypothesis had been believed as if it were a fact; it absolutely dismissed any idea of an action between electricity and so-called magnetized wires. The prejudice against this had reached the point that, when Arago spoke of these new phenomena at the institute, they were dismissed just like the stones that fell out of the sky. . . . They had all decided that it was impossible."

Ampère did not mention, however, the really touchy issue, where the prejudice really comes from. Let's look at this more closely.

What was it, that so upset the contemporary professional scientists in the work of Ampère and Fresnel? It was not simply the rather devastating flanking attack against Laplace's neo-Newtonian scheme. What is so threatening to the oligarchical mind, or the mind affected by oligarchical ideology?

Newton says, Descartes agrees, Kant emphatically concurs, that straight-line motion is simple, elementary. It is the "normal," the "natural" form of motion and action, simple and irreducible. Anything which is not straight-line motion, has to be explained by some forces or influences that are "bending" things away from their natural straightness and simplicity.

But, nowhere in the universe do we find straight-line motion! Everywhere we find curvature. As the ancient astronomers already grasped, the universe is organized on the astronomical scale in arrays of *cycles*. And Kepler, following Nicolaus of Cusa, demonstrated that the organization of these cycles is not simply circular curvature, but what we might call (approximately) spherically bounded elliptical curvature. Eratosthenes measured the curvature of a non-flat, spheroid Earth. And now, Fresnel and Ampère demonstrate that the apparent straight-line action of light is an illusion, and that on the microscopic scale, there are no rays of light, but complex, multiply-connected rotational action, reproducing itself at about 600 trillion cycles per second!

So, either we accept, that *the supposed elementarity of straight-line action is just a naive myth, a kind of illusion of the senses,* or, like Newton, Laplace and Biot, we will need to invent a "bending force" each time we see a cycle or a curvature. But the latter, as Fresnel pointed out, leads to the monstrous "bubble" of ad hoc "special hypotheses," not unlike the epicycles of Ptolemy which modern science was supposed to have overcome.

This *reductio ad absurdum* leaves open only one conclusion: that the physical space-time of the real universe is *not* the self-evident simple three-dimensional space of Newton and Descartes. Real space is somehow *curved* in a way we cannot see, and yet which shapes every process in the universe.

But now we can hear the anxious objection, coming even inside our own minds: "If space is not self-evident, how can I ever organize my facts? What do I start with? How can I reason without a premise? How can I measure without a unit?" It looks as though the rug is pulled out from under our feet. Indeed, most of us are accustomed to thinking of human reasoning as essentially deductive in character; that we always have to start with something, a premise "A," and then derive "B" from "A," "C" from "B," "D" from "E" and so forth. This is the essential linearity as it occurs in the mind, for which the supposed elementarity of the straight line is merely a kind of external image. Denying the *a priori* character of space (and other basic notions of physics), would seem to destroy the basic premise upon which our entire scheme of natural science is based.

But looking back on the intervention of Fresnel and Ampère, another possibility might occur to us. The development of concepts of light, confronts us with a *sequence* of geometries:

1) Rays of light, as we naively conceive them; 2) Huygens's wave-envelope construction; 3) Fresnel's original wave construction; 4) the Ampère-Fresnel concept of a transverse, polarized wave.

Note, that each of these geometries has a higher "order" than the preceding. At each step, we discover a new principle or "dimensionality" of the action underlying light, which did not exist in the previous geometry. We integrate the new principle to get a higher-order geometry. To the extent these principles are true physical principles—which means that they apply to *all* processes without exception—the progression of those geometries, from the lower to the higher, a process of increasing *richness* of the universe. That is our first approximation, our first mental picture of *anti-entropic* action, our first glimpse at the real curvature of the universe itself!

Now look inward. What is the *source* of that action? Human cognition itself, creative substance. The universe is bounded in a certain manner uniquely coherent with the nature of human reason: Human reason, acting through the method of Platonic hypothesis, can transform man's relationship to the universe to the effect of increasing mankind's per-capita potential to exist. So, the higher geometries are ordered by man's increasing *power* over the universe.

Unfortunately, Ampère did not, at least publicly, take up the implications of his and Fresnel's work in this direct form. Worse, in 1827, after having made his main discoveries on electrodynamics, Ampère published a long memorandum in which, in effect, he falsified the history of his own discoveries and tried to present himself as a classical Newtonian! This is Ampère's famous "Introduction to the Theory of Electrodynamic Phenomena, Deduced Uniquely from Experience," which subsequently became the nearly exclusive classical reference for Ampère's electrodynamic research. Although there is some sneakiness behind his "politically correct" formulations, Ampère's text is otherwise clinical in its attempt to completely bury and conceal the traces of the creative process which led himself and Fresnel to their discoveries. Ampère wrote:

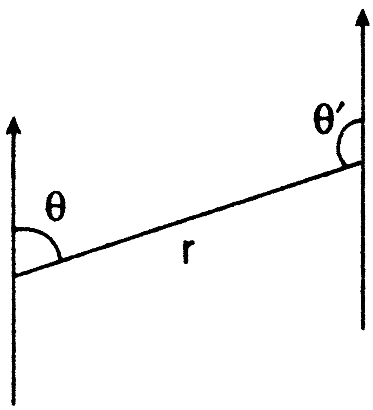
"The epoch marked by the works of Newton . . . is the epoch in which the human spirit opened a new road in the sciences. . . . Until then, people almost always sought for the explanation of phenomena in the motions of an unknown fluid . . . and wherever one saw a rotational motion, one imagined a vortex moving in the same way. Newton taught us that this sort of motion, like all other motions in nature, should be reduced to forces acting between pairs of material particles always along the line which connects them. . . . Newton knew that such a law of motion could not at all be invented on the basis of abstract arguments. He established that laws must be deduced from observed facts, or rather from the empirical laws which, like the laws of Kepler, are nothing but generalizations from a large number of particular observations."

This claim, taken from Newton, that Kepler found his laws by mere empiricist "generalization" is complete nonsense, as anyone knows who is familiar with Kepler's work. Kepler's discovery of the elliptical orbits of the planets, for example, was by no means a "deduction from the phenomena," but (like virtually everything Kepler did) flowed from Kepler's masterful use of the method of hypothesis. But Ampère continues:

"To deduce from the laws, thus obtained, independently of any hypothesis on the nature of the forces which produce the phenomena—this is the method which Newton follows. It has, in general, been adopted in France by the scientists to whom physics owes the great progress which it has recently made, and this is the method which has guided me in all my investigations on electromagnetic phenomena."

We shall see in a moment how these statements by Ampère, no doubt written under great political and other pressure, subsequently misled scientists and threw them off the track. But despite the Newtonian camouflage, Ampère had actually left a time-bomb under "standard theory." This was the famous *force-law* which Ampère had developed earlier and presented, in synthetic form, as his "deduction from experience." Following his neo-Newtonian mode of presentation, Ampère analyzed that force acting between two currents as a sum of forces acting between pairs of infinitesimal "current elements" along the two wires respectively. But—and this

FIGURE 8
Ampère current elements



The arrows show two imaginary, very small elements of electrical current passing through two wires. The current elements will have a force of attraction or repulsion, whose strength depends on three angles they make with the line r connecting their midpoints. These are angles theta and theta′ (pictured), and also the angle of rotation of the current elements in a third dimension around the line r.

caused enormous trouble—this "elementary force" between two current elements has a very bizarre, very complicated form. It depends on a combination of no fewer than *three angles,* as shown in **Figure 8.** Depending on the spatial orientation of the directions of the two current elements relative to each other and the line joining them, the elements attract, repel, or exert no force on each other.

This—from a Newtonian or Cartesian standpoint very peculiar, totally inexplicable relationship—has continued to be a *great embarrassment* to standard theory and a source of heated controversy up to this very day. What kind of a universe do we live in, in which such an effect can exist?

Working parallel to and simultaneously against Ampère, Laplace's agents Biot and Félix Savart went to work to "co-opt" the new electromagnetics into the Laplace system, using "standard procedures." To get rid of Ampère's law, they produced an alternative force law, castrated of its most interesting implications. It is that alternative formula which became integrated into "standard theory": Today's textbooks contain the so-called Biot-Savart formular, not Ampère's.

Ampère died in 1836, in isolation. One of his few scientific friends, Fresnel, had already died in 1827 at the age of only 39. But Ampère, together with Fresnel and a few others, had kept science alive in France. Meanwhile, the focal point of scientific progress shifted to Germany. In fact, it was the *reworking* of Fresnel's and Ampère's discoveries by Carl Gauss, Wilhelm Weber, and Berhard Riemann, which triggered the most far-reaching, revolutionary developments in mathematical physics—developments which have still not been fully digested today.

V. Epilogue

In 1831, Wilhelm Weber came to Göttingen, and for seven happy years worked together with Carl Gauss in a very joyful and fruitful scientific friendship. Together they launched the famous Magnetic Union, the world's first global scientific project, with simultaneous magnetic measurements from America to Europe to Russia and as far as Beijing. They built the first electromagnetic telegraph. They revolutionized the technology of physical measurement, creating new sorts of instruments. But above all, Weber and Gauss worked together to develop what Gauss called "absolute" physical measurement. This project was actually closely connected with Gauss's work on what he called "anti-Euclidean" geometry—although Gauss, like Ampère, was afraid to publish his ideas on this openly.

"Absolute measurement" addressed the problem that it is impossible to measure any single physical parameter as if it existed independently of the others. All physical principles interact; and so, what we really measure is always a relationship, an *interrelation* of physical principles. But in the middle of their work on integrating electrodynamic relationships into their absolute system, Weber was suddenly dismissed from his position in Göttingen for his membership in the famous "Göttingen Seven."[3] It was only ten years later, in 1845, that Weber came back to the crucial issue of Ampère's work.

Weber is disturbed by the complicated form of Ampère's angular force and the way Ampère, in his 1827 paper, claims to deduce it from experiments. Weber considered that the experiments reported by Ampère were relatively imprecise and did not by themselves justify the complicated, even bizarre form of the angular force law claimed by Ampère. Couldn't Ampère's formula be simplified? Weber writes to Gauss asking for his advice.

In his answer to Weber on March 19, 1845, Gauss remarks that he had worked extensively on Ampère in the period 1834-36. Then he cautions Weber:

"I would think, to begin with, that, were Ampère still living, he would surely protest [against your proposed modification]. . . . The difference is a vital question, because 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 a completely different formula."

At the same time, Gauss remarks that he himself had in-

3. In 1837, Ernst August, the Duke of Cumberland, uncle to England's Queen Victoria, ascended to the throne of the Kingdom of Hanover. One of the new King's first acts was to order all civil servants in Hanover, including the professors at the University of Göttingen, to swear a loyalty oath to the new King. A great protest arose, and seven professors, including Wilhelm Weber, the Grimm brothers and G.H. Ewald, Gauss's son-in-law, officially refused to take the new oath. All seven were summarily fired and ordered to leave the country. The action was a blatant attempt by the British monarchy to crush the scientific revolution going on at Göttingen at that time.

tended to remedy the flaw in Ampère, but:

"I would doubtless have published my investigations long ago, except that at that time the one thing was missing, which I regarded as the key to the whole . . . namely to derive the additional forces, which arise between electric particles when they are in relative motion, from an action which is not instantaneous, but which propagates in time in a similar way to light. . . . At the time, I did not succeed in working this out, but . . . I put aside my efforts with the hope, that I might perhaps later succeed, although—if I remember correctly—with the subjective conviction, that it would first be necessary to create a constructible image of the way in which that propagation takes place."

This is not the place to explore the profound implications of Gauss's latter remarks, which anticipate the whole development of the electromagnetic theory of light. In any case, Weber immediately thanked Gauss for having corrected his misunderstanding, that Ampère's law was simply "deduced from the phenomena." Weber wrote back:

"It has been of great interest for me to learn from what you wrote, that Ampère was guided by other reasons than the ones from immediate empirical experience which he cites at the beginning of his treatise."

Weber proceeded to investigate Ampère's work with a new set of experiments, integrating the technological breakthroughs made together with Gauss, which brought the precision of astronomical measurements to bear upon microphysics. Applying the method of absolute measurements, Weber measured the interrelationship between electromagnetic action and other known principles of action. He made a revolutionary discovery: The experimentally measured interconnection of physical principles implied the necessary existence of a *singularity* on the microscopic scale, a point of reversal in the characteristics of action! In fact, the continuation of these measurements by Weber and Rudolf Kohlrausch actually led to a first estimate of the radius of the electron, long before the existence of an electron as a distinct entity had been experimentally demonstrated. This was the actual beginning of quantum physics, and the first rigorous foray into the atomic and sub-atomic domain.

Ampère's conception of electromagnetic atoms was completely vindicated. Finally, it was Weber's student Bernhard Riemann, not James Clerk Maxwell, who made the last crucial step toward the so-called electromagnetic theory of light.

In 1858, long before Maxwell's supposed breakthrough, Riemann writes a short "Contribution to Electrodynamics" which begins with the words:

"I permit myself to report a remark to the Royal Society [of Göttingen], which brings the theory of electricity and magnetism into a close relationship with the theory of light and radiant heat. I have discovered, that the electrodynamic action of galvanic electrical currents can be explained, if one assumes that the action of one electric mass on the others does not occur instantaneously, but propagates with a constant velocity which (within the margin of experimental error) is equal to the velocity of light."

Behind this discovery of Riemann's was his revolutionary 1854 work, "On the Hypotheses Which Underlie Geometry," a breakthrough which addresses exactly the issue that Ampère and Fresnel were groping for, but failed to adequately address:

"I have posed the task to myself, to construct the concept of a multiply-extended magnitude out of general concepts of magnitude. From this it will follow, that a multiply-extended manifold is capable of different metric relations, and that space is only a special case of a three-fold extended manifold. However it is a necessary consequence of this, that the theorems of geometry cannot be derived from general concepts of magnitude; but, that those properties, which distinguish space from other imaginable three-fold extended manifolds, can only be derived from experience. Thus the task arises, to seek the simplest facts from which the metric relations of space can be determined. These facts are, like all facts, not necessary, but only have an empirical foundation; they are hypotheses.

"In the natural sciences, in order to recognize the causal relationships, one tried to follow the phenomena into the small, as far as the microscope allows. The question of the metric relations of space in the unmeasurably small is thus not without importance. On the other hand, it appears that the empirical concepts, upon which the metric relations of space are based—the concept of a solid body and of a light ray, lose their validity in the unmeasurably small; it is therefore quite conceivable, that the metric relations of space in the unmeasurably small do not agree with the assumptions of geometry. . . . The question of the validity of the assumptions of geometry in the unmeasurably small is connected with the question of the inner basis for the metric relations of space. . . . [But] this leads us over into the domain of another science, the domain of physics, which the nature of the present occasion does not permit us to enter in upon."

In 1952, a young man named Lyndon LaRouche was struggling with the conceptions of Riemann and his follower Georg Cantor. Suddenly, LaRouche grasped something in Cantor which unlocked for him the true significance of Riemann's work on multiply-extended manifolds. In his autobiography, *Power of Reason,* LaRouche wrote: "I saw Riemann in the right way for the first time. I read Riemann's famous 1854 inaugural dissertation, 'On the Hypotheses Which Underlie Geometry," with what can be described only as an empyrial quality of excitement. From that moment on, everything I had sought began to fall into place." Riemann's conception provided a missing key for LaRouche to elaborate the universal implications of his original discoveries in physical economy.

And so, the revolution launched by Fresnel and Ampère's brilliant flanking operation, leads all the way into this room, to you, dear listeners, whom we thank for your attention.

For further reading

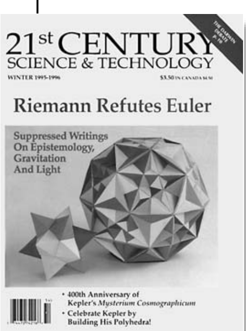
The following is a selection of articles by Lyndon LaRouche and associates on the question of non-linearity in mathematics and physics (in chronological order). See the end of this box for information on how to order. All prices are postpaid.

Ralf Schauerhammer and Jonathan Tennenbaum, "The Scientific Method of Bernhard Riemann. Part 1: Riemann and the Göttingen School," ***21st Century Science & Technology***, Vol. 4, No. 4, Winter 1991; and "Part 2: Riemann the Physicist," Vol. 5, No. 1, Spring 1992. **$5** per issue.

LaRouche, "How Bertrand Russell Became an Evil Man," ***Fidelio***, Vol. 3, No. 3, Fall 1994. Includes an extended discussion of the work of Felix Klein. **$9**

Dino de Paoli, "Georg Cantor's Contribution to a New Renaissance"; Lyndon H. LaRouche, Jr., "No Limits to Growth: Cantor's Concept of Infinity in Economic Science"; Jonathan Tennenbaum, "Cantor and the Future of the Natural Sciences" ***EIR***, Aug. 4, 1995. Speeches to a conference in Halle, Germany on May 6, 1995, marking the 100th anniversary of the discovery of the "paradox of the Absolute" by Cantor. **$12.**

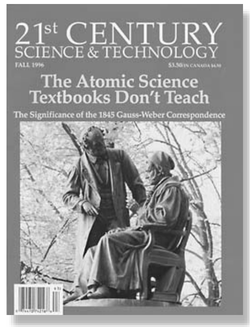
Lyndon H. LaRouche, Jr. takes on the fraud of Isaac Newton in a two-part series: "Why Most Nobel Prize Economists Are Quacks," ***EIR***, Vol. 22, No. 30, July 28, 1995; and "Non-Newtonian Mathematics for Economists," *EIR*, Vol. 22, No. 32, Aug. 11, 1995. **$12** per issue.



Lyndon H. LaRouche, Jr. "Riemann Refutes Euler," ***21st Century Science & Technology***, Winter 1995-1996. **$5.**

Lyndon H. LaRouche, Jr., "Leibniz from Riemann's Standpoint," ***Fidelio,*** Fall 1996. **$9.**

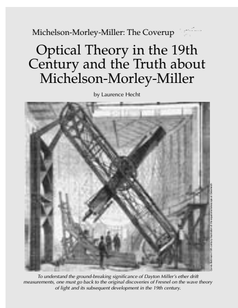
Laurence Hecht, "The Significance of the 1845 Gauss-Weber Correspondence," ***21st Century Science & Technology***, Fall 1996. Includes an English translation of the text of the 1845 Gauss-Weber correspondence. **$5.**



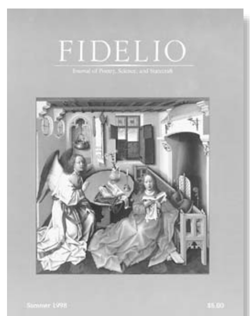
Lyndon H. LaRouche, Jr., "How Cauchy Ruined France," and Pierre Beaudry, "The Bourbon Conspiracy that Wrecked France's Ecole Polytechnique," ***EIR***, Vol. 24, No. 26, June 20, 1997. **$12.**

Dino de Paoli, "Gödel, Cantor, and Leibniz: Mathematics and the Paradoxical in Nature," ***21st Century Science & Technology***, Vol. 10, No. 2, Summer 1997. **$5.**

Lyndon H. LaRouche, Jr., "Intelligence Policy: Truthful, or Merely 'Factual'?" ***EIR***, Vol. 25, No. 2, Jan. 9, 1998. With extensive discussion of Gauss, Kepler, and the issue of non-constant curvature. **$12.**



Laurence Hecht, "Optical Theory in the 19th Century, and the Truth about Michelson-Morley-Miller," ***21st Century Science & Technology***, Spring 1998. Includes a discussion of the work of Augustin Fresnel. **$5.**



Jonathan Tennenbaum and Bruce Director, "How Gauss Determined the Orbit of Ceres," ***Fidelio***, Vol. 7, No. 2, Summer 1998. **$9.**

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