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FALL 1998

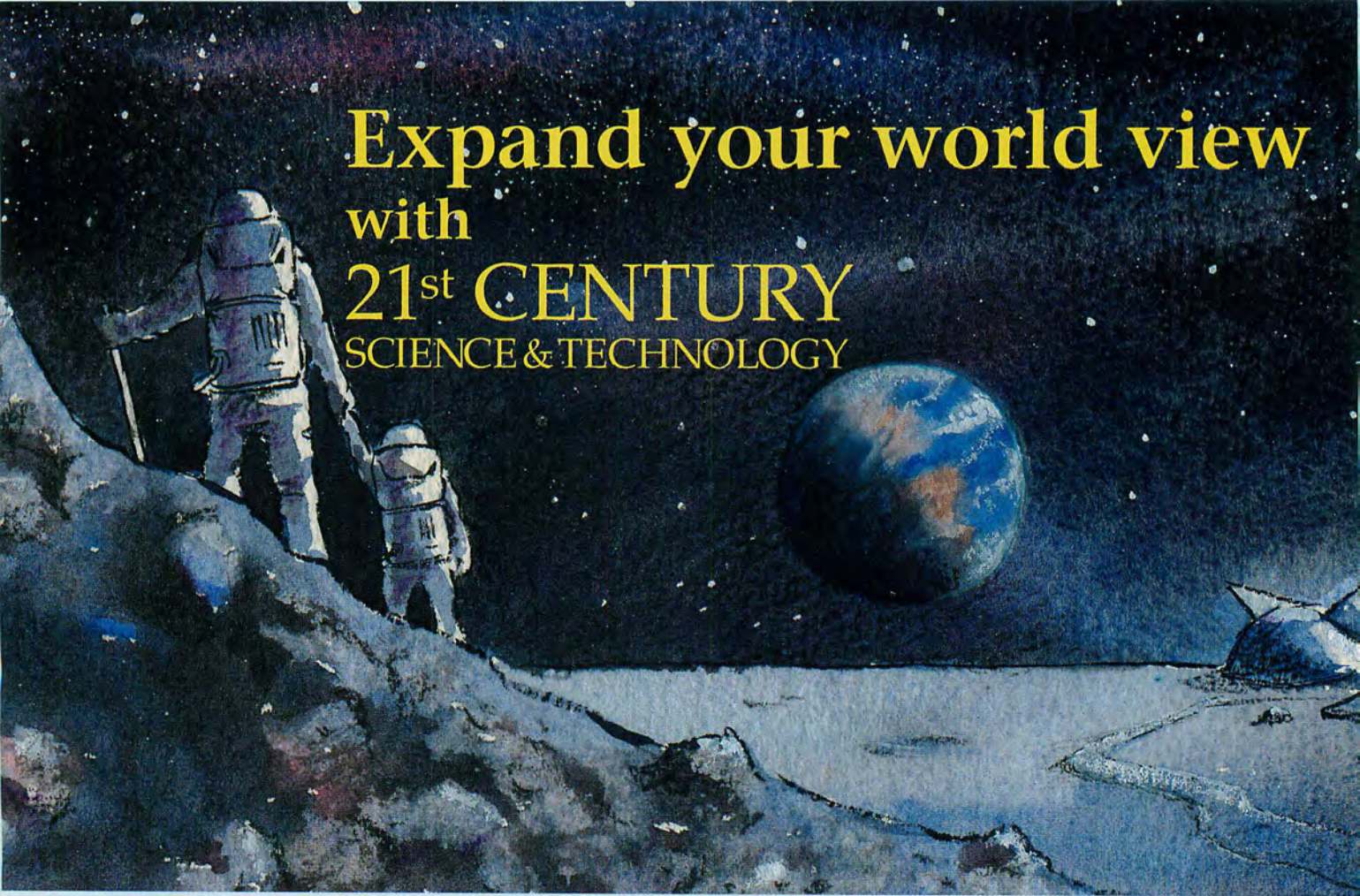
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GURWITSCH RADIATION
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Maurice Allais on Reconsidering Gravitation
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21st CENTURY SCIENCE & TECHNOLOGY

Vol. 11, No. 3

Fall 1998

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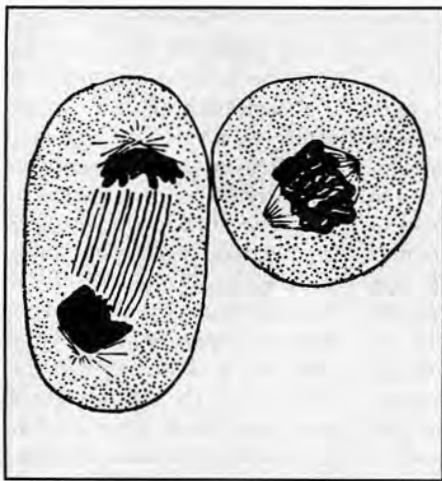
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Alexander Gurwitsch's extensive data on the theory of the biological field (feature, p. 34) are virtually unknown today. Here, one of many examples of the field geometry on the cellular level—the intersecting vector from the field of one mitotic cell affects the symmetry of the mitotic spindle in the neighboring cell.

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On the cover: Photo by Col. James Buchli, USMC, mission specialist aboard the Challenger, from an altitude of 180 nautical miles, looking south across the Aegean Sea, toward the island of Crete. Crete and the smooth waters appear black, or dark blue, because a small aperture was used on the camera to make sure that the bright glitter of the spiral eddies did not overwhelm the film's emulsion. The bright, curving lines, showing the eddies' flow-lines, are the result of films of biological oils on the surface. Photo courtesy of NASA; cover design by Rosemary Moak.

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21st Century Science & Technology (ISSN 0895-6820) is published 4 times a year in 1997, every third month, by 21st Century Science Associates, 60 Sycolin Road, Suite 203, Leesburg, Va. 20175. Tel. (703) 777-7473.

Address all correspondence to **21st Century**, P.O. Box 16285, Washington, D.C. 20041.

Second-class postage is paid at Leesburg, Va. and additional mailing offices.

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POSTMASTER: Send address changes to 21st Century, P.O. Box 16285, Washington, D.C. 20041-0285.

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Printed in the USA ISSN 0895-6820

EDITORIAL

Rethinking the Laws of Gravitation

To best appreciate the significance of Prof. Maurice Allais's report in this issue on his experiments with the parabolic pendulum, it is helpful, and even essential, to look back at some of the now little known work on gravitation carried out by leading figures in 19th century physics. Only in that way, by re-examining the origin and history of the subject, can the widespread prejudices and misperceptions embedded in contemporary thinking be uprooted.

The first thing one must know in approaching this subject, is that Newton's formulation (there exists a force of attraction between all bodies in the universe, whose strength is inversely proportional to the square of the distance between them), was always contested by a leading current within scientific thought. Almost a century before Newton, Johannes Kepler had recognized the inverse square law of attraction; he regarded it only as a minor mathematical consequence of his seminal discoveries concerning the arrangement and motions of the bodies in the solar system.

'Occult Forces'

In Newton's own time, Gottfried Leibniz, as spokesman for the leading faction of continental physicists, criticized Newton (a notorious practitioner of alchemy and the black arts) for reintroducing, with his concept of gravitation, the scholastic conception of "occult forces" into science. The hegemony of Newton's view, over that of Kepler and Leibniz, was established only after a concerted and politically motivated effort by the British Royal Society to discredit Leibniz, by falsely attacking his original discovery of the infinitesimal calculus. (Leibniz was the likely candidate for British Prime Minister before the accession of George I of Hanover.) Even so, further advances in mathematical physics were accomplished by the students and collaborators of Leibniz, such as the famous Bernoulli brothers. British science, meanwhile, labored in the darkness of the Newtonian "method of Fluxions" for more than a century, until the collaboration of John Herschel and Charles Babbage brought

enlightenment to Cambridge in the 1830s.

For those who had grown to accept Newton's "occult force," the mathematical formulation of the laws of physics appeared, by the early 19th century, to have gained a certain symmetry and elegance around the conception of "central forces." The attractive, and repulsive, forces between the presumed elementary particles of static electricity and magnetism had been shown to obey the same *inverse square law* as did the gravitational attraction hypothesized by Newton.

Ampère's Revolution

André-Marie Ampère's work between 1820 and 1826 put all that in doubt. Following on Oersted's 1819 discovery that electricity from a battery had the power to change the orientation of a magnetic compass needle, Ampère went to work to determine the law governing the relationship between two almost infinitesimal elements of electrical current. He came to the inescapable conclusion, that the force between two current elements is solely dependent on the inverse square of the distance *only* in the special case that the line connecting their centers make angles of 90 degrees with the direction of each of the elements. In every other case, the angle between the current elements must be taken into account in determining the force, according to a law which Ampère deduced from careful experimentation. It even results that, at a certain critical angle, the attractive force may become repulsive, and *vice versa*, giving rise to what is now referred to as the Ampère *longitudinal force*.

A whole branch of mathematical analysis, known as potential theory, which rested on the assumption of a central force obeying the inverse square law, was now in need of revision. Recognizing the deep implications for mathematical physics, Carl Friedrich Gauss, with the assistance of Wilhelm Weber, undertook an experimental program, beginning 1829-1830, to verify the Ampère deductions. The results were positive. In an 1846 paper, Weber subsumed the phenomenon of induction (not known to

Ampère) in his conception of electrodynamic action, and reformulated the fundamental electrical law in a form in which the force between electrical particles was shown to be dependent on their distance, their relative velocities and acceleration, and a constant, c .¹

Since matter was thought to consist of electrical particles, the Weber law implied that the relative motions of large bodies, such as planets, with respect to the Sun, might generate a force of attraction or repulsion beyond the already known gravitational effect. Among the anomalies in planetary motions not fully explicable by the postulate of gravitation, the advance of the perihelion of Mercury was high on the list. In 1864, the astronomer C. Seegers of Göttingen published a paper deriving the anomalous variation of Mercury's orbit from Weber's electrical law.² This work was continued by Schiebner in Leipzig and Tisserand in France.³

The 'Mossotti Force'

Weber himself took a different tack. In a posthumously published work, probably dating from the 1880s, he examines the relationship of his electrical law to gravitation. His point of departure was the hypothesis of O.F. Mossotti (about 1830), that the gravitational attraction results from a very slight excess in the force of attraction between unlike electrical particles, over the force of repulsion between like electrical particles. Assuming bodies to consist of equal numbers of positively and negatively charged electrical particles, this would result, according to Coulomb's Law, in a net attractive force, proportional to the mass of the bodies and the inverse square of their distance.

Weber attempted to measure the "Mossotti force" experimentally, using strongly charged spheres, but was unable to come to a definite conclusion. Nonetheless, his speculations on the subject led him to conjecture an electrical *aufbau* principle for the periodic table, much in advance of his time.⁴

At the beginning of this century, the Swiss physicist Walther Ritz, a pioneer in the study of atomic spectra, proposed that the orbital motion of electrons would generate an attractive force, according to the Weber law, which would not be cancelled out by the random average orientation of atomic axes. However, Ritz suffered a tragic early death,

and was unable to follow through on these ideas.

In the *Philosophical Fragments* of Bernhard Riemann, the brilliant student of Gauss and Weber, we find a different and entirely unique approach to the problem. Riemann makes a fundamental, ontological critique of Newtonian gravitation, echoing Leibniz. The reductionist concepts of self-evident extension (space), and elementarity (mass), must be superseded by a hylozoic concept: A "particle" is the place in space where matter flows into, and out of, existence, by a process somewhat analogous to the pulling up of a thought from memory.⁵ These ideas were not pursued. Riemann died early in 1866, after which a flood tide of reductionism, empiricism, and positivism overwhelmed, and nearly drowned, his intellectual legacy.

Although we touch on some of the leading thinkers of the last century, we can only scratch the surface. Our point is not to offer a complete review of the theories of gravitation, but to demonstrate the impoverished level to which our theory has fallen today. Already in 1826, Ampère's work had both demonstrated a fundamental flaw in the theory of gravitation, and opened the way to a solution unifying our conceptions of gravity, electricity, and the atom. Today, nearly two centuries later, we are further than ever from such a unifying conception. We not only do not know; we virtually forbid that the question be asked.

We thus welcome in this issue the contribution by Prof. Maurice Allais, who dared to challenge the deadly complacency on the subject of gravitation with a careful experimental research program carried out from 1953 to 1958. Although the results were published in a U.S. journal in 1959, at the request of rocket scientist Wernher von Braun, they have become virtually unknown today. They are too important to remain thus ignored. The reader will gain a deeper appreciation of Prof. Allais's

work in physics by reference to his contribution in the Spring 1998 issue of *21st Century*, particularly Allais's summary statement, "On My Experiments in Physics, 1952-1960," which appears on pages 32-34.

—Laurence Hecht

Notes

1. When in 1855, Weber and Kohlrausch, with the assistance of Bernhard Riemann, determined the value of that constant (thenceforth known as the *Weber constant*) to be correlative with the velocity of light *in vacuo*, the essence of what contemporary textbook wisdom today presents as the work of Lorentz and Einstein was already known.
2. *De motu perturbationibusque planetarum secundum legem electrodynamica WEBERIANAM solem ambientium* (On the motions and perturbations of the planets in the solar system according to Weber's electrodynamic law).
3. *Sur le Mouvement des Planètes autour du Soleil d'après la loi électrodynamique de Weber*.
4. Already in 1870, Weber had shown that his electrical law led to the conclusion that the "Coulomb repulsion" of like particles is overcome at a certain critical length, which, for negatively charged particles, he showed to be equal to the expression now known as the *classical electron radius*. This is most interesting in view of the common assertion by today's experts that the electron was only *discovered* several decades later by J.J. Thompson at Cambridge. (See Laurence Hecht, "The Atomic Science Textbooks Don't Teach: The Significance of the 1845 Gauss-Weber Correspondence," *21st Century*, Fall 1996, p. 21.)
5. An English translation of Riemann's "Philosophical Fragments" appears in *21st Century*, Winter 1995-1996, p. 50.



Letters



Review Miller's Work to Combat Relativity Virus

To the Editor:

I just finished your Spring 1998 cover story ["The Experiments of Dayton C. Miller (1925-1926) and the Theory of Relativity," p. 26] by Maurice Allais.

I am one of those who has been of the opinion that the evidence supporting the wave theory of light should not be so lightly dismissed, although the phenomena that helped create quantum theory can not be lightly dismissed either.

Until I read your articles I was not aware of the Miller experiments. Now I am of the opinion that you are correct in urging a complete review of Miller's work, to combat those who are infected with the Relativity Virus! Further, the experiments should be run under different conditions, as the nature of an "ether"-type medium would certainly lock the medium into the surrounding environment. Embedding the experiment in concrete would yield null results, just as an air-motion detector imbedded in the ground would not detect the presence of a hurricane outside the room!

Unfortunately, it will take more than Miller's experiment to convince some, just as simple observations were insufficient at the turn of the century when Plate Tectonics was first proposed by serious geologists. It just seems to show that some people, educated though they may be, are still afraid of standing up and being counted, for fear of losing their position. It is no wonder that progress has been so slow in some fields.

What is needed is an experiment that directly detects the ether in such a way as to be nearly irrefutable.

Michelson-Morley-Miller:

The following experiment I dreamed up some years ago might qualify:

Using a *fiberoptic* "cable" looped around, and very near, a flywheel, check the attenuation of the transmitted light with the flywheel running versus the flywheel stopped.

The beauty of this is that air currents from the flywheel would not affect results, as they might in other such experiments. Also, great sensitivity can be achieved by using several miles of fiber in circular loops. What might happen is that the light path in the fibers will be altered to hit the side wall with a greater incident angle, thereby increasing the attenuation, and resulting in a measurable loss of light intensity.

At one time, I had hopes of performing the experiment myself, but have not been able to do so. Besides, no one pays attention to engineers, right?

If, in fact, a spinning flywheel is throwing off the ether—it is in effect pumping! If it is pumping, then it can be deflected. If it can be deflected, then it might be channeled and create a "drive" through what is currently called a vacuum!

B.E. Johnson
Issaquah, Washington

In Defense of Special Relativity

To the Editor:

I subscribed to *21st Century* magazine because of its good articles on the history of science, a subject matter of my special interest, since I am a physicist, now retired (age, 71). Unfortunately, with the Spring 1998 issue, I felt a deception. Why? When I was in active research at the Physics Department of the Instituto Tecnológico de Aeronáutica (São José dos Campos, SP, Brazil), I had published several papers on relativistic cosmology in international scientific journals. (I am a member of the American Association for the Advancement of Science, the American Physical Society, and the New York Academy of Sciences.) Thus, as a theoretical physicist, I disagree strongly with the French economist Maurice Allais, who thinks he can discredit Einstein's theory of special relativity. Allais's viewpoint of the genesis of the special theory of relativity is completely wrong.

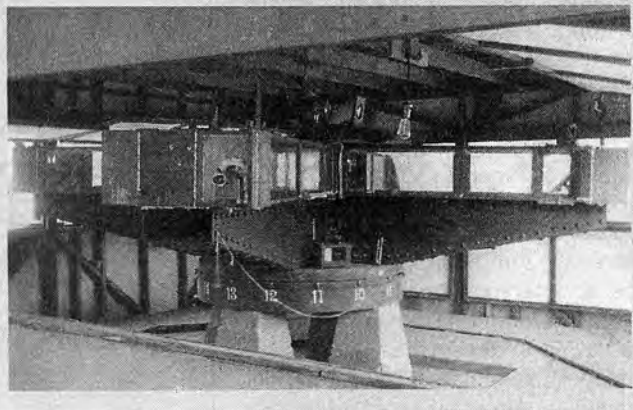
First of all, the Michelson-Morley experiment is not the experimental basis of Einstein's ideas. In his celebrated paper of 1905 ("On the Electrodynamics of Moving Bodies," in *Principles of Relativity*, Dover, 1923), Einstein formulates two fundamental hypotheses, which afterwards became cornerstones of relativistic dynamics: the principle of relativity, and the light principle. These two axioms were formulated by Einstein after a theoretical analysis of the unsatisfactory status inherent to classical electrodynamics, in relation to space reference frames. Einstein was then informed of several experiments (not only Michelson's) dealing with attempts to measure the motion of the Earth relatively to the ether. However, he made no description or analyses of those experiments. In Einstein's words:

"Examples of this sort, together with the unsuccessful

Michelson-Morley-Miller: The Coverup

The Experiments of Dayton C. Miller (1925-1926) And the Theory of Relativity

by Maurice Allais



The Coverup

attempts to discover any motion of the Earth relatively to the 'light medium,' suggest that the phenomena of electrodynamics, as well as of mechanics, possess no properties corresponding to the idea of absolute rest."

Note that *Einstein doesn't mention the experiment of Michelson-Morley*. From his conjectures on that *unsatisfactory theoretical situation* of electrodynamics, he *postulated* the two fundamental principles of special relativity. From the two principles, he *deduced* the laws of transformation between inertial reference frames. Now, these laws, deduced from his two fundamental postulates, are exactly the Lorentz transformation equations obtained by the latter through a completely different way from Maxwell's field equations. Einstein had then no knowledge of Lorentz's feat, which was done some months before. M. Allais's statement that "following Lorentz, Einstein developed his Theory of Relativity," is highly erroneous.

Maurice Allais invokes the famous Dayton Miller experiment of 1933, a version of Michelson's test, in order to dethrone the theory of special relativity, as if it rested on that laboratory verification. First, let me recall an epistemological principle: A single laboratory experiment is not a serious argument against a theory whose different predicted effects are corroborated with high accuracy through a constellation of laboratory experiments. This reminds me of the Portuguese saying, "*uma só andorinha não faz verão*" ("a single martin-bird doesn't produce summer").

Miller's experiment is that single martin-bird, for a galaxy of scientific experiments fulfills with high precision several predictions of relativistic dynamics. Modern physics of high energy processes, quantum field theories, and particle theories are unthinkable without relativistic dynamics. There is an overflow of experiments washing away Miller's solitary experiment.

Let me remind you that 12 experiments from the 19th century to the Kennedy-Thorndyke experiment of 1932 (*Phys. Rev.*, Vol. 42, p. 400), were consistently interpreted by Einstein's predictions. Several of those experi-

ments were tentatively interpreted at the beginning by ad hoc hypotheses. But it happened that whenever one of those hypotheses seemed to render an experiment understandable, nonetheless it entered into contradiction with another of those hypotheses. The considered hypotheses such as the partial ether drag, total ether drag, Lorentz-Fitzgerald contraction, and so on, were completely discredited (Panofsky-Phillips, *Classical Electricity and Magnetism*, Addison-Wesley, 1962).

Only Einstein's theory was able to put order in that chaos of experiments, badly tackled with isolated ad hoc hypotheses. A theory was needed, not isolated hypotheses, and Einstein's was that theory.

We must be suspicious of people without scientific education, who adventure to criticize highly specialized scientific subject matters. Unfortunately, *21st Century* accepted an economist Nobel Prize winner, not a physicist, to discredit a physical theory of the highest importance in modern physics. If Maurice Allais's arguments possessed really sound scientific status, it could have been published in a physics *journal*. But he published his ideas against Einstein in a *magazine*, *Aero/Space Engineering*, not devoted to science, but to technological matters.

Laurence Hecht's scope to deny the scientific seriousness of the Shankland, McCuskey, Leone, Kuerti paper (*Rev. Mod. Phys.*, Vol. 27, p. 167, 1955) is also unfortunate. When those four experimental physicists did their work, nobody in the physical community had doubts as to the solidity of Einstein's scientific achievement. The four American physicists, in effect, proved that Miller's experiment was a lonely martin-bird that could not produce summer, and it was flawed.

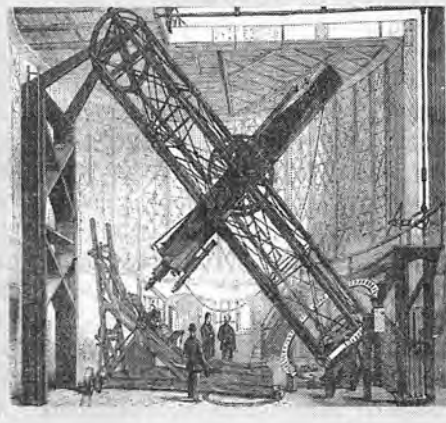
May I add the following: New technological devices in the last years have given, through the highest accuracies, more empirical corroboration to the theory of special relativity. Examples:

A group of experimental physicists at CERN during 1964 and 1965, using

Michelson-Morley-Miller: The Coverup 

Optical Theory in the 19th Century and the Truth about Michelson-Morley-Miller

by Laurence Hecht



high-energy neutral pions, verified with an accuracy of 1.3×10^{-2} percent the second postulate of special relativity (*Science*, Vol. 251, p. 359, 1991). In other words, a precision of 130 parts per million. In 1985, improving the Ives-Stillwell test, which corroborates relativistic aging, a group of physicists from Denmark and Colorado State University obtained a precision of 4×10^{-3} percent, that is, 40 parts per million. Also in 1985, an updated Kennedy-Thorndyke experiment by Hall and Hils yielded a precision of 7×10^{-3} percent. This result is accurate by 300-fold over the previous experiment by Kennedy-Thorndyke (*Science*, Vol. 242, p. 1207, 1990).

The increasing sophistication and accuracy of measurement in physical laboratories have reduced the Miller experiment to the category of a prehistoric event. Hence, no "coverup."

It seems to me that an epistemological error looms over Allais's lucubrations—this: scientific theories are extracted from experiments. The opposite is true. A scientist, especially a theoretical physicist, imagines conjectures at the start, passing to formulate hypothetical propositions from which a theory is deduced. A good theory is predictive of unknown physical processes and, as such, allows the possibility of

inventing experimental devices that may or may not corroborate theoretical predictions.

The Michelson, Fizeau, Trouton-Noble, and Airy experiments, for instance, were invented to test predictions of Newton and Maxwell's theories. The new experiments devised, as for example, Kennedy-Thorndyke, Ives-Stillwell, and so on, were made to test a new theory, the special relativity theory. Thus, the theory determines the existence of the laboratory, not the contrary. The scientific procedure is based on Plato's hypothetic-deductive method, not Aristotle's empirical-deductive method. Let me quote Einstein, who states it clearly:

"We now realize, with special clarity, how much in error are those theorists who believe that theory comes inductively from experience. . . . There is no inductive method which could lead to the fundamental concepts of physics. . . . Logical thinking is necessarily deductive; it is based upon hypothetical concepts

and axioms." ("Physics and Reality," *J. Franklin Institute*, Vol. 221, p. 349, 1936).

Prof. Fernando M. Gomide
Petrópolis, RJ, Brazil

Laurence Hecht Replies

I do not question that some sort of correction in the false assumption of simple linear extension in space and time, is necessary in the interpretation of high-energy/high velocity experiments. The relativistic correction is an approximation, but the actual nature of the underlying phenomenon is the issue for physics. In my view, as I noted in my article ["Optical Theory in the 19th Century and the Truth about Michelson-Morley-Miller," Spring 1998, p. 35], the "paradox of simultaneity" is the philosophical underpinning of Einstein's Special Relativity theory, as its author stated, not the

Michelson-Morley experiment. The issue goes much deeper than whether Special Relativity is "right." Physics must seek out anomalous results; look for the contradictory singularities, and ambiguities; not attempt to suppress them, because they don't fit a textbook formulation.

To continue to cling to Special Relativity, in view of not only Miller's, but so many other anomalous results in so many branches of research, is the problem, in my view. Isn't it obvious that our inability to clearly explain the atomic spectra beyond hydrogen poses some fundamental problems?

If you are familiar with the work of Fresnel, Ampère, Gauss, Weber, and Riemann, which we have attempted to present in recent issues, you see how little we have progressed in *fundamentals* concerning these matters, since the early 19th century, despite the sophistication of our applications. Recent issues of our publication have attempted to direct our

The Cost of Not 'Investing' In the Space Program

To the Editor:

Marsha Freeman's article in the Summer 1998 issue of *21st Century* ["Krafft Ehrlicke's Moon: A Lush Oasis of Life," p. 19] represents the overly optimistic view of a super space salesman rather than the harsh realities of today's and the foreseeable future's space technology.

The energetics and economics of spaceflight certainly dictate a far different picture of transportation systems compared to the steamship, railroad, auto, and aircraft. Let us remember that in the aforementioned systems, the government played only a minor role. This was not the case of rocketry, which started out as a weapons system with cost not a major factor, and not with spaceflight as a goal.

With rockets as the only choice, the average launch cost for a commercial communications satellite is about \$67 million, and for a meteorological satellite about \$64 million. With the limited present providers, and a \$95 to \$115 billion market over 10 years, through 2004, users will again have to pay the high price, according to Euroconsult, a French

group evaluating the launch services market.

The Apollo mission returned Moon rocks for about a half billion dollars per pound. The Shuttle orbital payload cost is over \$14,000 per lb. Based on a crew of six, a ticket on the Shuttle costs about \$83 million per person. The Venture Start SSTO [the planned follow-on to the Shuttle], with its propellant mass fraction of over 92 percent (corresponding to a robustness of a pop can), will be lucky to halve the Shuttle cost.

The Shuttle and SSTO will be transportation systems failures: the payload [fraction] of the Shuttle is only 1.43 percent. The Saturn Apollo payload was only 1.6 percent. By comparison, the Concorde is only 7.27 percent, a 747 is about 21 percent, and a loaded passenger car is about 25 percent, while a 75-car train is 77 percent.

Commercial spaceflight will never be viable on an economic basis with the rocket system (including nuclear and electric systems), whereby most of the mass is expended. [Wernher] Von Braun's 1948 Mars mission was estimated to cost more than the Berlin airlift. The entire Apollo program cost was \$25 billion in 1963 dollars. Returning another three astronauts to the Moon, with return, would cost more than \$100 bil-

lion in year-2000 economics. And there are no vehicles in existence, or planned, to do that, let alone start and supply a Moon colony.

NASA has low-balled the cost of erecting and maintaining the future International Space Station at \$30 billion to the year 2013. And for a single six-man mission to Mars, the cost would easily be \$500 billion for a chemical rocket system, or \$1 trillion for a nuclear rocket system (not yet developed or likely to be developed). The nuts-and-bolts Dr. [Eugen] Sanger estimated a manned Mars mission at about the entire cost of World War II, and a Moon mission about the cost of a large aircraft carrier.

Ehrlicke, on the other hand, states that the Moon is not a scientific base, but grounds for a city, Selenopolis. But he neglects the above costs. He also argues not only for development of habitats, but also of material extraction and processing. At present economics, however, large-scale return of Moon materials is not feasible. If not these, then what kind of economics would be required? A Disney attraction? Book your vacation to Disneyopolis. But be prepared to pay the price!

Alfred J. Zaehring
Troy, Michigan

readers' attention to the consideration of such fundamentals.

As you will see in the leading piece in this issue (p. 23) Prof. Maurice Allais cannot be dismissed by physicists as a "mere economist." He has carried out fundamental work in experimental physics over a series of decades, and of a most provocative kind. We uphold his research on the anomalous behavior of the pendulum, as exemplary of the sort of fundamental probing into physical phenomena that ought to be going on today. That he was forced to publish his results in an aerospace journal, and not one of the "approved" journals of "pure" physics, is, in our opinion, only a commentary on the almost legendary and hidebound, conservatism of the physics establishment, not on the quality of his work. Note that it was Wernher von Braun who recommended publication.

Regarding modern corroboration of Michelson-Morley, I do not see how Hall-Brillet have answered the objec-

tions which Miller had already made to other attempts, in his time, to repeat the experiment, including the Kennedy-Thorndyke effort: Namely, the problem of closed chambers, and possible consequent effects of some sort of other entrainment. As you must know, the greatest sophistication of measurement accuracy does not, in any way, overcome fundamental problems of assumption embedded in experimental design.

Concerning Shankland, I strongly suspect that he engaged in a career-motivated hatchet job, rejecting his previous collaboration with Miller and attempting to ingratiate himself with Einstein at a time when it was politically advantageous to do so. As Professor Allais reiterates in this issue (Note 38), there was no basis for dismissing Miller's observations as instrument error.

You lift yourself above the run-of-the-mill defenders of today's academy-approved, textbook mathematical-

physics in raising the epistemological question. However, I can agree with neither your methods, nor conclusions. Pierre Duhem's attack on Bacon's inductivism (which Bacon picked up from the Venetian Paolo Sarpi), does not provide an adequate rendering of Plato's Method of the Higher Hypothesis. Rather, I believe, it leads to terrible confusion.

Perhaps you will consider the writings on this subject by Mr. Lyndon LaRouche.¹ Here is an economist, who dares, not only to comment on matters of methodology in physics, but, who even claims that the discipline of physics must be subsumed by the study of physical economy—and this on epistemological grounds! We are sure you will find it, at least, provocative.

Notes

1. See, for example, Lyndon H. LaRouche, Jr., "Mathematics & Measurement: Science vs. Ideology," *Executive Intelligence Review*, Aug. 21, 1998, p. 20.

Marsha Freeman Replies

Alfred Zaehring, a space pioneer and founder of the Detroit Rocket Society in 1946, reflects in his letter a demoralization about the state of space exploration, the economy, and the nation's cultural outlook, that unfortunately has infected others in the space community.

Evaluating whether or not an activity should be undertaken has today been reduced to what it will "cost," rather than to that of the value it will return. And the accountants and bean counters insist that what it will return to society must be measured in money.

In reality it does not matter at all what it "costs" to have a space program. That money is not spent; it is an *investment* in the future. Space investment produces enabling technologies that increase the productivity of the *entire* economy, through spinoffs in every field from medicine to new materials. It also inspires and uplifts the cultural outlook of the population, which increases the density of new scientific breakthroughs in the future.

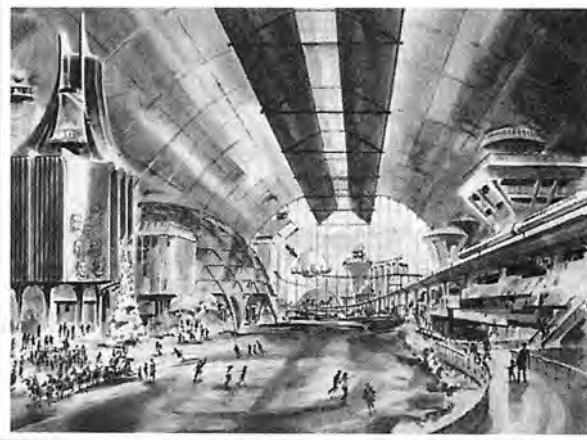
What is the monetary value of finding cures for debilitating and fatal diseases, using space-based microgravity tools? Can you put a figure of return on investment for money spent in space

that will encourage young people to become scientists and engineers? What is it worth to peer out into the universe from space and discover new worlds? For that matter, was it worth the money we spent on the Berlin airlift?

Cheapening the cost of access to space will broaden the uses to which this unique environment can be put, but no space program can be planned on the basis of accounting. Should we be pushing ahead on the frontiers of new technology? Absolutely. Should we be waiting to explore new worlds until it is "cheaper?" Certainly not.

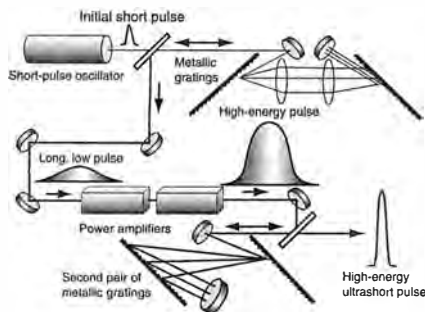
While it is the case, as Mr. Zaehring points out, that the car, airplane, and railroad were the product of creative inventors, in fact, turning these inventions into capabilities that changed the face of this nation was the responsibility of the elected government. In his article, "How the Government and Army Built America's Railroads," (*Executive Intelligence*

Krafft Ehrlicke's Moon: A Lush Oasis of Life



Review, July 17, 1998), historian Anton Chaitkin dispels the commonly held myth that it was "private entrepreneurs" who built the railroads.

Krafft Ehrlicke envisioned a future where the government would return to its historical role of investment in future technologies and infrastructure, enabling the creative contributions of individuals, this time in space. There is no better time than the present to begin the expansion of human civilization to other planets.



SCHEMATIC OF SHORT-PULSE PETAWATT LASER

The short pulse originates from a titanium-sapphire laser oscillator that produces a broadband initial short pulse. Mirrors deflect this to metallic diffraction gratings, which stretch it out into a long, low-energy pulse. One set of mirrors deflects this stretched pulse into broadband power amplifiers, which produce the high-energy pulse. A second set of mirrors deflects this pulse into a second pair of metallic diffraction gratings, which compress the high-energy pulse into a high-energy ultrashort pulse. A plasma mirror then focuses this final pulse onto the target.



NASA

John Glenn, practicing insertion into his Friendship 7 spacecraft, a few days before his history-making first American orbit of the Earth.

PETAWATT TABLETOP LASER WILL REVOLUTIONIZE MACHINE TOOL DESIGN

The petawatt (10^{15}) laser, designed initially as an ultrashort pulse to help ignite fusion fuel pellets, has demonstrated a new type of interaction with matter, with many potential applications for machine tool design. A broadband ultrashort laser pulse is generated from a solid-state titanium laser. The pulse is as coherent as ordinary monochromatic laser pulses, but consists of many different wavelengths. It is then passed through a diffraction grating, which breaks the pulse up into its various colors. Each of the colors then travels a separate path of varying length. The pulse is reflected off a second grating, generating an elongated version of the original pulse, which then is passed through a second series of gratings. There, the colors are recombined in space and time to regenerate the original pulse length, but at 100 billion times greater energy. A plasma mirror is then used to focus the final pulse onto a target.

Scientists at Lawrence Livermore National Laboratory have shown that as the laser pulses get shorter and shorter, there is a transition from the thermal mode of energy transfer to a new mode, where there is virtually no heat energy transferred to the metal in machining. Each laser pulse typically removes just a few microns of material. Because the pulses can be generated thousands of times per second, the machining process is both rapid and "cold," with no significant transfer of heat to the material being worked on.

The petawatt laser grew out of work at the University of Rochester, Lawrence Livermore, and other laboratories primarily working on inertial confinement fusion. A report on the petawatt laser by Associate Editor Charles B. Stevens will appear in the Oct. 9 issue of *Executive Intelligence Review*.

RATE OF GROWTH OF WORLD POPULATION FELL IN 1997—AGAIN

According to the latest data of the U.S. Bureau of Census, the decline in the growth rate (now a 20-year continuous phenomenon) again accelerated in 1997 and the first half of 1998. The Census Bureau figures, covering 157 countries or island groups and many other islands, principalities, or territories, show that 30 of the 157 countries now have falling populations. A year ago, there were 17 such nations. Of the 30 with declining populations, 16 are in West, Central, or Eastern Europe; 7 are in Africa; and 4 in the Middle East. An additional 16 countries are at zero growth, including 5 in Europe.

The overall figures give a mid-1998 world population of approximately 5,925,000,000 human beings. This is about 75 million more than in mid-1997, the lowest increase in more than a decade. The world growth rate was still 2 percent per year in the 1980s; 1.7 percent at the 1992 Rio Conference. It fell to 1.4 percent by 1997, and now, a year later has fallen to 1.29 percent. By 2000, the "extreme goals" of the Malthusian NSSM 200 and the Global 2000 Report—a 1.1 percent world rate at the end of the century—will be reached or exceeded.

A more detailed analysis will appear in the next issue of *21st Century*.

SEN. JOHN GLENN SET FOR SECOND HISTORIC MISSION IN SPACE

When John Glenn made his Mercury space flight in February 1962, he assured his place in history as the first American to orbit the Earth. At age 77, Glenn will become the oldest person to fly in space, when he boards the Space Shuttle in late October. While political pundits have decried Glenn's flight as a waste of money and a political stunt by NASA, millions of Americans and organizations, including the American Association of Retired Persons and the American Federation for Aging Research, have hailed his flight for the contribution it will make to research on the process of aging, by looking at analogues in the adaptation to microgravity, and to the vital image of what Americans can accomplish in their later years.

FREEMAN PRESENTS MEMOIR ON SPACE PIONEER TSANDER AT IAF

21st Century Associate Editor Marsha Freeman presented a paper on the contributions of space pioneer Fridrikh Tsander (1887-1933) at the 49th congress of the International Astronautical Federation in Melbourne, Australia, Sept. 29. Tsander, a Latvian-born space engineer, established the first amateur space society in the Soviet Union, and made numerous contributions to advanced designs for space vehicles.

Copies of the paper are available; send a self-addressed #10 business envelope with \$.55 postage to 21st Century, Attn.: Tsander paper.

MORE ICE AT LUNAR POLES THAN PREVIOUSLY THOUGHT

Scientists who have been analyzing the data collected by the Lunar Prospector spacecraft over the past six months, reported in early September that they have upped their previous estimate of water ice at the lunar north and south poles from 300 million tons to 6 billion tons. The ice, which has collected in the permanently shadowed craters at the poles, is thought most likely to have come from impacts of watery comets. The new analysis indicates that near-pure water ice deposits are buried beneath as much as 18 inches of dry regolith (soil). Such a cache of water on the otherwise bone-dry Moon could aid in human colonization.

'SCIENCE FOR KIDS' IS NEW USDA AGRICULTURAL WEB SITE

The Agricultural Research Service of the U.S. Department of Agriculture has established a web site for children ages 8-13, with interactive stories on agricultural science and research. "Sci4Kids" can be found at: <http://www.ars.usda.gov/is/kids>. "We're hoping children will use the site to gain a greater understanding of agriculture's importance to their daily life," said Under Secretary of Agriculture I. Miley Gonzalez.

CUMBRIANS BRING ANTI-NUCLEAR CAMPAIGN TO WASHINGTON, D.C.

In a presentation that was long on color slides of the beautiful Cumbrian countryside but short on numerical data, representatives of the British group Cumbrians Opposed to a Radioactive Environment (CORE), told a Washington, D.C., audience Sept. 25 that the Sellafield nuclear reprocessing plant is responsible for little children dying of cancer. When nuclear engineer Dr. Theodore Rockwell, representing 21st Century, commented that neither the scientific community nor the courts have been willing to attribute such deaths to Sellafield, CORE's Janine Allis-Smith answered that there was no dispute that the number of deaths near Sellafield is abnormally high, but that scientists have not been able to connect this situation to radiation. CORE termed as "ominous" the entry into the U.S. market of Sellafield's owner, British Nuclear Fuels. The press briefing was sponsored by the Institute for Energy and Environmental Research and the Safe Energy Communications Council, both of which are anti-nuclear. As for the name of CORE, Rockwell noted that there aren't any places on Earth to go to avoid a "radioactive environment."

SCIENCE COALITION PROMOTES BASIC RESEARCH IN SCIENCE

"Great Advances in Science" is the title of a report issued Sept. 24 in Washington, D.C., by an alliance of institutions, including public and private universities, "dedicated to sustaining the federal government's historic commitment to U.S. leadership in basic research." The report features scientific discoveries in many fields, which grew out of university-based research. Among the projects highlighted are the imaging of gamma-ray bursts, techniques to genetically alter mosquitoes so that they cannot transmit diseases, a system to monitor the movements of continents and the growth of mountains from space, and the fabrication of atomic-scale magnets. For more information: www.sciencecoalition.org.



Fridrikh Tsander as a student in Riga, Latvia, in 1913.



Courtesy of the Science Coalition

The Science Coalition released its report at an event hosted by the House Science Committee. From left: Prof. Jim Head, Brown University, Rep. George Brown (D-Calif.), and George Rupp, president of Columbia University.

VIEWPOINT

THE SICKLE CELL DEBACLE How Research Cuts and the Free Market Virus Kill People

If you were severely ill, would you want to have to fight an insurance company, an HMO, a pharmaceutical company, or the government merely to receive your medication?

This report on sickle-cell and beta thalassemia, two deadly blood diseases, is part of a series that pinpoints why government fostering of science (and technology) means the difference between life or death for millions of people. It also shows why a dirigist approach to fostering scientific investigation and development, consistent with the spirit of our nation's founding principles, today needs to be revived at home, and replicated around the globe.

No Funds for Killer Diseases?

A promising treatment program for sickle cell and beta-thalassemia lost its federal funding at the end of March. The Boston University Medical Center is one of the medical facilities affected by the loss. Although small in numbers, the Boston program involves a diverse group of research-patients—African-American, Italian, African, and Arab—ranging from 9 to 45 years old, with either sickle cell-beta thalassemia, or beta thalassemia (major). The five-year program was designed to conduct crucial studies to show the efficacy and appropriate dosing parameters of the drug arginine butyrate, in ameliorating symptoms and complications of



by Cloret Richardson

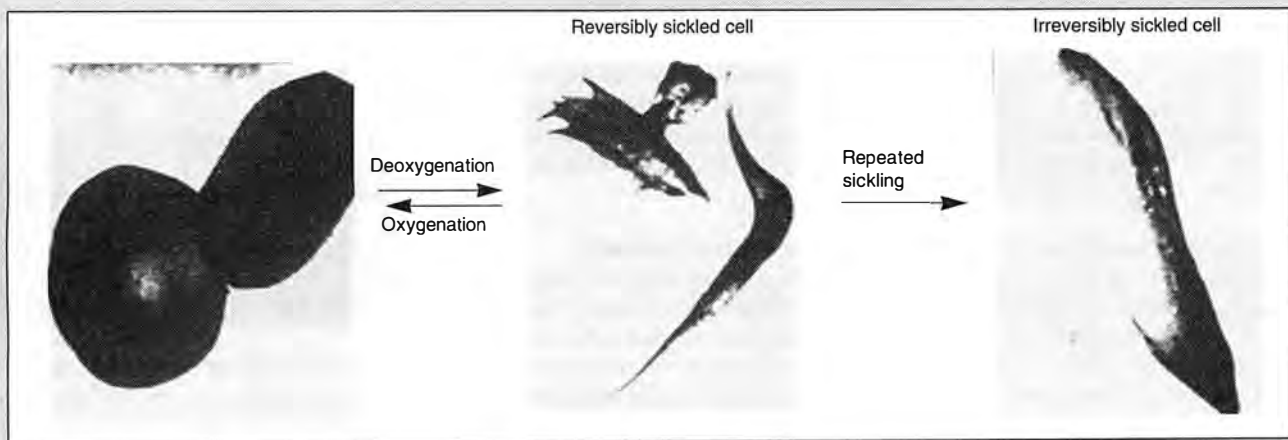
both hereditary diseases. The budget involved was approximately \$110,000 per year, mostly for patient supplies.

Without these government funds, programs like this one will end, and the research patients afflicted with sickle cell disease and beta-thalassemia (major) will lack the medical equipment and supplies needed to administer their life-saving medication. For some of the patients, who are participants in the Boston Medical Center project, this program has literally meant the "difference between life and death."

In America, health organizations estimate that, between 84,000 and 90,000 African-Americans, and 1 in 350 African-American newborns, are afflicted with sickle cell disease, while 1 in 12 African-Americans are said to be carriers of sickle cell trait. Somewhere between 1 in 800 and 1 in 2,500 Americans of Greek or Italian ancestry

are estimated to have beta thalassemia major. In addition, it is estimated that more than 2 million Americans are carriers of the beta-thalassemia trait. Since the 1960s, the life expectancy of sickle-cell disease patients has considerably improved. A 1994 study indicates that the median age at death for sickle cell anemia patients was 42 years for males, and 48 years for females. Slightly more than half of all sickle cell anemia patients are living into their fourth and fifth decades of life; in the past, relatively few were fortunate enough to survive into their 20s.

Contrary to textbook expositions, health officials remain unclear about how many people worldwide are afflicted with the two diseases, or the reason certain groupings of people, rather than others, inherit them. For example, thalassemia, once presumed to be inherited only by people of Italian or Greek ancestry, is also prevalent in Asia, India, the Middle East, and parts of Africa. It may also occur among African-Americans. Sickle cell disease and sickle cell-thalassemia (when both sickle cell and thalassemia traits are inherited together) occur widely in the nations of the Middle East and Arabian peninsula, Central Asia, Caribbean, South America, and Africa. The wide prevalence of both diseases among peoples of least-developed, or so-called



Educational Media/BUMC

The sickling process deoxygenates the red blood cell, resulting, after repeated sickling, in an irreversibly sickled cell.

Third World, nations suggests that ancestry plays a lesser role than usually claimed, in determining who exactly will pass these diseases along to their progeny.

In this vein, it is essential to investigate the hypothesis of physical scientist Lyndon LaRouche that certain types of anemias are borne out of generations of impoverishment—that is, malnutrition—and to examine the role political-economic factors, such as collapsing living standards, play in the incidence of severe forms of these diseases. Also to be investigated are the new clinical findings that show greater numbers of sickle cell trait and beta-thalassemia trait carriers becoming symptomatic.

Sickle-Cell and Beta-Thalassemia Syndromes

Sickle cell syndrome and beta-thalassemia syndrome refer to two different groupings of genetic disorders affecting the hemoglobin—the substance in red blood cells that transports oxygen throughout the body. The red blood cells of those with sickle cell disease change from their usual donut-like, balloon form to elongated, curved shapes, like a crescent moon or a sickle. These rigid, sticky blood cells then clog the blood stream, cutting off the flow of blood to vital organs of the body.

In a sickling crisis, deprivation of oxygenated blood can cause chronic fatigue; chronic infections; acute episodes of excruciating pain in the limbs, abdomen, lungs; stroke; life-threatening damage to vital organs; and tissue necrosis. Even under conditions of appropriate hospital treatment, complications caused by the sickling of blood can be far-reaching and deadly.

For example, at Boston's Mass General Hospital, a 22-year-old African man, with a history of sickle cell anemia and numerous sickling crises, was placed on a ventilator to alleviate respiratory distress caused by sickling of the blood in his lungs. On the second day in the hospital, he suffered cardiac arrest. All attempts to resuscitate him were unsuccessful. An autopsy showed that liberated fat from the dead bone

tissue of his hip (the bone necrosis had been caused by frequent deprivation of blood) had travelled to his lungs and, in combination with the sickled cells, had caused lung and heart failure.

The highest percentage of deaths among sickle cell anemia patients, a recent report concludes, occurs with adults who appear relatively fit but are highly symptomatic. The greatest percentage of deaths occurs not with overt chronic organ failure, but during classic sickling crisis, as a result of bone marrow and fat embolization.

Beta-thalassemia is a disease which causes red blood cells to be unusually small and fragile. Healthy red blood cells survive for four months; the thalassemic red blood cells break down within a few weeks. Most of the life-threatening problems and complications of this disease result from the "iron overload."

Until recently, children born with beta-thalassemia (major) rarely survived their first decade of life. The onset of the disease usually occurs in the first few months of life. The early signs are paleness, irritability, fatigue, fever, feeding problems, diarrhea, gastrointestinal complications, and, most notably, the complex of symptoms characterized as failure to thrive.

As the thalassemic patient lives longer, treatable symptoms become progressively more severe: enlarging spleen, severe anemia, jaundice, leg ulcers, easily fracturing bones, and enlargement of the heart. Damage to the spleen, liver, and heart occur as a result of the accumulation of iron and waste products from the rapid death of red blood cells.

The Physician As Scientist

In the 1970s, Richard Perrine, M.D., then chief of internal medicine for a Saudi Arabian-based corporation, led an international research team which discovered that among Saudi Arabian sickle cell patients who had high levels of fetal hemoglobin, the symptoms of the disease were far less prevalent. These individuals were discovered to have significantly better health, compared to patients who had low levels of fetal hemoglobin. Before birth, all hu-



Educational Media/BUMC

Sickled red blood cells: elongated and crescent shaped.

man beings possess what is called fetal hemoglobin (a form of oxygen-bearing protein present in red blood cells).

Working with infants of diabetic mothers a decade later, clinician-scientist Susan P. Perrine, M.D., the daughter of Richard Perrine, found that these babies continue to produce fetal hemoglobin long after they are born. Extrapolating from this discovery and the earlier results of her father, Susan Perrine sought to apply this knowledge in addressing the underlying problems of both sickle cell disease and beta-thalassemia (major). Was there a way to "artificially" stimulate the body's own ability to produce a healthy, functioning form of the oxygen-bearing substance that is defective in older sickle cell and thalassemia patients?

Ten years of medical trials, spearheaded by Perrine, demonstrate that intravenous infusion of a simple fatty acid—arginine butyrate—intermittently, over a series of months, can ameliorate the symptoms of sickle cell disease, and lessen the anemia of beta-thalassemia (major). Arginine butyrate stimulates the body's own production of fetal hemoglobin. Perrine designed both arginine butyrate, the intravenous drug used in the Boston-based study, and its oral derivative, isobutyramide.

Published accounts of Perrine's ground-breaking line of clinical research, conducted at the Children's Hospital in Oakland, California, appeared in *The New England Journal of Medicine*, the *New York Daily News*,

and *Jet* magazine early in 1993. At the time, Perrine received an overwhelming number of requests for the intravenous drug from doctors around the world. These requests outpaced production of the drug, which she was then producing by herself, in her lab at the Children's Hospital Oakland. Because there is at present no cure for either of the two deadly blood diseases, her treatment was viewed "as good as gold" by doctors internationally.

Free Market?

Having a pharmaceutical company take over responsibility for producing the sickle cell drugs would seem to be a promising development; the drugs could have been made available in larger quantities, and readily so. However, less than two years after Vertex Pharmaceuticals, Inc., of Cambridge, Massachusetts, gained "exclusive worldwide rights from Children's Hospital Oakland to develop, manufacture, and market" the two butyrate-based drugs designed by Susan Perrine, future development of the drugs became highly unlikely.

To appreciate the injustice done to Dr. Perrine, and understand why her research-patients' prospects for improved health look so bleak, in spite of her promising research, I provide a brief history of the problem.

In the spring of 1994, Vertex won the Food and Drug Administration's designation which classifies both arginine butyrate and isobutyramide as "orphan products." Granted earlier to Susan Perrine, this federal designation applies to drugs used to treat a disease the federal government categorizes as rare because (a) it affects fewer than 200,000 persons in America, or (b) it affects more than that number of individuals, but the anticipated costs of developing the drug and making it available for the disease might not be recoverable from sales of that drug.

The government allows the "orphan product" only one sponsor per medical indication (that is, purpose), for a



Educational Media/BUMC

Susan P. Perrine, M.D., discoverer of the drug that artificially stimulates the blood to produce fetal hemoglobin, the oxygen-bearing substance that is defective in older sickle cell and thalassemia patients.

period of seven years from the government's date of designating the sponsor.

Why is this designation so important? It gives the sponsor exclusive control over how much, and how often, the drug is produced. It makes the sponsor's clinical work with such a drug eligible for (1) federal assistance in the development of (medical) study protocols; (2) exclusive marketing rights; (3) tax credits for clinical research; and (4) clinical research grants to develop "orphan products."

In addition to winning exclusive rights to produce the two butyrate-based drug, Vertex also negotiated a lucrative financial partnership with another company, Alpha Therapeutic Corporation, to exclusively license the oral-derivative of the drug.

In numerous press releases, and in a prospectus for Vertex investors, the company led the public to believe that it was committed to developing both drugs. The company painted its work as "... an opportunity for Vertex to develop products with demonstrated clinical promise in an area where there is an important medical need."

However, once it possessed exclusive sponsorship, Vertex abandoned its work with both drugs, step-by-step.

In 1995, Vertex ended its work with arginine butyrate (the intravenous drug). A company press release stated, [Vertex] "... has committed resources to the development of other drug candidates in its pipeline." And in September 1997, a Vertex press release announced that it would also discontinue its work with the drug's oral derivative, and conclude its partnership license with Alpha Therapeutic Corporation, as well. In that one press release, Vertex terminated its entire hemoglobin program. However, Vertex still held exclusive rights to produce the drugs that it had decided not to produce! Why?

In the prevailing "strictly business" outlook of free trade ideologues, making a profit takes priority over everything else. In other words, let the sick people, who need these medications fend for themselves; profits before patients. Both companies decided that it would be easier to make money producing something other than these "orphan drugs."

(It should be noted that operations at Alpha Therapeutic Corp. are being scrutinized on an unrelated matter: the recent scarcity of another "orphan product" whose purchasing price has now skyrocketed, immune globulin, or "IG." IG is primarily used to treat life-endangering immune deficiencies in children. Its other medical indication, as an "orphan product," is also to treat sickle cell disease.)

Now, although Vertex has abandoned work with both arginine butyrate and its oral derivative, the company still holds exclusive rights to license the drugs for development and commercialization. In fact, even Susan Perrine, who designed both drugs, is legally prohibited from producing them in her lab. To speak plainly, any clinician-scientist producing these drugs to perfect their usefulness in saving lives, is liable to punishment as a criminal, even though the company holding the rights of production has abandoned development of the drug.



Roger Ham/EIRNS

The apparatus for infusing the life-saving drug, arginine butyrate, which Vertex Pharmaceuticals is refusing to produce, while it holds on to its exclusive license to develop the drug.

Accounts of why Vertex was awarded the rights to develop the drug, instead of Susan Perrine, its inventor, are contradictory. Vertex claims that individual doctors were not able to set up rigorous trials of the drug. Others claim that Vertex board members, who are also medical professionals, may have had political reasons for the decision.

From Bad to Worse

As if the Vertex abandonment of arginine butyrate were not bad enough, in March 1998, the situation for the Boston-based research program took a turn for the worse: Its government grant ran out. Applications for renewed government funding have been submitted, but at the moment, there is no money to continue treating the current research-patients, or to add new ones. Also, the federal government now puts limitations on the amounts it will grant any one type of research. Unless, this policy is changed, the prospect of this particular line of research receiving any more federal funding is very doubtful.

For many of the research-patients, this treatment-program is the only means of staying alive. Because of medical complications, some patients cannot undergo the "conventional" bi-monthly blood transfusions, or they lack medical insurance or the income

necessary to purchase insurance. Bi-monthly blood transfusions, daily supplies of iron-chelating drugs (to remove excess iron), and bone marrow transplants are extremely expensive.

At present, pre-mixed stocks of the arginine butyrate are available for an

undetermined number of months, and stopgap measures are currently holding the Boston Medical Center project together. However, a much better solution—a real solution—involves reassessment and enforcement of specific federal regulations set down to prevent such occurrences. For example, Public Law 100-290 (1988) of the Federal Food, Drug, and Cosmetic Act, states, "It requires sponsors with orphan designation to notify the Secretary of the Department of Health and Human Services (DHHS) If they either discontinue active investigation of the product, or discontinue manufacture of the product. . ." [emphasis added].

Above all, such predicaments remind us that our Founding Fathers, in anticipation, framed the fundamental principle from which government today should take its cue for approaching a solution, "To promote the [health and] general welfare" of all citizens in practice and deed.

Cloret Richardson is a longtime political activist with the LaRouche movement, and a sickle-cell thalassemia patient participating in the Boston University Medical Center sickle cell program.



Roger Ham/EIRNS

A patient flushes the implanted catheter of the Vascular Access Device into the superior vena cava, in preparation for infusing arginine butyrate directly into the bloodstream. The drug can ameliorate the symptoms of sickle cell disease and lessen the anemia of beta-thalassemia (major).

THE RECIPROCITY OF EXTREMES

The Astrophysics of Gurwitsch Radiation

by Lyndon H. LaRouche, Jr.



NASA
Inset: A.G. Gurwitsch, *Das Problem der Zellteilung* (The Problem of Cell Division), 1926

"If a principle of action corresponding to Gurwitsch Radiation exists in this universe, what does that principle thus prove about the nature of the universe itself?" Here, the Andromeda galaxy. Inset is Gurwitsch's onion experiment, which demonstrated that mitogenetic radiation from one onion root increased the cell divisions in a second onion root.

In my experience with relevant circles, both in oral exchanges and written works, the most frequent, and often most devastating flaw in the mental life shown among today's ostensibly best-educated science professionals, is a stubborn refusal to accept what ought to be the most obvious, and persisting challenges to their customary assumptions. Typical of the type of such problem met from among professionals of various specialties, is an axiomatic problem from the domain of one of the most significant, if relatively lesser known branches of science. I refer to a matter from the domain of biology. I focus upon what should be perceived as the most obvious of the implications of the most elementary experi-

mental definition of Gurwitsch Radiation. For my purposes here, I simplify the argument to be made, by defining the issue immediately at hand more narrowly: "the Riemannian implications of Gurwitsch Radiation."

The setting within which the discussion is situated, is the same topic which has dominated my philosophical and related concerns for six decades. It was, notably, the basis for my attacks against Professor Norbert Wiener's hoax, so-called "information theory," five decades ago; it has been the centerpiece of all my own original discoveries and their development and application, since that time. During the recent two decades, it has become, for readers of my published

work, the most frequently recurring theme of my published work. Thus, no science professional presently familiar with my life's work, will fail to recognize the theme.

Although I had been occupied by related topics from the work of Vernadsky, Rashevsky, and others since the middle to late 1940s, the work of Gurwitsch was first brought to my attention, about a decade and a half ago, by my associate Jonathan Tennenbaum. The latter contact startled me; Gurwitsch's discovery agreed with the related work of Vernadsky in the most remarkable degree. The reports on Gurwitsch's work by Professor Fritz Popp, were our initial point of reference. As a result, in light of the im-

portant bearing that work has on the entire domain of optical biophysics, researches into the area of Gurwitsch's discoveries became an integral feature of my own work and the work of the Fusion Energy Foundation (FEF) on the Strategic Defense Initiative (SDI) during the middle of the 1980s. Since the U.S. Department of Justice's fraudulent bankrupting of FEF's *Fusion* magazine, in 1987, continued interest in Gurwitsch's important contributions to biology has been revived by *Fusion* quarterly (Germany and France), and *21st Century Science & Technology*. The point of reference for the present treatment of the latter topic, is a report on that subject appearing, as a series, in Vol. 11, Nos. 2 and 3 of *21st Century Science and Technology* quarterly, in which a report by a Gurwitsch associate, Michael Lipkind, is featured [Sumner and Fall 1998].

Gurwitsch Radiation is an area of crucial experimental issues, which poses, implicitly, some of the most fundamental questions of epistemology for science as a whole. Not only does Gurwitsch's and related argument and evidence imply such questions; it is impossible to resolve the crucial-experimental issues except by designs of experiments which address that epistemological issue most directly.

On those and related accounts, the theme within which the discussion of Gurwitsch Radiation is properly situated, is the following. Since Plato, the most elementary mathematical conception of all scientific thought, has been, as Luca Pacioli, Leonardo da Vinci, and Johannes Kepler emphasized this principle, the challenge of recognizing both the distinction in axiomatic principles of ordering, between living and non-living processes, and the still-deeper implications of the existence of such a distinction within a universe which must be coherent throughout. The very concept of Gurwitsch Radiation poses precisely this topic as typical, axiomatically, of the leading issue of all known problems of mathematical physics.

To sum up the relevant setting in which my own comment on Gurwitsch Radiation is situated, restate the situating argument in the following terms.

Humanity's present knowledge of the universe recognizes three axiomatically distinct qualities of ordering of processes. We recognize the ostensibly "entropic"

ordering usually associated with non-living processes. Secondly, we recognize the "anti-entropic" ordering of living processes. Finally, we recognize that the archeological-historical record of willfully ordered increases of the potential relative population-density of cultures, places the quality of "anti-entropy" of human cognitive processes apart from, and beyond the quality of ordering of all other living processes. As Plato argued, and as Johannes Kepler was the first to give generality to a fourth point respecting these orderings; as this is demonstrated by the fact that the lawful ordering of the Solar System as a whole is also anti-entropic principles, the ordering of the universe as a whole, is underlain by an anti-entropic principle.

By correlating increases in society's potential relative population-density with the impact upon productivity of scientific, technological, and Classical-cultural forms of progress, I have made two points bearing upon the fundamental questions of physical science. First, that those forms of cognition which correspond to crucially-experimentally validated discoveries of physical principle, are expressed as the transmission of increased anti-entropy from the cognitive processes of the individual human mind, to man's increased power over the universe, as such increase of power is expressed in per-capita and per-square-kilometer terms. Secondly, as the relevant work of both Plato and Kepler imply, the ostensibly geometrical characteristics of the process correspond to continuing, successive such increases of power, and *therefore* coincide with the fundamental, lawful characteristics of the universe as a whole. This, by implication, situates the process of development of higher living species within a Riemannian form of multiply-connected manifold.

From this standpoint, we must begin our epistemological investigation into the matter of Gurwitsch Radiation, by acknowledging four distinct ordering principles in nature. First, the apparently entropic characteristics commonly attributed to so-called "non-living" processes. Second, the contrasting, characteristically anti-entropic ordering of living processes. Third, another anti-entropic characteristic, unique to human cognition, by means of which mankind is enabled to increase the power of its species within, and over the

universe at large. Fourth, the anti-entropic ordering principle, as Plato and Kepler argue some of the relevant evidence, which subsumes the potential of man's cognitive powers to increase our species' power over the universe. To restate the latter point: the ordering principle which corresponds to the successful expression of man's anti-entropic development of his cognitive potentials.

If we situate the discussion of the evidence bearing upon Gurwitsch Radiation, two general conclusions, of relatively axiomatic authority, must govern our reading of that evidence. First, that the evidence of typically crucial phenomena of Gurwitsch Radiation compels us to direct the investigation of living processes' distinguishing characteristics, on the assumption that these are governed by the notion of a Keplerian form of interaction between living and non-living processes. Second, that the global ordering of development within and among living species, as underlain by the implications of such Gurwitsch-Radiation effects, must be coherent with the notion of a Riemannian form of multiply-connected manifold. Thirdly, that both of these engage no less than the four distinct types of characteristic ordering which I have listed above.

In the practical experience of today's putatively educated strata, the sundry ironies of the proposition which I have thus just restated, are expressed in two interconnected ways.

The more immediate obstacle thrown up as objection against Gurwitsch's experimental principle, reflects the fact that we are living presently in a global culture whose most educated professional strata are miseducated, predominantly, and thoroughly polluted by reductionist ideologies. These ideologies are, in the first instance, the intellectual and moral degeneracy taught by the writings of Aristotle; in the second case, we have the more radically degenerate, more popular of today's reductionist cults, of empiricism and its radical-positivist offshoots. Relative to the issues implicit in the central fact of Gurwitsch Radiation, the leading obstacle to a rational view of Gurwitsch Radiation, among mathematicians and science professionals today, is the popularity of the common, empiricist dogma of Isaac Newton, Leonhard Euler, Augustin Cauchy, et al., that the physical universe



Nicholas of Cusa (1401-1464)



Illustration by Jan van der Heyden,
Courtesy of New York Public Library Prints Division
Johannes Kepler (1571-1630)



New York Public Library Picture Collection
Carl Friedrich Gauss (1777-1855)



Library of Congress
Bernhard Riemann (1826-1866)

"The issues posed by a Riemannian reading of Gurwitsch Radiation, prompt us to focus upon the crucial distinction between the notion of an anti-entropic ordering . . . and the higher standpoint which emerged, beginning with Cusa's De docta ignorantia, with the emergence of the process leading into the development of modern hypergeometric methods, by, successively, Kepler, Leibniz, Gauss, and Riemann."

must be regarded as linear in the infinitesimally small. That latter assumption precludes any serious consideration of the nature of the fundamental principle upon which the mathematical "possibility" for the existence of life depends.

The second obstacle is the failure of even many of those otherwise opposed to reductionist ideologies, to recognize the relevance of a crucial connection between the founding of modern experimental physical science by Nicholas of Cusa, and that original discovery by Johannes Kepler which sets Kepler's elementary view of modular functions above and beyond all other, earlier fol-

lowers of Plato's study of the Golden Section. Expressing this issue in the form of a question: If a principle of action corresponding to Gurwitsch Radiation exists in this universe, what does that principle thus prove about the nature of the universe itself?

The first obstacle is only generally noted, as it must be, to put the sillier, commonplace objections to my argument to one side. The issues posed by a Riemannian reading of Gurwitsch Radiation, prompt us to focus upon the crucial distinction between the notion of an anti-entropic ordering, as pervading, for example, Plato's *Timaeus*, and the

higher standpoint which emerged, beginning Cusa's *De docta ignorantia*, with the emergence of the process leading into the development of modern hypergeometric methods, by, successively, Kepler, Leibniz, Gauss, and Riemann, most notably. Cusa's discovery that the generation of circular action was of a higher cardinality than Archimedes had assumed, marks the point of conceptualization, which separates the higher mathematical-physical standpoint of modern hypergeometry, as distinguished qualitatively from the level of such followers of Plato as Archimedes. It is among the implications of that latter distinction that the axiomatic implications of Gurwitsch Radiation is lodged.

A Discussion of Cusa's Point

To begin the relevant discussion, take as a point of reference, the conventional standpoint of scientific opinion today, the heuristic view expressed in action by the cooks working in science's kitchens, that the "universe began" in some relatively simpler form, out of which successively higher forms of existence were generated. Some of those "cooks," a minority, go further. The latter insist, that a global directedness of such successive development of higher forms, is implicitly adducible even in considering the most rudimentary of those forms conceivable. This latter is the standpoint impressed upon us by Johannes Kepler's and Carl Gauss's approach to astrophysics, the standpoint implicit in the general notion of the Gauss-Riemann form of a multiply-connected manifold.

That "evolutionary" view of the universe flows directly from the methods of modern experimental-physical progress. The point of reference should be identified as follows.

We have two points of reference. On the one side, looking outward toward the presently known boundaries of astrophysics, we must situate ourselves, as observers at a point on the surface of the Earth, with respect to all those motions within the universe, within which the Earth, and our moving position, as observers, on it, are situated. On the other side, we must situate the action with which we are dealing in respect to all of those motions which intersect it, from the most distant smallness of microphysics. What most of the "cooks"

of science have failed to do, is to recognize what should be acknowledged as an unavoidable implication of the interaction among the mutually distinct, interacting, cohabiting types of ordering (processes). Whether many among the "cooks" acknowledge that fact, or not, until now, in each and all of these observations, we must take into account the role of multiple-connectedness among ostensibly not-living, living, and cognitive processes, and, also, we must situate the multiply-connected relationship among those four qualities of processes ("non-living," living, cognitive, universal) within the including, defining framework of the universe as a whole.

Cusa's discovery, that circular action represented a higher cardinality than the Classical Greeks, including Archimedes, had located within the bounds of irrational-number orderings, broke the mathematical barriers standing in the way of the subsequent emergence of hypergeometry. Kepler's response to the impact of his predecessors Cusa, Pacioli, and Leonardo da Vinci, carried us to the beginning of a general notion of physical hypergeometries, as shown most clearly by the implications of the elliptical orbit of Mars. The progress from Cusa's proof of the higher ("transcendental") cardinality of circular action, led, thus, to the standpoint established by Kepler's approach to the problems of a multiply-connected manifold. Kepler's work took the notion of the transcendental and still higher-order cardinalities, out of the formal-mathematical domain of the Golden Section, into the higher domain of physics. It was Kepler who, with his grasp of the implications of Mars's elliptic orbit, contributed the crucial first step into that higher domain of investigation. In that sense, it was Kepler who made possible the defining of the physical, as distinct from merely formal-mathematical, meaning of the source of the distinction between non-living and living processes.

All of the axiomatic issues respecting interactions between living and non-living processes are situated, in an elementary way, within that framework of epistemological reference which is implicitly provided by, chiefly, the further development of the notion of multiply-connected manifolds, by, chiefly, Leibniz, Gauss, and Riemann.

A Synopsis of the Point

Let us assign a special implication for Gurwitsch's use of the notion of a biological *field*.

For our first approximation, here, let us employ the term, *field*, in its included sense, as a term of distinction employed to present the conception, that the distinctions among the orderings of living and non-living processes, the interactions of such orderings, and the interactions of all with the implicitly Keplerian ordering of the universe as a whole, represent orderings which each designate a distinct *field*. Let us go further, to include all four of those general types we have listed above, among the interacting *fields*.

As in the case of Cusa's proof, that circular action is elementarily transcendental, rather than simply algebraic, the distinctions in ordering which separate one type of *field* from another, are congruent with the differences among such types to be recognized in terms of what Leibniz defined as the characteristically non-constant (non-linear) curvature of processes in their infinitesimally small intervals of action. *From the standpoint of elementary epistemology, these "non-linear" differences must necessarily correspond to what modern convention would oblige us to describe as relatively "very strong forces," acting with global effects, upon the infinitesimally small.*

These "forces," which are expressed with global effects, must be located experimentally among the smallnesses of the microphysical scale. These are epistemological conclusions, not reflections of speculative guesswork. These "forces" are subtended as the interactions between *fields*, as we have, for the moment, assigned a special meaning to the term *field*. We have, thus, the "strong forces" which reflect the stresses of interaction between ostensible living and non-living processes, or the impact on both of the universal, or "Keplerian" *field*.

This notion of "strong forces" has two principal implications for our discussion. First, when one of the *fields*, as we have assigned special usage to that term here, "imposes its will," as expressed by its distinctive ordering principle, on another, there is a "bending" action exerted by the one field on the intersected field. It is as if the geometry

of the universe represented by the latter were altered to conform, as subordinated, to the geometry of the universe represented by the former. Second, the notion of such "imposition of will" brings us to Leibniz's overlapping notions of *analysis situs* and *monadology*, as this was explored fruitfully by Lazare Carnot and other associates of Gaspard Monge.

To wit: from the standpoint of the thus-perplexed mathematical formalist, what is the form of action expressed by the relationship of multi-connectedness, as that relationship is integral to the Gauss-Riemann notions of a multiply-connected manifold, as the astrophysical manifold? This defines a set of questions which may be posed in mathematical terms of the complex domain, but the answers are to be found in the domain of crucial-experimental physics. To wit: the undiscovered portions of the reach of the multiple-connectedness of the universe as a whole, both in the astrophysical large and microphysical small, are acting efficiently upon the subject-matter of our inquiry into a lesser domain of multiple-connectedness. Thus, from this vantage-point, by definition of the case: The "non-linear" discrepancy yet to be measured, is reflected for measurement into the ever more extreme, yet to be discovered remotenesses of the infinitesimally small.

With certain qualifications, each distinct living species and associated, subsumed type, must also be considered a *field* in such a multiply-connected domain. The crucial qualification, is the interdependency pervading the living biosphere in any present state. The existence of the representative of the individual species must necessarily (epistemologically speaking) depend upon not merely the superimposition of one such field upon another, but a reciprocal kind of interdependency.

That completes the statement of the general point I wish to introduce at this time.

Lyndon H. LaRouche, Jr., is a member of the scientific advisory board of 21st Century. This statement was written in August 1998. LaRouche's remarks on Gurwitsch's method, written in March 1987, appear on page 54 of this issue.

Africa: Projects for Transformation

by Linda de Hoyos

In Africa, the deficit in infrastructure is far greater than that of the world average. After malaria, diarrhea is the second biggest child-killer in Africa; children are dying for the lack of clean water. Children can die of famine in one part of a country, for the lack of a transport system to bring food from another part of the country, where there is more than enough, to the place where it is desperately needed. In short, for every day that the infrastructure void persists in Africa, people are dying for the direct lack of it. There is no time to lose to begin the types of projects that will answer this glaring requirement.

But how, exactly, is that challenge to be met? What is the criterion for deciding upon which project will absorb resources?

Aside from the actual technical feasibility studies that must accompany any project, the answer must lie in the project's capacity to *transform* the landscape of Africa. It must lie in the project's potentiality to revolutionize the economies and internal production and trade flows within a nation, bringing it up to 21st century standards. It must lie in the project's effect, not only on the lives of children today, but on the lives of *their* children and grandchildren.

Two such projects are the Jonglei Canal in Sudan, and the Transaqua Project, which cuts across the Democratic Republic of Congo, the Central African Republic, and Chad. The explosive potential of these projects reaches far beyond borders of the mentioned countries.

The Transaqua Project envisions the construction of a canal, using the waters from the catchment basin of the Congo River, and bringing that water north into the Sahel region, filling up Lake Chad. As the project was developed in the early 1990s by the Italian state energy firm, IRI, this would be accompanied by a superhighway stretching from Mombasa, Kenya, to Lagos, Nigeria.



Sudanese Ministry of Information

Construction on the Jonglei Canal in the early 1980s. The Jonglei Canal was 75 percent completed, before work was halted by the war in southern Sudan in 1983, a war which still continues.

The purpose of the Transaqua Project is to reverse the desertification of the Sahel. The authors are IRI's Bonifica Institute, who motivated their project as follows in 1992: "The figures of the tragedy of the Sahel are by now known: tens of millions of persons with a per capita income of under \$200 a year; hundreds of thousands of head of livestock dying of thirst or starving, several thousand million dollars spent on generous, albeit complex, operations to save millions of human beings who, every year, risk starvation."

However, they continue, "specific but piecemeal projects have their precise role and a clear political and social rationale But our more than 30 years' experience of the development of emerging nations—so miserably failing to meet the expectations of the beneficiaries—has amply demonstrated that any 'piecemeal project,' however well implemented, is bound to prove an end in itself; or worse still, will not even at-

tain its economic and social take-off, unless closely tied into the regional and interregional context with solid, long-lasting transport and commercial infrastructure."

So, they say, why not solve the problem of the Sahel, instead of living—or rather, dying—with it?

"Why not solve the problem of the Sahel, instead of living—or rather, dying—with it?"

Transaqua's proposed "longlasting and commercial infrastructure" completely revolutionizes the environment of Central Africa, opening it to the rest of the world, for trade and for commerce. A new city is created at the junction of the highway and the canal in the middle of the Central African Republic—a country where today only 16 percent of the population has clean water. Transaqua trans-

forms the Heart of Darkness into the crossroads of Africa.

Since the highway goes right through Kenya and Uganda, all the way across to Lagos, Nigeria, it is to be expected that industries will grow along the highway and its accompanying railways, just as the United States was developed along the spine of the intercontinental railroad in the mid-19th century.

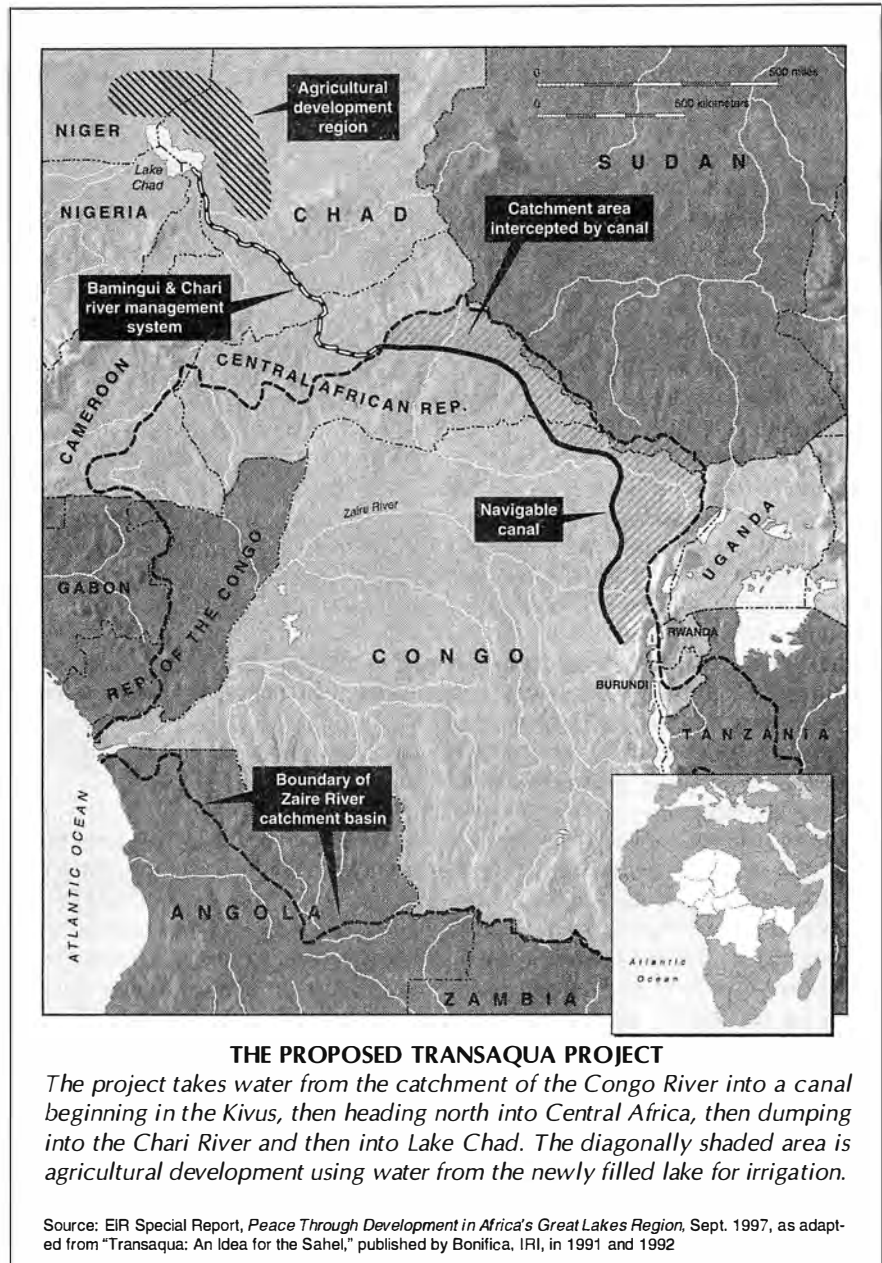
Jonglei Canal

The Transaqua Project had been approved by the Presidents of the Central African Republic, Chad, and the former Zaire, but instead of its construction, central Africa has been the scene of war. In Sudan, war has also stopped the construction of the Jonglei Canal, which was 75 percent completed when the war in southern Sudan brought the project to a halt in 1983.

The Canal cuts through the swamps of the Sudd, bringing this area under agricultural production, turning the rich delta of southern Sudan into a breadbasket for Africa and the Middle East.

One supporter of the Jonglei Canal was John Garang, today the leader of the Sudanese Peoples Liberation Army, whose war against the Khartoum government stopped the canal. But in 1981, Garang was at the University of Iowa and wrote his doctoral thesis on the canal. His very thorough, detailed paper is designed to answer the question as to whether the Jonglei Canal's construction should be used for the purposes of "improving" the lives of the citizens living in southern Sudan, or to "transform" it. Garang concludes that transformation is what is required.

He wrote: "Two such strategies, the 'improvement approach,' and the 'transformation approach,' are in contention. The improvement strategy emphasizes the modernization of the present traditional subsistence agriculture. . . . Agricultural development would proceed within existing traditional subsistence production units and institutions. . . . There is no philosophical commitment in this strategy to bring about fundamental changes in the social and economic systems of the inhabitants of the Jonglei Projects Area. Economic development according to proponents of this strategy should 'affect as little as possible the existing social, economic, and political structure of the people . . . because too rapid change may have detrimental



repercussions.' It is argued that a sudden and disruptive change of the 'Dinka way of life' should be avoided.

"The second budding strategy," Garang wrote, "may be called the transformation of traditional subsistence agriculture through mechanized or semi-mechanized modern agricultural schemes. . . . This strategy embraces from the onset commercial agricultural production with a large export potential. . . . According to this strategy, the best way that maximum benefit for the inhabitants would be obtained from the conditions created by the canal lies in the transformation of the simple subsis-

tence and traditional economy into a modern and complex economic system. Furthermore, proponents assert that the 'improvement approach' fritters away scarce resources and effort to widely scattered and unorganized production units, and hence in the long run the 'transformation approach' is much less costly."

This point is similar to that of the authors of the Transaqua Project: without transformation, economic resources are wasted.

Garang continued: "There appears to be sufficient political commitment to the Southern Region to implement funda-

mental changes in the political, social, and economic institutions should these changes be required for the achievement of the preceding two results—creation of the Breadbasket for the Middle East in Sudan.

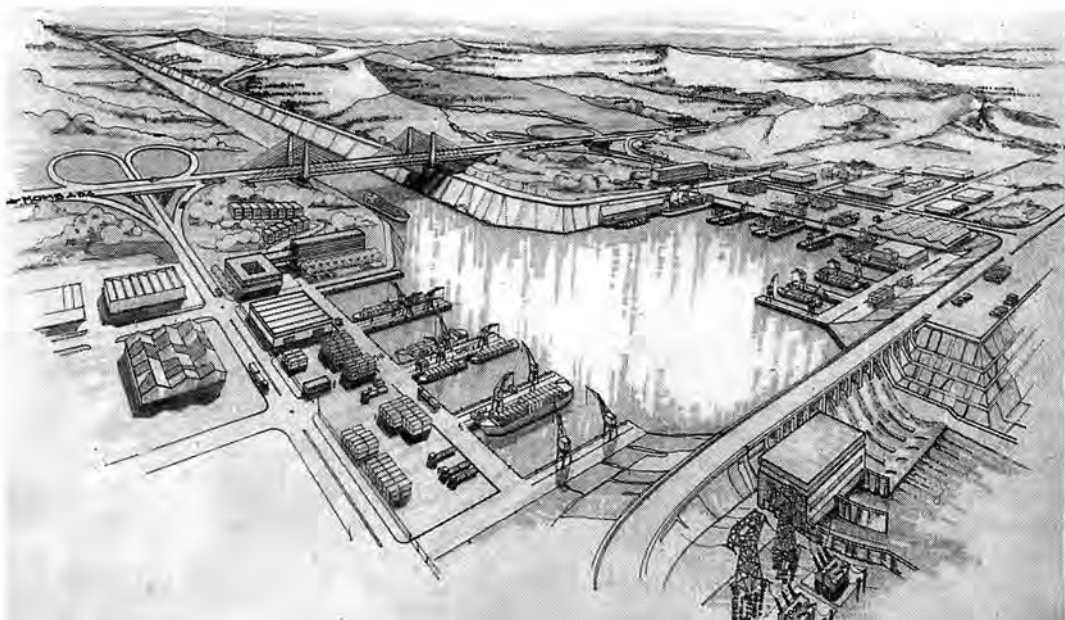
“The inhabitants of the JPA [Jonglei Projects Area], although poor and illiterate, are nevertheless intelligent, creative, and responsive, and will participate in change of whatever magnitude if they perceive such change to be in their interests and that of their posterity. Indeed, the people in the rural areas of the

JPA appear to be more interested in change than some of their educated brethren who appear to be mission-bound to protect the Dinka, Nuer, or Shilluk ‘way of life,’ which they themselves appear to have rejected.”

It was exactly because of the power of the Jonglei Canal project to bring about such transformation—to lift the people of southern Sudan out of the drudgery of self-subsistence agriculture into the 21st century—that the Canal was considered a near *casus belli* by those who stand behind such institutions as the World Bank and the International Monetary Fund. In October 1982, for instance, one year after Garang had submitted his doctoral thesis, the Royal Geographic Society of Great Britain, sponsored a conference in direct opposition to the Canal, titled, “The Impact of the Jonglei Canal in the Sudan.” According to the conference speakers, the canal would drastically affect the climate, destroy the fish of the region, and, most important, cause “dramatic changes in the lifestyle of the Nilotic peoples.”

The Century Water Scheme

In 1950, a Century Water Scheme for the Nile River basin was formulated, which envisioned storage and regulators at the lakes in Uganda; the construction of the Jonglei Canal circumventing the Sudd; storage and regulators at Lake Tana in Ethiopia and the Sennar



The IRI artist's rendition of the river port that would be built at the point in the Central African Republic where the Transaqua Canal intersects the Mombasa-Lagos highway.

Dam; and a flood control system for the Lower Nile.

It is noteworthy that a 1996 report on the Nile River, by the University of Maryland Center for Conflict Resolution, in the United States, indicates that Ethiopia would likely take a larger share of the Nile River waters, and that most of these projects in the Century Water Scheme would be carried out. But, it is assumed, the report says, that the Jonglei Canal will never be finished.

This is very odd (especially coming from a Conflict Resolution Center), because the Jonglei Canal would *increase* the flow of the Nile by 14 percent, as it brings in the water from the swamps and reduces evaporation, while all the other projects of the Century Water Scheme do not increase the flow of the Nile itself, and therefore lay the basis for conflict. The Jonglei Canal would add to the downriver Nile volume about 3.8 billion cubic meters yearly, as measured at Aswan, subtracting for losses in transmission. In other words, the Jonglei Canal would otherwise be the centerpiece of the development of the Nile River Basin, as the most efficient project for solving the basic problem of the Nile River, which is that north of the Sudd, it is not fed by rain, presenting problems for northern Sudan and particularly Egypt.

The Canal's draw-off of 25 million cubic meters daily from the feed waters of

the Sudd would reduce the swamp area by an estimated 36 percent, from an average of 16,800 square kilometers to 10,800 square kilometers. The designed flow rate is 3.5 km per hour, to inhibit weed growth.

The reduction of the swamp means that its water is now usable, and the drainage of the swamps thus permits this area to become a real breadbasket, as it has some of the richest soil in the world.

Furthermore, the Jonglei Canal opens up the Nile River for far greater navigation. With an extension to the southern Sudan town of Bor, the canal would run 360 kilometers, making the Nile navigable from the Kabala Falls in Uganda, to Khartoum. Since river transport is the least expensive method of transporting goods, especially bulk goods, it is an essential task that Africa's waterways become far more navigable.

Combined, the Transaqua Project and the Jonglei Canal would increase the productivity of the 200 million people in central and east Africa by orders of magnitude—a leap that is by no means impossible, if the political will and a New Bretton Woods system (supplying low-cost credit for infrastructure, and the requisite machine-tool orientation) are there.

Linda de Hoyos is the Intelligence Director for Asia and Africa of Executive Intelligence Review magazine.

Should the Laws Of Gravitation Be Reconsidered?

by Maurice Allais

Anomalies in the behavior of a paraconical pendulum, observed continuously for months, suggest the existence of a previously unknown field.

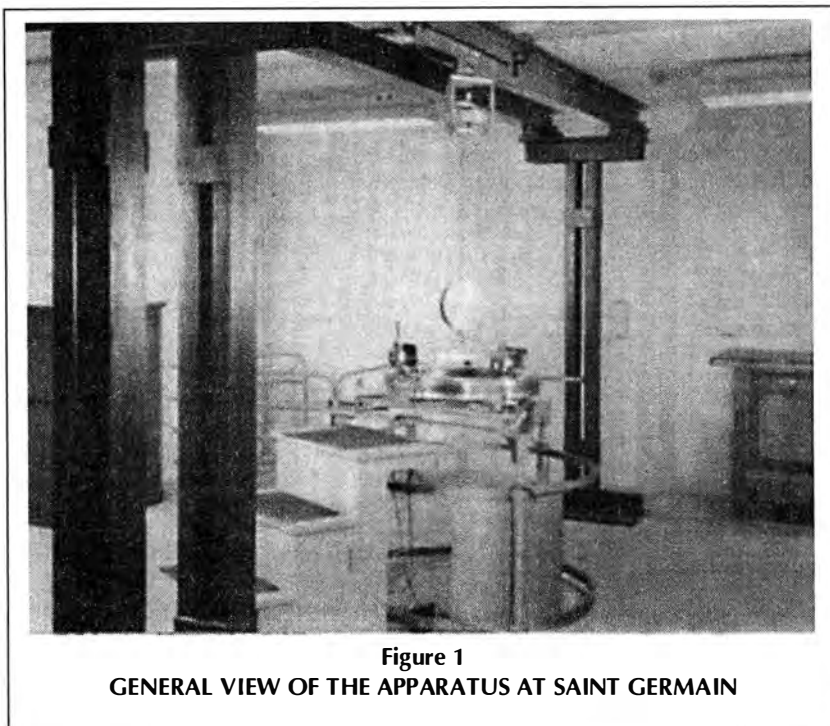


Figure 1
GENERAL VIEW OF THE APPARATUS AT SAINT GERMAIN

EDITOR'S NOTE

Maurice Allais, who won the Nobel Prize in Economic Science in 1988, began his professional career as a state mining engineer in France in the 1930s, simultaneously working on economics and history. From April 1948 on, he devoted his time to teaching, research, and writing, working in both physics and economics. Although he retired in 1980, he has continued to work actively in all these areas. As Allais wrote in an autobiographical essay in 1988, ". . . [O]ver the past 50 years, I have never stopped reflecting and working on the problems involved in the elaboration of a unified

theory of physics."

This article on Allais's experiments during the 1950s, was originally published in English by the American Institute of the Aeronautical Sciences, at the recommendation of space scientist Wernher von Braun. It appeared in *Aero/Space Engineering*, September and October 1959 (Vol. 18, Nos. 9 and 10), and is reprinted here, in edited form, with permission. Allais's article "The Experiments of Dayton C. Miller (1925-1926) and the Theory of Relativity" appeared in the Spring 1998 issue of *21st Century*.

PART 1: ABNORMALITIES IN THE MOTION OF A PARACONICAL PENDULUM ON AN ANISOTROPIC SUPPORT

Whenever a physical theory is revised or transformed, it is revealed that, nearly always, the observation of one or several facts which could not fit within the framework of the theory in its then current form is at the base of the changes. The facts always remain the keystone on which the stability of any theory depends, no matter how important it may be.

For a theoretician really worthy of the name, it may be said in passing that nothing could be more interesting than a fact which runs counter to a theory until then held to be sound; for him, the real work begins at that point.

—Max Planck¹

The motions of a pendulum, suspended on a ball and resting on an anisotropic support, have statistically significant amplitude and periodic components, of periods approaching 24 and 25 hours.

The installation and the experimental technique are briefly described. The observed motions result from four conjugate effects: the Foucault effect, an effect of the suspension release, the aleatory [chance] influence of balls, and, finally, a periodic influence.

The observed periodic structure cannot be considered as the result of the disturbances of an aleatory order. Neither can it be considered as produced by an indirect influence of known factors (temperature, pressure, magnetism, and so on). Finally, it cannot be identified with periodic lunisolar effects resulting from the actual theory of gravitation.

A remarkable disturbance has also been observed at the time of the total solar eclipse—June 30, 1954.

At this stage of the discussion, the observed effects must be considered as produced by the direct action of a new field.

Findings. From 1953 to 1957, I carried out various experimental research projects on the motion of a pendulum resting on an anisotropic support S'' through a steel ball, this anisotropic support being characterized by very small differences in its elasticity as measured in two rectangular planes.²

1. *Initiation to Physics*, French transl., page 40; Flammarion, Paris.

2. My findings and the investigations to which they gave rise are dealt with in six notes of the Academy of Sciences: *C.R.A.S.*, Vol. 245, 1697; *C.R.A.S.*, Vol. 245, 1875; *C.R.A.S.*, Vol. 245, 2001; *C.R.A.S.*, Vol. 244, 2469; *C.R.A.S.*, Vol. 245, 2467; *C.R.A.S.*, Vol. 245, 2170. The reader may refer to these for useful data which cannot be quoted here for lack of space. The object of the present paper is to reveal only the general philosophy of the results achieved. It is but an abstract of a general report which will be published shortly.

Even though various types of pendulum were used in succession, I shall limit myself to a brief description in the arrangements used and the results obtained during the series of continuous observations which were run for 30 days in June and July of 1955.

Description of the Pendulum. The paraconical pendulum used was an asymmetrical one, consisting of a vertical bronze disc weighing 7.5 kg, attached to a bronze rod hung from a bronze stirrup E resting on a steel ball 6.5 mm in diameter, free to roll in any direction on a horizontal plane surface S .

The latter was itself on a hollowed-out circular support S' , made of aluminum, with an extension A , 4.5 cm thick. This design (hollowed-out part) made it possible for the pendulum to rotate while in motion, over a total angle of 210 centesimal degrees.* This circular support S' finally rested on three micrometric screws V . The pendulum rod and its stirrup weighed 4.5 kg so that the total weight of the pendulum was 12 kg and the length of the equivalent elementary pendulum approximately 83 cm.

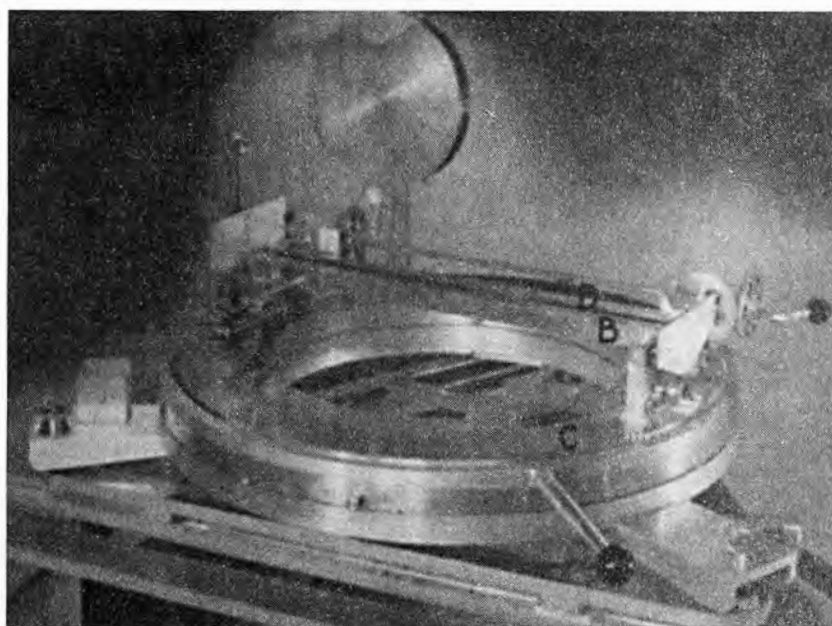


Figure 2
THE MEASURING CIRCLE

The steel balls in use were high-precision SKF balls, with bearing surfaces of tungsten carbide and cobalt.

The experiments were conducted in a basement, and the center of gravity of the pendulum was moving at a level of approximately 1.50 m below the surface of the natural ground. Support S'' was bolted to a beam, pressed against the ceiling by a set of beams.

The pendulum and hanging device are shown in Figures 1-4.

Experimental Process. The pendulum was released from a resting position every 20 minutes, using an initial amplitude of

* In the centesimal system of measuring angles, the right angle is divided into 100 degrees, each degree into 100 minutes, and each minute into 100 seconds. In French, a centesimal degree is a *grade*.—Ed.

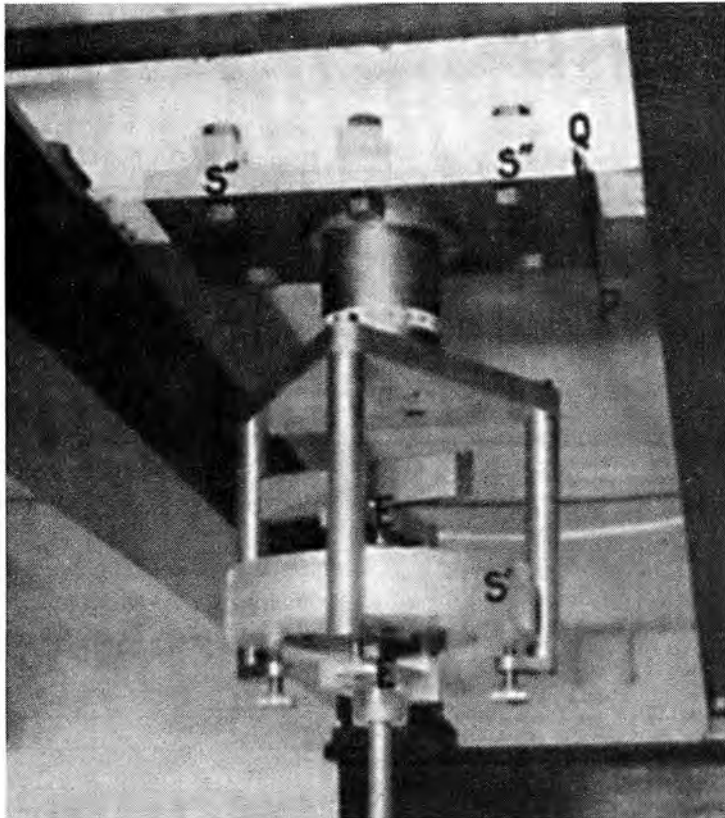


Figure 3
THE SUSPENSION

about 0.11 radian, by the burning of a thread. Its motion was then observed for about 14 minutes by aiming at a needle attached to its lower extremity.

Generally speaking, the point so observed generated a curve comparable to a flattened ellipse, the plane of the major axis of which was observed with an aiming system placed on a circle *C* centered on the axis of the pendulum, as defined at rest, and equipped with a scale graduated in centesimal degrees and a vernier. This system made it possible to determine the azimuth of the plane of oscillation with a precision of about 0.1 centesimal degrees.

After 14 minutes, the pendulum was stopped, and it was again released in the plane of the last observed azimuth. Thus the successive series of observations were *connected*, with releases every 20 minutes, day and night, so that each 24-hour period was made up of 72 series of connected azimuth observations.

In order to rule out any systematic effect, the steel ball which carried the pendulum was changed after *each experiment*, every 20 minutes, and surface *S* was changed at the beginning of each week of observations.

A curve showing the azimuths observed from June 7 to 12, 1955, is given in Figure 5. Each

point represents the release azimuth corresponding to each series of 14-min observations, equal to the azimuth of the plane of oscillation established after 14 minutes in the above experiment.

Anisotropy of the Support. Since support *S''* was characterized by a very *small* difference in its elasticity values in two rectangular planes, the mean position of the plane of oscillation tended, under this influence, to locate itself parallel to the plane of greatest elasticity of the support indicated by vector \vec{PQ} in Figures 1 and 3, the azimuth of which was approximately 171 centesimal degrees, measuring azimuths from the south in the direct sense. Here again, *the overall tendency was to generate ellipses* when the pendulum was released in a plane other than \vec{PQ} . These influences were determined more accurately by releasing experiments in various azimuths, in eliminating the influence of the epoch with a random choice of the release azimuths.

Observed Phenomena. During a continuous series of observations, however, the oscillating plane had not evinced any tendency to settle in the vicinity of direction *PQ*, as might have been expected—allowing for the Foucault effect—and the variation of the azimuth as a function of time was found to be an oscillation which appeared to be very irregular, at least at first glance, about the mean direction *PQ*. The deviations observed over a given 24-hour period were very large; azimuth variations occasionally reached and exceeded 100 centesimal degrees. The mean observed azimuth *P'Q'*, as a matter of fact, was 150 centesimal degrees on June-July 1955, less than the azimuth of *PQ* by 22 centesimal degrees.

22 centesimal degrees.

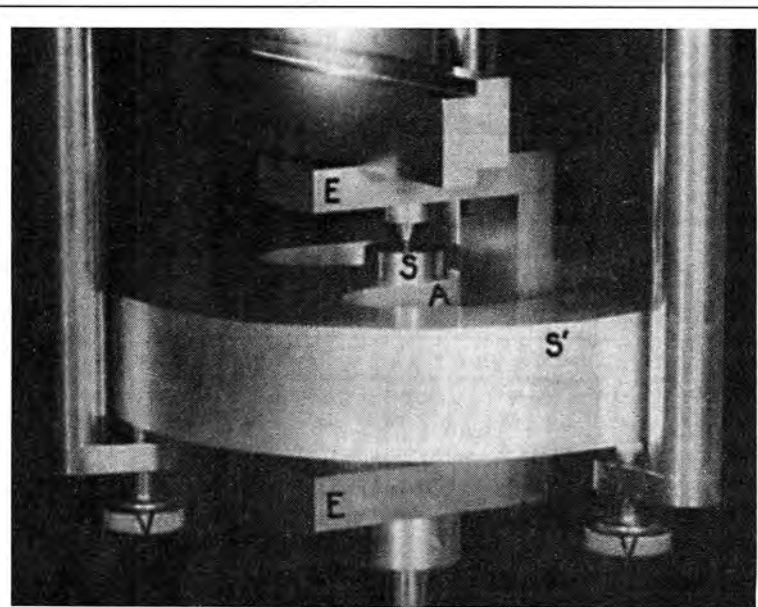


Figure 4
DETAIL OF THE SUSPENSION

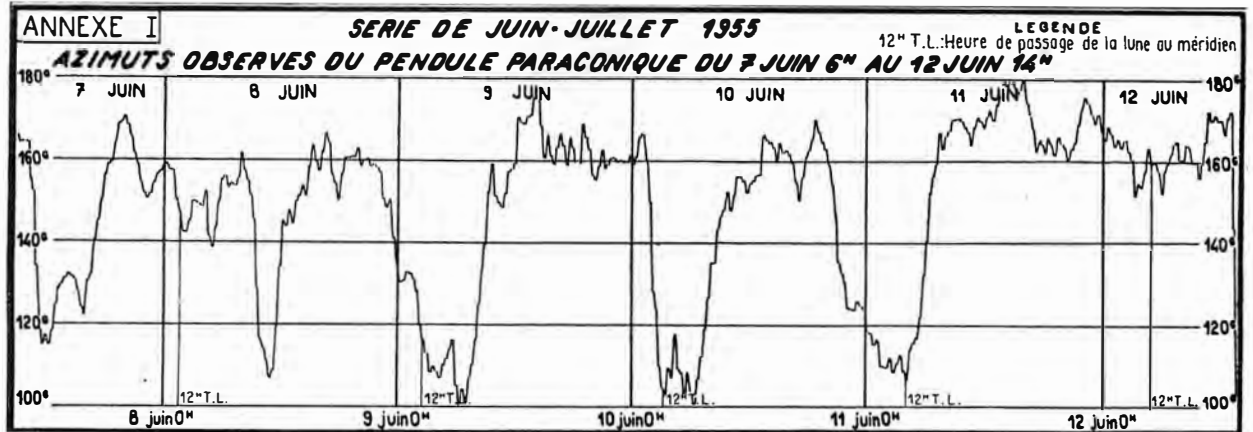


Figure 5
OBSERVATIONS FROM THE JUNE-JULY 1955 SERIES

The pendulum was released from a resting position every 20 minutes, and its motion observed for about 14 minutes. After 14 minutes, the pendulum was stopped, and it was again released in the plane of the last observed azimuth. The releases continued every 20 minutes, day and night. The curve shows the successive azimuths observed from June 7 (6 a.m.) to June 12 (2 p.m.), 1955. Each point represents the release azimuth corresponding to each series of 14-minute observations.

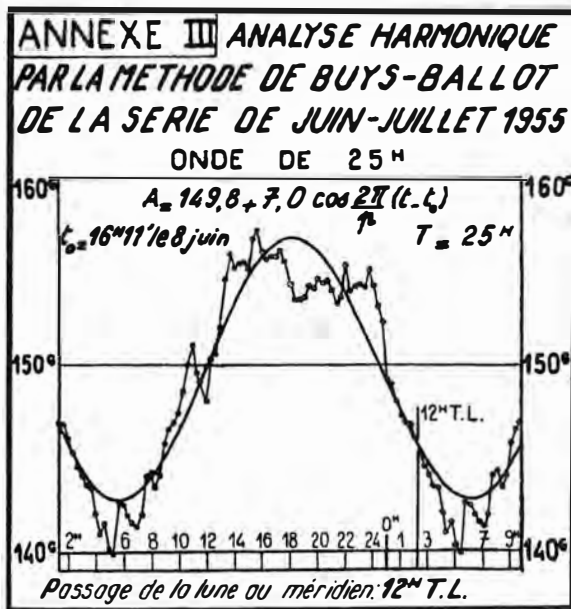


Figure 6
HARMONIC ANALYSIS WITH THE BUYS-BALLOT METHOD

The harmonic analysis of the June-July 1955 series, for the 25-hour wave, using the Buys-Ballot method. Other methods of harmonic analysis—periodogram, correlogram, and adjustment to a given group of waves by the Darwin or the least squares method—were also used, producing results in remarkable agreement.

Σ	2R		R _{25^H}/R_{24^H}}}	R/Σ	
	24 ^H	25 ^H		24 ^H	25 ^H
19.99	11.66	14.01	1.20	0.29	0.35

Table 1
THE PERIODIC EFFECT IN THE JUNE-JULY 1955 SERIES

The periodic effect—the very striking aspect of the phenomenon reviewed—is seen in the time series of observed azimuths, using a number of techniques of harmonic analysis whose results were in remarkable agreement.

Σ is the typical deviation in the time series made up of the values of the azimuths observed, and R is the radius of the wave which corresponds to the analysis made with a Buys-Ballot filter.

The azimuth rates corresponding to the amplitudes (2R) of the two major periodic components revealed in the series—the periods of which are close, respectively, to 24 and 25 hours—are each of an order of magnitude equal to one-tenth of the Foucault effect. However, the disturbing influences observed and recorded are, on an average and as a whole, about twice the Foucault effect.

The values are given in centesimal degrees.

It is noteworthy that the tangent to the start of the mean of the various curves that correspond to the 2,160 series of 14-minute elementary observations making up the monthly series for June-July 1955, is an accurate representation of the Foucault effect.

Factors Influencing the Motion. In the present condition of my information, it may be assumed that the observed azimuth movements are the result of four conjugated effects: the Fou-

cault effect, a "return" effect caused by the suspension, the random influence of the spherical ball, and, finally, a periodic effect.

This periodic effect, which constitutes the very striking aspect of the phenomenon reviewed, was revealed, in the time series made up of the azimuths observed over a given period, by a number of techniques of harmonic analysis, the results of which were in remarkable agreement: Buys-Ballot filter, adjustment to a given group of waves by the Darwin or the least squares method, periodogram, and correlogram.

Figure 6 shows the adjustment graph obtained by the application of the Buys-Ballot method to the June-July 1955, series for the 25-hour wave.

Defining Σ as the typical deviation of the time series made up of the values of the azimuths observed, and R as the radius of the wave which corresponds to the analysis made with a Buys-Ballot filter, we give (in Table 1) the results obtained for the series of observations of June-July 1955:

Order of Magnitude of Effects Noted. The azimuth rates which correspond to the amplitudes of the two major periodic components revealed in the June-July 1955, series—the periods of which are close, respectively, to 24 and 25 hours—are each of an order of magnitude equal to one-tenth of the Foucault effect. However, the disturbing influences noted are, on an average and as a whole, about twice the Foucault effect.

Abnormality Noted during Total Solar Eclipse. Let us point out, finally, that an abnormal lunar and solar influence also became apparent in the form of a remarkable disturbance of the motions of the paraconical pendulum (which gave the very definite impression of a screen effect) during the total solar eclipse of June 30, 1954. The plane of oscillation of the paraconical pendulum shifted approximately 15 centesimal degrees during the eclipse (see Figure 7).³ The forces

3. Figure 7 shows an azimuth curve tracing for the period extending from June 28, 1954 (8 p.m.), to July 1, 1954 (4 p.m.), as well as a curve symmetrical to the left part of the curve, which represents the azimuth referred to, about the vertical straight line for June 30 (midnight). Just at the beginning of the eclipse, the azimuth of the plane of oscillation suddenly was raised 5 centesimal degrees above the trend which first characterized its motion. Twenty minutes before the maximum of the eclipse, which was recorded at 12:40, this deviation reached a maximum of 15 centesimal degrees and then decreased progressively—but more suddenly than it had increased. The deviation was no more than 1.20 centesimal degrees prior to the end of the eclipse.

It will be noted that, to such an extent as may be ascertained, the shift of the plane of oscillation resumed, after the eclipse, the appearance of a motion CD, analogous to AB, which had been noted prior to the said eclipse—Figure 7(b).

Figure 7(a) reveals an approximate symmetry of the azimuth curve with respect to the vertical for June 30, at 12 midnight. This symmetry, which can be ascribed to the periodic structure of the motion, is noted for

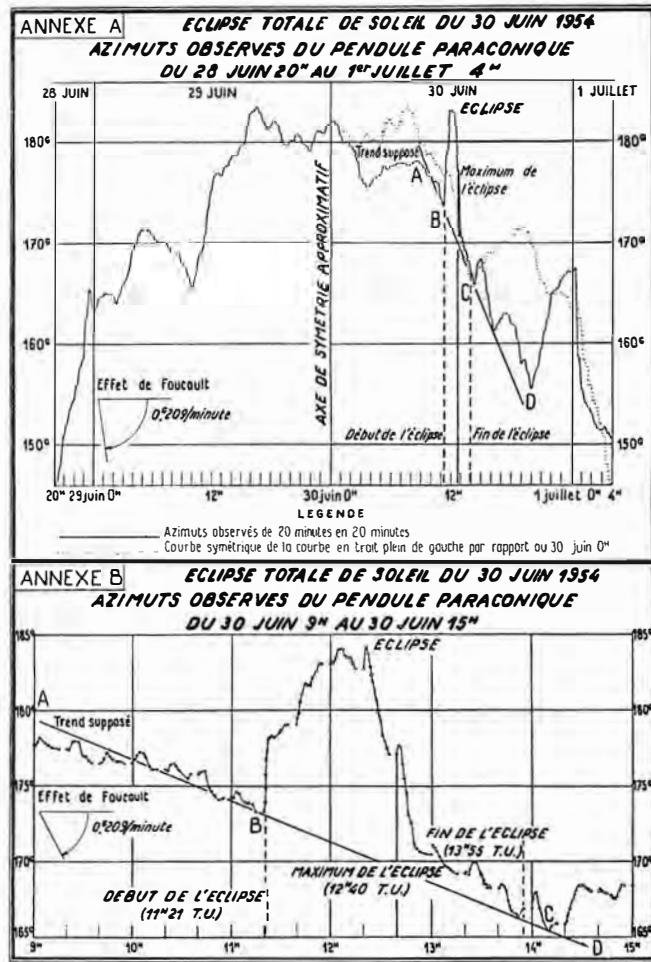


Figure 7
ANOMALOUS ROTATION OF THE PENDULUM'S PLANE DURING THE TOTAL ECLIPSE OF JUNE 30, 1954

Azimuths of the paraconical pendulum observed from June 28, 8:00 p.m., to July 1, 4:00 a.m., are shown by the solid line in 7(a). Note the spike at the onset of the eclipse. No such variation of the azimuth curve has been observed in any other continuous observation period. The dashed line is the mirror image of the curve on the other side of the approximate axis of symmetry at June 30, 0 hours. A more detailed graph of the excursion is shown in 7(b), which runs from 9:00 a.m. to 3:00 p.m. on June 30.

approximately 28 hours. If we assume, as is likely, that this symmetry corresponds to a physical reality independent of the disturbances created by the contact between the steel ball and the surface, it is notable that nothing in the branch of the azimuth curve which precedes the time corresponding to the center of symmetry is in any way comparable to the very strong deviation noted during the eclipse.

It must be further underscored that, during all continuous observation periods, no variation of the azimuth curve similar to branch BC, corresponding to the solar eclipse of June 30, 1954, was ever observed.

It should be noted that the maximum deviation resulting from the eclipse took place 20 minutes prior to the maximum of the eclipse. Thus, there is a measure of dissymmetry in the effect noted. A similar dissymmetry has been observed for terrestrial magnetism, but in the opposite direction, the maximum of the effect having been observed after the maximum of the eclipse. (Lion, *C.R.A.S.*, 1851, T. 33, p. 202; Lion, *C.R.A.S.*, 1852, T. 34, p. 207; Lion and Muller, *C.R.A.S.*, 1874, T. 74, p. 199. For the terrestrial electric field: Nordmann, *C.R.A.S.*, January 1906, p. 40; Chevrier, *C.R.A.S.*, 1933, T. 197, p. 1143; Rouch, *C.R.A.S.*, 1954, T. 239, p. 465.)

Series	Values (H - H')	
	June-July 1955	
	24 ^h	25 ^h
1 + 2 + 3 + 4	0 ^h 06 ^{mn}	0 ^h 02 ^{mn}
1 + 2	-1 ^h 09 ^{mn}	0 ^h 02 ^{mn}
3 + 4	+0 ^h 43 ^{mn}	+0 ^h 15 ^{mn}
1	-1 ^h 08 ^{mn}	-0 ^h 33 ^{mn}
2	+0 ^h 59 ^{mn}	+2 ^h 20 ^{mn}
3	-1 ^h 23 ^{mn}	-0 ^h 56 ^{mn}
4	+0 ^h 59 ^{mn}	+0 ^h 57 ^{mn}

Table 2
AGREEMENT BETWEEN THE SINE-CURVE PHASES OF THE EXPERIMENTAL PERIODS

Sine curves are obtained from the data by the method of least squares. If the sine curves really exist in the raw series, the Buys-Ballot method must give, for each elementary period, a sine curve having phases that are comparable for both the crude and the computed series. The table shows the difference (H - H') between those two phases in hours and minutes. The periods are denoted at the left—the numbers represent individual weeks. Each week is also treated as an individual experiment. The agreement between the phases must be deemed to reveal the existence of true periodicity.

involved were of the same order of magnitude as those which correspond to the Foucault effect.

Here, reduced to essentials, are the facts noted to date.

Four Basic Questions

The interpretation of the experimental results leads to the following four basic questions, to be raised in the order given.

First Question. Do the monthly series of observations contain statistically significant periodic terms, with periods in the vicinity of 24 and 25 hours?

Second Question. If so, can the periodic effects so noted be identified with those resulting from the current theory of gravitation (as derived from the double principle of inertia and universal gravitation, which is assumed to apply with respect to the whole set of Galilean frames of reference) as complemented (possibly) by corrections derived from the theory of relativity, and such as this current theory of gravitation is applied within the framework of the current theory of relative motions?

Third Question. If not, can the existence of periodic terms which are of significance in the series so obtained, be ascribed to an indirect influence of a known periodic phenomenon, specifically, to one of the following phenomena:

- (1) Deviation of the vertical (terrestrial tides).
- (2) Variation in the intensity of gravity.
- (3) Thermal effect:
 - (a) General (temperature at Le Bourget).⁴
 - (b) Local (laboratory temperature).
- (4) Barometric effect:
 - (a) General (pressure at Le Bourget).

	2R			
	25 ^h	24 ^h	12 ^h 30	12 ^h
June-July 1955	14.01	11.66	3.71	2.69

Table 3
AMPLITUDES OF THE WAVES

The amplitude (2R) of the 25-hour wave is of the same order of magnitude as that of the 24-hour wave, and very much larger than the amplitude of the 12- and 12.5-hour waves. This structure does not correspond to variations in such factors as barometric pressure, magnetic effects, cosmic rays, thermal effects, and others, and so these factors are ruled out as causes of the periodicity.

- (b) Local (pressure in the laboratory).
- (5) Magnetic effect:
 - (a) Normal effect (terrestrial magnetic field as recorded at Chambon la Foret).⁴
 - (b) Magnetic agitation (K numbers of Bartels).
- (6) Microseismic agitation:
 - (a) Industrial microseisms.
 - (b) Wind effects.
 - (c) General microseismic agitation.
- (7) Cosmic rays.
- (8) Periodic character of human activity.
- (9) Periodic modification of the structure of the device.

Fourth Question. If a negative answer to the third question is in order—namely, if we must conclude that the effects noted are the result of the direct action of a new field—should the origin of this field be assumed to be solar, lunar, lunar and solar, or spatial?⁵

Answers to the Four Basic Questions

Answer to the First Question. Any discrete series of $2n + 1$ numbers may be represented by the sum of a constant and n sine waves.

The obtaining of a sine wave of a given period by any method of harmonic analysis can, therefore, be of real significance only if its radius is sufficiently large and if the periodic structure noted is found again in the various elementary periods into which the period of observation under review can be broken down.

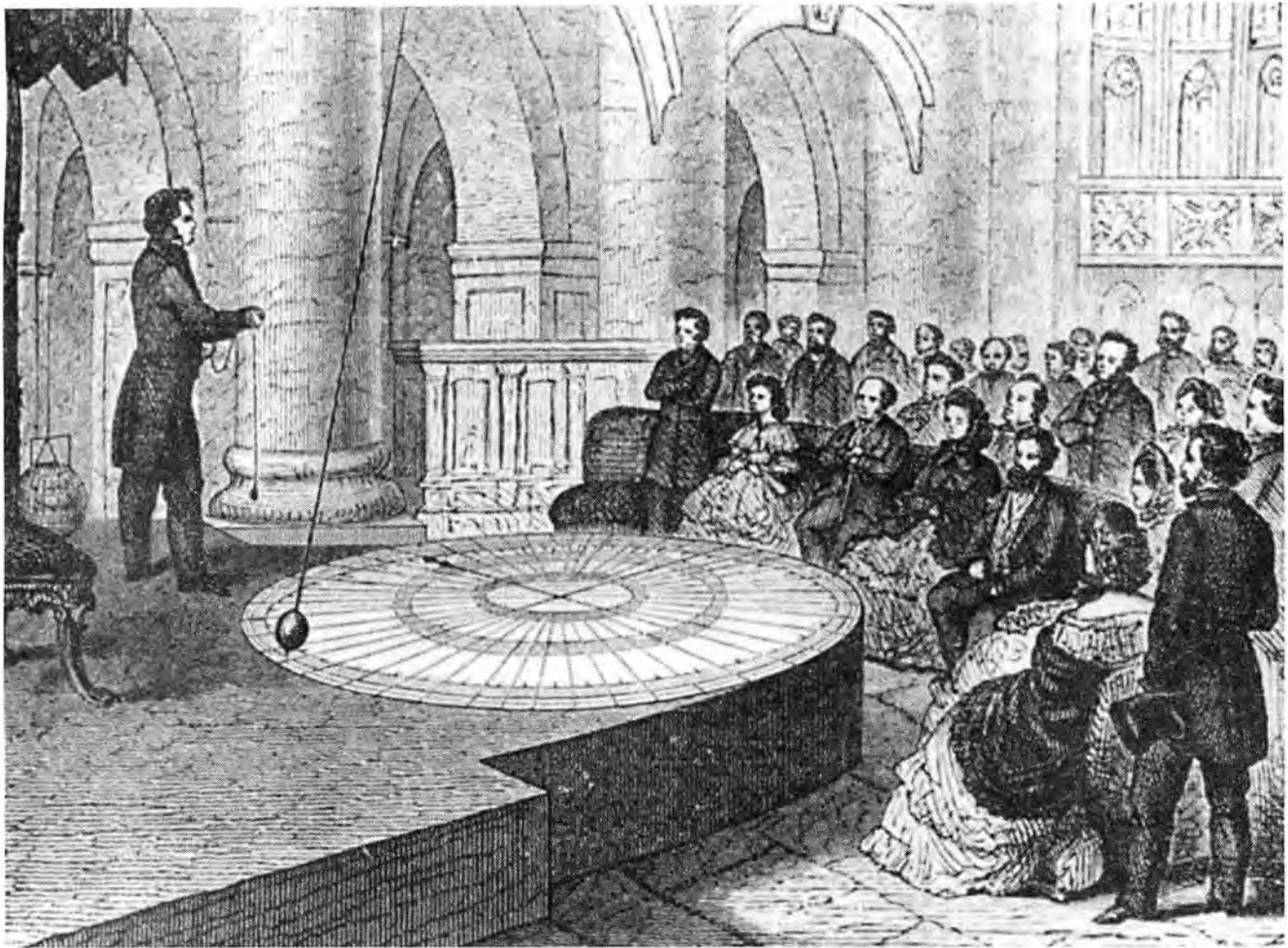
(a) The generalization of the Schuster test⁶ leads to the conclusion that, for the two monthly series of November-December 1954, and June-July 1955, the amplitudes of the waves (or groups of waves) which have periods close to 24 and 25 hours must each be considered to be very significant statistically (the significance level is at least 10^{-4}).

(b) The periodic structure of the monthly series must be considered to hold for the two periods of one fortnight, and even

4. Observatory nearest my Saint-Germain laboratory.

5. By this, I mean a field which could not be related to the Sun or to the Moon. This could be, for instance, a field resulting from a dissymmetry of the inertial sidereal space. A possible period would then be 24 sidereal hours.

6. See Note 2.



Corbis-Bettmann

Foucault's pendulum experiment to prove the rotation of the Earth on its axis, as depicted in an 1870 woodcut. Foucault used a 28-kg ball suspended on a 60-meter wire in the Pantheon in Paris. The wire constrained in the vertical direction only. The bob is set swinging along a meridian, and over a 24-hour period, completes a 360° circle (clockwise in the Northern Hemisphere). As Professor Allais notes, nothing in his experiments runs contrary to the Foucault results, and "all the earlier results, on the contrary, consistently show that there are abnormalities with respect to which we were quite remiss up to date so far as the investigation of them is concerned."

for the periods of one week, into which each one-month series can be broken down, for the following reason:

Simultaneous analysis, by the method of the least squares, for 13 waves of the tide series, gives 13 sine curves, the sum of which can be found with the help of Lord Kelvin's tide predictor. The calculated series so obtained, *which is the sum of the 13-sine curve*, can be analyzed, for 24 and 25 hours, by the same method of the Buys-Ballot filter.

If the sine curves obtained *really* exist in the raw series, the Buys-Ballot method must give, for each elementary period, a sine curve having phases that are comparable for both the crude and the computed series. Table 2 shows the results ob-

tained for the value $H - H'$ representing the difference between those two phases in hours and minutes, for the series of June-July 1955.

Notation 1 represents the first week; notation 1 + 2 represents the first 2 weeks, and 1 + 2 + 3 + 4 represents the whole of the month.

Allowing for the fact that each week can be considered an independent experiment, such agreement between the phases must be deemed to reveal the existence of true periodicity. This leads us to the conclusion that the monthly series of June-July 1955, *actually* contains periodic elements with periods close to 24 and 25 hours.

Thus the answer to the first question must be "yes" in all certainty.⁷

Answer to the Second Question. The current theory of gravitation (being the result of the application, within the framework of the current theory of relative motions, of the principles of inertia and universal gravitation to any one of the

7. Much store has been set in the defects of the equipment used—imperfect steel balls, imperfect horizontal positioning of the support, and so on. I cannot stress enough that the only possible effect of imperfections in the equipment are effects of a systematic or random type and that, under no circumstances, could they entail, whatever they be, the existence of any real periodicity.

Galilean spaces), complemented or not by the corrections suggested by the theory of relativity, leads to orders of magnitude for lunar and solar action (which are strictly not to be perceived experimentally) of some 100 millions of times less than the effects noted.⁸

These effects are so small that none of the 19th-century authors who worked on the theory of the pendulum, some of whom were excellent mathematicians, ever had a desire to compute them.

The extreme smallness of the effects computed can readily be accounted for if we allow for the fact that, in order to obtain the true gradient \vec{f} of the Moon and Sun attraction at a point, on the surface of the ground, with respect to the Earth, we must take the difference between the attractions at this point and at the center of the Earth, respectively. Gradient \vec{f} is of the order of 10^{-8} .

Furthermore, the plane of oscillation of the pendulum can rotate, under the influence of the solar and lunar attraction, only because of the variations of the gradient about the point considered. Therefore, the difference $\Delta\vec{f}$ between the value of \vec{f} at the mean position of the pendulum and its magnitude at a nearby point must be considered. It⁹ is of some 10^{-13} .

Furthermore, nothing in the current theory of gravitation can be considered likely to account for the screen phenomenon observed during 1954.

Therefore, the answer to the second question must be *no, and this in all certainty.*

Answer to the Third Question. The very peculiar periodic structure of the series observed (amplitude of the 25-hour wave of the same order of magnitude as that of the 24-hour wave and very much larger than the amplitude of the 12- and 12.5-hour wave) leads to the elimination, as possible causes of the observed abnormalities, of all the phenomena noted above under the order numbers 1 to 9. (Table 3 shows the results obtained for the series of June-July 1955, the periodicity of which is significant.)

Indeed, for all these phenomena, the total of the amplitudes of the waves having periods close to 25 hours is small as compared to the total of the amplitudes of the diurnal solar wave group, the semidiurnal solar wave group, or the semidiurnal lunar wave group.^{10,11}

The answer to the third question therefore must be, for elements 1 to 9 as limitatively listed above, that the effects observed cannot be assumed to arise indirectly out of the action of any of these elements. This statement can be made *categorically.*

As long as a phenomenon other than those listed above has not been proposed as a possible explanation, it will be necessary to assume that the phenomena observed are the result of the direct action of a new field.

Thus, the answer given to the third question is a qualified one.¹²

Answer to the Fourth Question. If, in the present condition of the discussion, we must answer the third question with a hypothesis of the direct action of a new field, there will arise the question of determining whether this field is derived from the action of the Moon, from that of the Sun, from their conjugated action, or, again, from a spatial influence.

Two remarks are in order:

(a) In reviewing monthly series, there is no way of specifying, when a wave with a period of 24 hours is revealed, whether one is dealing with a solar or sidereal 24-hour period.

(b) Similarly, when dealing with a period close to 24 hours, 50 minutes, nothing justifies the claim that one is dealing with a lunar—rather than a solar—effect. The mean synodic rotation of the Sun about its own axis is 27.275 mean days, whereas the sidereal revolution of the Moon is 27.321 days. As for the mean solar day, it is very close in value to the mean sidereal day.

In order to reach a definite decision, it would be necessary to use far longer periods of observation.

Thus it appears to me that it is impossible to conclude with definite certainty that the periods revealed, of an order of magnitude equal to 24 and 25 hours, are derived respectively from a solar and a lunar action. *In the current status of available information, such an action only appears to me as very likely.*¹³

The answer given to the fourth question, therefore, has to be of the qualified type.

PART 2: EXPERIMENTS IN CONNECTION WITH THE ABNORMALITIES NOTED

The irregularities observed in the motion of a paraconical pendulum on an anisotropic support, whose order of magnitude is of approximately a few millionths of gravity, do not in fact disagree with any of the experimental results arrived at either in the astronomical domains or on the Earth's surface.

The periodic irregular components of the pendulum motion appear to be in connection with the irregularities encountered during the study of multiple mechanical, optical, and electromagnetic phenomena—particularly in Michelson, Morley, and Miller's tests—and all these irregularities can probably be attributed to the same single source.

8. On the order of 10^{-13} instead of the periodic effects noted of some 10^{-5} radians per sec.

9. See the accurate expression of the effect in my paper to the Academy of Sciences (Dec. 16, 1957).

10. Thus, for instance, for the lunar and solar gravitational potential, the total of the amplitudes of the waves having periods of close to 24 hours is approximately 18 times greater than the total of the amplitudes of the waves with periods of close to 25 hours.

11. Aside from the general argument of the specific periodic structure of the results obtained, which, of itself, is enough to rule out causes 1 to 9, a certain number of additional arguments may be presented, some of which are of considerable value and lead to the same conclusion but, for lack of space, are not presented here.

12. I believe I should point out that nothing else can be the case. I can give my answer only with regard to the phenomena which I considered or which were

suggested to me as being such as to account for the effect noted. It is quite possible that an explanatory phenomenon be propounded very soon which would definitely prove decisive when investigated. However, in the present condition of the discussion and allowing for all the factors already reviewed, the existence of such a phenomenon seems at least to be unlikely.

13. The only known phenomenon related to the rotation of the Sun is that of the spots. It really seems quite unlikely that the variations in the radiation resulting from the spots can have effects of an order of magnitude similar to that of the suppression of radiation during the night. As a matter of fact, there is no connection at all between the observed azimuths and the Wolf numbers, which are characteristic of solar activity (for which, unfortunately, we have only one value per diem).

However, it cannot be claimed that there are no other effects related to solar rotation. This is enough to rule out a fully certain and unequivocal conclusion.

It would be advisable to continue the experimental study of these phenomena by continuous measurements over a period of at least one month. Such a study is of great interest for the development of a unitary theory on gravitation, electromagnetism, and quanta.

Theory

Part 1 outlined the very remarkable abnormalities evinced by the motion of a paraconical pendulum with an anisotropic support. These abnormalities appear to reveal some shortcomings in the currently accepted laws of gravitation.

When theory has been verified by countless facts, it is impossible to modify it slightly. In the first place, an attempt must be made at relating the new facts observed to the already known phenomena. If this appears to be impossible, which indeed is the case as I indicated, one is justified in wondering whether the abnormalities so noted can be assumed to be isolated or, again, whether they can be related to other abnormalities already noted elsewhere.

(A) Abnormalities Noted In the Classical Foucault Experiment

The bibliography of experimental research on the Foucault pendulum is extensive, but any search through it cannot fail to reveal two facts:

- (1) There is a great scarcity of really significant papers.
- (2) The numerical data on the results obtained are very few.

The only important experiments on the conical pendulum with numerical data on the findings are, to our knowledge, those of Bravais (1851), Willigen (1866), Kamerlingh Onnes (1879), Longden (1919), and Dasannacharya (1937-1939).

The experiments conducted by Bravais bore on the motion of the circular pendulum; those of Willigen, on the conical pendulum; those of Kamerlingh Onnes, on the asymmetrical pendulum; those of Longden, on various types of supports; while those of Dasannacharya bear on the influence of the support. The very best study by far, both from the experimental and theoretical standpoints, is that of Kamerlingh Onnes.¹⁴

Taken as a whole, these investigations strike us by the relative scarcity of observational data. To my knowledge, *the motion of the Foucault pendulum never was observed continuously, day and night, over a period of time of about a month.* Foucault himself never published the results of his findings other than in a general form,¹⁵ and it is truly surprising to read, in the very hand of so eminent an experimenter: "Even though the amplitude of the oscillations decreases rather rapidly, they are still large enough, some five or six hours later, to reveal a deviation which is, by then, of 60 to 70 degrees,"¹⁶ or again: "Watch in hand, it can be seen that, in Paris, the deviation is one degree in five minutes."¹⁶

Even though a number of spectacular experiments have been carried out (1852, the Pantheon, Paris; 1852, Cologne Cathedral; 1902, the Pantheon, Paris; 1904, Hall of Justice, Brussels; about 1930, St. Isaac Cathedral, Leningrad; 1951, Hall of Justice, Brussels; 1955, United Nations building, New York¹⁷), nowhere could I find the numerical series corresponding to the observations made. This is a detail which, to say the least, is surprising.

The only series I was able to find were fragmentary, but they *all include substantial abnormalities*, which are generally ascribed to defects in the support. They do give a Foucault effect, *but only on an average.*¹⁸

Finally, and to such an extent as might be possible on the strength of the information currently available, nobody ever achieved a perfect $-\omega \sin \lambda$ rotation other than on averages derived from numerous series of observations.

All the numerical series of observations now available—and, incidentally, there is a very small number of them—reveal, on the contrary, some variations in the rate of rotation as a function of time.

Having brought out these facts, I do not believe it would be amiss to clarify the following:

(1) The mean curve of our elementary experiments bearing on a connected series has *exactly* the Foucault slope as its tangent at the origin, when the oscillation is in a plane.

Thus our experiments are not by any means in contradiction with the general result of Foucault's experiment as has been claimed all too often.

(2) The support used for the pendulum is *anisotropic*, and it tends, on the whole, to bring back the plane of oscillation to a given direction.

The effect of this anisotropy is, on the one hand, to compensate for the Foucault effect on an average during a 14-minute experiment and, on the other hand, to cause the development of ellipses, whereas, in Foucault's classical experiment, these are nearly planes.

Now there is every reason to believe that the phenomena noted, if they are not the result of elliptical oscillations, are at the very least amplified by them, so that it is entirely possible for the disturbance to have a zero effect when the trajectory is plane, and a substantial effect as soon as the trajectory is elliptical.

(3) The pendulum used is a *short* one, the length of which is about 1 meter against several meters, indeed several tens of meters, as in the experiments conducted by Foucault and those who followed him. It is a known fact that it is very difficult to achieve the Foucault effect with short pendulums. Abnormalities are nearly always noted.

(4) The pendulum used can *rotate about itself*, whereas, in the Foucault pendulum, it is bound to the wire which carries it.

14. Bravais, *J. de Math. pures et appl.*, Vol. XIX, 1854, pp. 1-50; Willigen, *Arch. Musée Teyler*, I, 1866, pp. 341-363; Kamerlingh Onnes, *Nieuwe Bewijzen voor de Aswenteling der aarde*, Dissertation submitted to the University of Groningen, July 10, 1879 (this remarkable work was analyzed in detail by J. Stein in the second appendix to the work of Hagen, *La rotation de la terre, ses preuves mécaniques anciennes et nouvelles*, Tipographia Poliglotta Vaticana, Rome, 1911); Longden, *Phys. Rev.* XIII, 1919, pp. 241-258; Dasannacharya and Hejmadi, *Phil. Mag.* XXIII, 1937, pp. 65-88; Dasannacharya and Balam Singh Gantom, *Phil. Mag.* XXV, 1938, pp. 610-622.

15. L. Foucault, *C.R.A.S.*, 1851, pp. 135-137; *Set of Scientific Works*, Gauthier Villars, Paris, 1878.

16. *Set of Scientific Works of Léon Foucault*, Gauthier Villars, Paris, 1878, p. 386.

17. Haringx and Suchtelen, *Philips Technical Rev.*, Vol. 19, 1957-1958, pp. 248-254.

18. The reader also will find a number of interesting references in Hagen, *op. cit.*, Part 2; and in C. Wolf, *Bibliographie du Pendule (1629-1885)—A Set of Memoranda, Published by the French Society of Physics, Vol. IV, Papers on the Pendulum*, Gauthier Villars, Paris, 1889, pp. B1-B216.

(5) The motion of the pendulum used was observed *without any single interruption*, day and night, for periods running to about a month. This never was the case with the Foucault pendulum.

From all these indications, it is quite clear *that nothing in the result of my experiments runs contrary to those obtained earlier*. All the earlier results, on the contrary, consistently show that there are abnormalities with respect to which we were quite remiss up to date so far as the investigation of them is concerned.

(B) Abnormalities Noted in the Realm of Mechanics

The abnormalities noted in the motion of the paraconical pendulum strike me as being closely related to the difficulties or abnormalities encountered when one has to account for a number of dynamic phenomena, which, until now, still have to be explained:

- (1) Abnormalities in the tide theory.¹⁹
- (2) Motions of the top of the Eiffel Tower.²⁰
- (3) Size of the deviations to the South noted on falling bodies.²¹
- (4) Variations in the amplitude of the deviations to the East noted on falling bodies.²¹
- (5) Abnormalities noted in the action of terrestrial rotation on the flow of liquids (Tumlirz's experiments).²²
- (6) Abnormalities noted in the motion of the horizontal gyroscope of Föppl.²³
- (7) Abnormalities noted in the experiments carried out with the isotomeograph.²⁴
- (8) Abnormalities noted in experiments carried out with a suspended pulley.²⁵
- (9) Various abnormalities noted in the geophysical measurements, ascribed until now to experimental errors.
- (10) The apparently unaccountable results obtained by Louis Pasteur (General, French Medical Corps) in his experiments on the oscillation of the pendulum (1954).²⁶
- (11) Remarkable characteristics of the solar system, for which there has been, until now, no satisfactory explanation.²⁷

To these abnormalities—which are related to motion—we should add the static types:

- (1) The abnormalities of gravity. There is an excess of gravity over the ocean and a deficiency above the continents. The theory of isostasis provided only a pseudoexplanation of this, in my view.²⁸
- (2) The abnormalities in the experiments on Newtonian attraction. There is, on the one hand, some absorption of gravity (experiments of Majorana²⁹), but also—and mainly—a variation of the Newtonian force according to the medium in which it is exercised (Cremieu's experiments³⁰).

Accuracy of the Verification of the Laws of Gravitation

It is not without interest, at this point, to investigate the accuracy with which the laws of gravitation are verified, both in the realm of astronomy and on the surface of the Earth. This



The author in his office in 1958.

may come as a great surprise, but all the treatises of mechanics and astronomy remain notoriously silent on this fundamental question. This is a very significant gap in our knowledge and an obvious deficiency from the standpoint of scientific discipline. Any law is devoid of significance if we do not know with what degree of accuracy it has been verified.

(a) **Accuracy of the Astronomical Verification of the Postulates of Mechanics.** The fundamental laws of mechanics at the surface of the Earth are the result of an extrapolation of the results obtained in astronomy; it is not without interest, therefore, to ascertain the accuracy with which these laws actually are verified.

Unfortunately, this discussion is not given anywhere, for it is stated as a matter of principle that Newton's laws are accurately verified. Without going into a detailed discussion which would go beyond this article, it is relatively easy to determine what this degree of accuracy is.

A consideration of the remainders left by the adjustments in keeping with the least squares method, as used to draw up the tables currently employed in astronomy, shows that the order of magnitude of the deviations noted for angular displacements between observation findings and theory is of some 1 sexagesimal second of arc, giving a relative error of some

$$1/90 \times 1/60 \times 1/60 \approx 3 \times 10^{-6}.$$

Such is the order of magnitude of the accuracy with which Newton's laws have been verified astronomically. These laws, as all experimental ones, are verified with only some approximation. This conclusion runs counter to the ideas which are commonly accepted—without a true discussion, to be sure; but it seems to me that it must be accepted.

(b) **Accuracy of the Verifications of the Postulates of Mechanics at the Surface of the Earth.** The mechanical experiments at the surface of the Earth which have been carried out with the greatest precision are those bearing on the pendulum which gives 1 second. These experiments, in effect, assume the well-known formula

$$T = 2\pi\sqrt{L/Mg}$$

which is deduced from the postulates of mechanics. The quotient L/M is computed from the length measurements; T is measured and g deduced. The experiments of M. Volet at the Pavillon de Breteuil at Sèvres—which enable us to measure g directly by the photograph of the fall of invar metal rulers—enabled us to confirm the values deduced from the observations of the pendulum to 10^{-5} . Such is the order of magnitude of the accuracy with which the principles of mechanics appear to be verified at the surface of the Earth.

Order of Magnitude of the Abnormalities Noted in the Motion of the Paraconical Pendulum

It is of interest to relate these figures to the order of magnitude of the abnormalities noted. This order of magnitude is that of the Foucault effect, which, in the case of the pendulum used, is itself some 3×10^{-6} of the gravity. *The effects noted,*

therefore, are of an order of magnitude smaller than, or equal to, the order of magnitude with which we may consider that the principles of mechanics are verified at the surface of the Earth or in the field of astronomy.

As a matter of fact, it should be pointed out that the abnormalities noted have a periodic structure and that, on an average, they are cancelled. If new forces must be considered, therefore, they apply only within the framework of the solar, the sidereal, or the lunar day. In the field of astronomy, where planetary motion is dealt with, it is therefore necessary to match them with forces, the integral of which would add up to zero over the path of these planets. Thus, their order of magnitude is indeed comparable to the order of magnitude with which it may be thought that Newton's laws are verified during a revolution.³¹

From this it will be seen that the abnormalities that have been revealed do not in any fashion run contrary to the earlier experimental data, either on the surface of the Earth or even in the field of astronomy.

19. For instance, the western coasts of the continents, all other things being equal, are subject to far higher tides than the eastern coasts.

Similarly, the full tide does not coincide with the passage of the Moon at the meridian, but rather follows it by about 3 hours. At the syzygies and quadratures, the maximum or minimum tide is encountered only a day and a half after that of the relevant syzygy or quadrature. This happens anywhere on the Earth. It is to be noted that these two phase shifts are very different although the solar force is no more than a fraction of the lunar force. It should also be underscored that the delay is the same at the quadratures, where the solar action, instead of being added to that of the Moon as it is at the syzygies, is deducted from it.

Let us further point out that no satisfactory theory of marine currents has been given as yet, although some of their characteristics are very remarkable, such, for instance, as the preponderance of an easterly trend.

It is not without interest to note that mechanical effects of the tides are relatively large when compared to the tide-inducing forces due to the Moon and Sun, which cause them and which represent, at most, the following fractions:

$$2(M_s/M_e)(r_e^3/d_s^3) = 11.2 \times 10^{-8}$$

$$2(M_m/M_e)(r_e^3/d_m^3) = 5.18 \times 10^{-8}$$

of the gravity.

This abnormality has been accounted for by mentioning the possibility of oceanic areas of resonance, but this assumption, quite plainly, is entirely gratuitous.

20. Hagen, *op. cit.*, p. 24. See also *Inst. Géol. Nat., Report on Control Measurements of the Eiffel Tower Stability (1893-1951)*, May 1, 1952.

21. Hagen, *op. cit.*, pp. 22-40.

22. *Ibid.*, pp. 110, 111.

23. *Ibid.*, pp. 94-96.

24. *Ibid.*, pp. 142-147. See also the second appendix to this work, pp. 36, 37, and 46.

25. *Ibid.*, pp. 166, 167.

26. The objection has been raised that the experimental equipment used by Gen. Louis Pasteur could not be viewed with any degree of confidence. I must stress that his pendulums start only in the east-west direction and in the presence of some close obstacles arranged in a certain fashion. This rules out a great many hypotheses. (In the same sense, see the results obtained by Victor Panissetti, *Cosmos*, 1856, p. 503.)

27. These numerous characteristics cannot be the result of chance. The reader is referred to Gaussen, *C.R.A.S.*, Vol. 90, 1880, p. 518; Gaussen, *C.R.A.S.*, Vol. 90, 1880, p. 593; Belot, *C.R.A.S.*, Vol. 143, 1906, p. 1126; Belot, *C.R.A.S.*, April 1907, p. 885; Delauney, *Lois des distances des satellites du soleil*, Gauthier Villars, Paris, 1909; Butavand, *Les lois empiriques du système solaire*, Gauthier Villars, Paris, 1913; Ollive, F., *C.R.A.S.*, Vol. 157, 1913, p. 1501; M.A. Blagg, *Roy. Astr. Soc.*, Vol. 73, 1913, p. 414; Demozay, *Relations remarquables entre les éléments du système solaire*, Gauthier Villars, Paris, 1919; Delauney, *Problèmes Astronomiques*, Gauthier Villars, Paris, 1920; Vilar, *Notes sur les distances des planètes au soleil*, Jouve, Paris, 1923; Bourgeois and Cox, *C.R.A.S.*, Vol. 198, 1934, p. 53.

28. The reason mentioned in this case is about equivalent to the "sleep-inducing virtue" of opium as mentioned in Molière's play!

29. Majorana, *C.R.A.S.*, Vol. 173, 1921, p. 478; *J. de Phys. et Rad.*, Vol. I,

(C) Abnormalities Noted in Some Optical And Electromagnetic Phenomena

The abnormalities revealed in the motion of the paraconical pendulum with an anisotropic support strike me as having an obvious relationship with the abnormalities revealed by Michelson, Morley, and Miller in their experiments designed to show the absolute motion of the Earth with respect to the ether,³² by Esclangon on the dissymmetry of space,³³ by Fizeau in his experiments on the polarization of light,³⁴ and by J. Hely and P. Malsallez in their electromagnetic experiments on the anisotropy of space.³⁵

It would strike me as difficult not to be impressed by the similarity in the appearances of the curves derived by Miller and others, and I can hardly refrain from concluding that all these phenomena are the result of one and the same cause.^{36,37}

It appears to me that the phenomena I have revealed are such as to suggest a thorough and rewarding reappraisal, on the experimental and theoretical planes, of the findings made

1930, pp. 314-324; *Phil. Mag.*, Vol. XXXIX, 1920, pp. 488-504; *Schlomka, Zeit. für Geophys.*, 1927, p. 397.

30. Cremieu, *C.R.A.S.*, Dec. 1906, p. 887; *Rev. Gén. Sc. Pur. et Appl.*, Vol. 18, 1907, pp. 7-13. According to Cremieu, everything takes place as though gravitation measured in water were greater than that computed by means of the theory of attraction from a distance, the difference being about 1/10. Therefore, it is a considerable difference.

31. In other words, if, to the Newtonian effects, we added actions 10^{-6} times smaller, and which would have a zero value on an average during the revolution of the planet, these would probably remain undiscovered.

32. One should read, in particular, the remarkable paper by Miller, "The Ether Drift Experiment and the Determination of the Absolute Motion of the Earth," *Rev. of Mod. Phys.*, 1933, p. 203, the findings of which—derived from 200,000 observations—are remarkably consistent; the "Proceedings of the Mount Wilson Conference of 1927," *The Astrophysical Journal*, 1928, p. 341. One should also consult the references given by Miller at the end of his paper. It is startling that the findings published in this paper should have been ignored for 25 years. The outright pigeonholing of Miller's paper strikes me as one of the scandals of contemporary physics.

33. "Sur l'existence d'une dissymétrie optique de l'espace," *J. des Obs.*, Vol. XI, pp. 49-63. Here again, the internal consistency of the results obtained goes beyond any and all doubt. By the same author, "La dissymétrie de l'espace sidéral et le phénomène des marées," *C.R.A.S.*, Vol. 183, 1926, pp. 116-118; "Sur la dissymétrie mécanique et optique de l'espace en rapport avec le mouvement absolu de la terre," *C.R.A.S.*, 1926, pp. 921-923.

It has been possible to relate satisfactorily the results obtained by Miller and Esclangon (see E. Carvallo, "Vitesse de la terre mesurée par des expériences purement terrestres," *C.R.A.S.*, 1934, p. 247; "Vitesse de la terre et Relativité," *Rev. Scientif.*, 1934, pp. 405-410; "Les lois absolues de la lumière et la loi de relativité," *Rev. gén. Electricité*, Vol. XXIX, pp. 493-546). The results obtained by Esclangon at Strasbourg have not been found again in Paris (*C.R.A.S.*, 1935, p. 1165), but the experimental setup was not the same.

34. *Ann. de Chim. et Phys.*, 1860, p. 129.

35. *Mesures*, 1937, No. 11, pp. 13-17, and No. 12, pp. 19-21.

36. There is no doubt, in our view, that the phenomena which I have revealed are such as to support Miller's papers indirectly in such a way as to confirm their validity. The very bases of the theory of relativity thus could again come under scrutiny.

37. That some of the experimenters (A. Piccard and E. Stahel, Georg Joos for the Miller effect; B. Strasser, D.B. Brace for the Fizeau effect) should not have found the same results is perfectly accounted for, in our opinion, by the fact that, at some time, the total lunar and solar effect, as actually noted in the case of the paraconical pendulum, is very small (Piccard and Stahel, *J. Phys.* Vol. IX, 1928, pp. 49-60; *C.R.A.S.*, Vol. 185, 1927; Joos, *Ann. der Phys.*, 1930, pp. 385-407; Strasser, *Ann. der Phys.*, 24, 1907, pp. 137-144; Brace, *Phil. Mag.*, 1904, pp. 317-329; *Phil. Mag.*, 1905, pp. 591-599).

As a matter of fact, no parallel can be drawn between the Piccard and Stahel experiments carried out from a balloon, and the 200,000 observations by Miller carried out in a very well organized laboratory, with every possible precaution (see Brylinski, et al. *C.R.A.S.*, Vol. 185, 1927, p. 1198). Finally, the experiments carried out by Esclangon reveal that some small modifications in the equipment, which are of no apparent significance, might cause a cessation of the effects observed (see Note 33 above).

as the outcome of the various experiments mentioned above. The lunar and solar components revealed would indeed have remained undetectable if we had not carried out continuous observations, and the temptation would have been great to ascribe the differences observed to simple accidental disturbances, as was the case, for instance, in the interpretation given to the results of Miller by his critics.³⁸

I must insist once more on the remarkable abnormalities mentioned by J. Vignal.³⁹ Leveling operations revealed systematic errors having to do with the direction in which the work progressed. These systematic errors behave as accidental errors as soon as series of stretches over a few tens of kilometers in length are considered. They doubtless bear a close relationship to the results obtained by Miller.

I believe the same applies to the systematic lateral refraction errors observed in triangulation operations.

From all these data it would appear, in my opinion, to be of the greatest interest to carry out the various mechanical and optical experiments mentioned above with the utmost care, with all the accuracy which the equipment now available can provide, and with *continuous* observations over a period of at least a month. In such a case, it would seem likely, if not actually certain, that we should note, in the phenomena so observed, some periodic influences which are entirely similar to those I believe I have revealed in the case of the paraconical pendulum.^{40,41} These simple observations, which unfortunately cannot be developed in detail here, appear to throw the fullest light on the scientific interest of my findings.

(D) Significance of the Abnormalities Discovered

From our examination of the abnormalities mentioned and the discussion of the accuracy with which the principles of mechanics have been verified, it is plain that these principles do not have, by any means, the absolute value which an all-too-prevalent body of opinion appears to ascribe to them. These principles have acquired a sort of metaphysical quality which places them above the realm of discussion. In reality, mechanics is not at all a perfect science, a pure science in which we have nothing else to find. It is, and remains, an experimental science which can and should be improved.

The time has come, indeed, when one should go over all these phenomena once again. This re-examination manifestly seems to be of considerable interest for the development of a unified theory which could embrace, in one synthesis, the theories of gravitation, electromagnetism, and quanta. It is not at all the same thing to state

$$\Delta G + 4\pi\mu d = 0 \quad \text{Eq. (1)}$$

or to state

$$\Delta G + 4\pi\mu d(1 + \varepsilon) = 0 \quad \text{Eq. (2)}$$

where

$$|\varepsilon| \leq 5 \times 10^{-6}$$

in which G is the Newtonian potential, d the density, and μ is the constant of universal gravitation.

Whoever has worked on these difficult questions knows that Eq. (1) cannot be substituted for Eq. (2) without a considerable measure of danger for, in the integration of partial derivative equations, the corrective terms are very important. Thus, at a time when the development of a consistent unified theory of physics might appear to offer more difficulty than ever before, an examination in depth, on the experimental

and theoretical planes, of all the abnormalities mentioned above strikes me as being of the greatest interest; for it appears to be of such a type as to call for the revision of some postulates, the rigorous validity of which was accepted without true experimental support.

Facts alone must guide us, rather than mummified principles, even though they may be most useful for a first approximation. We learn only through experiment, and any thought which permanently withdraws into a set of abstract principles thus sentences itself automatically to a form of sclerosis.

CONCLUSIONS

The whole set of data given in Parts 1 and 2 seems to me to lend itself to the following summary:

(1) The motion of the paraconical pendulum using an anisotropic support is made up of periodic components having a significant statistical amplitude, of the order of the Foucault effect, with periods in the vicinity of 24 and 25 hours.

(2) These periodic components cannot be identified with those due to the gravitational effect of the Moon and Sun, such as they may be computed from the double principle of inertia and of universal attraction, for those are approximately one hundred million times smaller.

(3) The very peculiar periodic structure of the phenomena observed, being due to the relative importance of the wave having a period of about 25 hours, rules out any explanation based on one of the already known periodic phenomena which had been taken into consideration as possible explanations for the periodic nature of the phenomena.

In the present status of the discussion, the abnormalities observed can be accounted for only by considering the existence of a new field—namely, by envisioning the existence of complementary terms which until now had remained unnoticed.

(4) The effects observed, the order of magnitude of which is about a few millionths of gravity, are not actually incompatible with any of the earlier experimental findings, for the accuracy

38. See, in particular, R.S. Shankland, S.W. McCuskey, F.C. Leone, and G. Kuerti, *Rev. of Mod. Phys.*, Vol. 27, 1955, pp. 167-178, and the appended references. The authors ascribe the effects obtained by Miller to the conjugate effect of random disturbances and temperature disturbances. However, this criticism does not account for the extraordinary consistency of Miller's results with the motion of the Earth about the Sun (see Figures 23 and 28 of his paper, pp. 232, 237). Similarly, it does not account for the remarkable adjustments with phases which agree with sidereal time, as shown on p. 235 of his work. It also leaves out the agreement between Miller's and Esclangon's results (see the papers by Carvallo already mentioned in Note 33 above).

39. "Evaluation of the Accuracy of the Leveling Method," *Bull. Géod.*, Vol. 53, 1936, and "Precision Leveling," *Publ. de l'Inst. Géog. Nat.*, Paris, 1948.

40. The fact that the abnormalities noted in most of the phenomena mentioned are distributed according to the normal law cannot by any means be interpreted by ascribing the effect to an accidental cause. I was thus able to note that the sum of the 11 sine curves obtained in the analysis of my numerical series by the method of the least squares is distributed according to *the normal law*. Yet we are dealing indeed with 11 sine curves, thus with a periodic magnitude. The random aspect of a numerical series does not by any means thus rule out the possibility that it may represent a periodic phenomenon.

41. A remarkable fact is that the relative order of magnitude of the different departures noted (whether we are dealing with Miller effects, systematic errors related to the leveling or triangulation operations, abnormalities in the fall of bodies, or again abnormalities in the motions of the paraconical pendulum) always remains the same—namely, 5×10^{-6} . Everything happens as though all these phenomena had one and the same cause.

with which these results have been obtained does not exceed a few millionths.

(5) The abnormalities noted are not isolated. Many abnormalities have been observed by other workers in a number of geophysical phenomena, and it seems likely, if not certain, that they are derived from one and the same cause.

EDITOR'S NOTE

After the **crucial** experiments of June and July 1958, Maurice Allais published a second article in November 1958, in French, which was later printed in English in *Aero/Space Engineering*, November 1959 (Vol. 18, No. 11). These new results confirmed in a striking way the validity of the conclusions of his first article, which appears in the preceding pages. This Complementary Note is reprinted with permission of the American Institute of Aeronautics and Astronautics.

In 1997, Allais published a 750-page book, *L'anisotropie de l'espace* (Paris: Editions Clement Juglar), in which he gives a general and complete presentation of his experimental and theoretical research.

COMPLEMENTARY NOTE

The experiments which I have made simultaneously (during June and July 1958) on two identical installations in my laboratory at Saint-Germain and in a new laboratory at Bougival, in an underground gallery 57 meters deep, have shown that the previously observed anomalies are still present and that they possess, in both cases, periodic structures which are interrelated in a remarkable manner.¹

For illustration purposes, I give in Figure 8 a graph representing the results of harmonic analysis obtained by the Buys-Ballot filter method over a period of 24 hours, 50 minutes, starting from day and night observations made simultaneously in both laboratories during a month (from July 2, 0 hour Universal Time to July 31, 23 hours, 40 minutes, Universal Time) under the conditions *identical* to those of my experiments during the period of June-July 1955.

This graph permits a comparison of results obtained in both the Saint-Germain and Bougival laboratories. The difference in the amplitude of both waves is very small, and they possess a remarkable concordance of phase.

These parallel experiments made at the same time and under the same conditions allow the introduction into my earlier argument of elements of great value for the elimination, with a high probability if not absolute certainty, of almost the totality of proposed explanations for the observed periodic effects. I will simply indicate that:

1. The reader could usefully refer himself to the four following notes which I presented at the Academy of Sciences at the end of 1958:

"New Experiments on the Paraconical Pendulum on an Anisotropic Support," *C.R.A.S.*, Vol. 247, 1958, p. 1428.

"Periodical Structure of the Motion of the Paraconical Pendulum at Saint-Germain and Bougival, July, 1958," *C.R.A.S.*, Vol. 247, 1958, p. 2284.

"Experimental Determination of the Effect Produced by the Anisotropy of the Support on the Motion of the Paraconical Pendulum," *C.R.A.S.*, Vol. 248, 1959, p. 764.

"Experimental Determination of the Effect of Inclination of the Support on the Motion of the Paraconical Pendulum," *C.R.A.S.*, Vol. 248, 1959, p. 359.

2. In particular, the explanation presented by Mr. Goguel ("Remarks on the So-Called Paraconical Pendulum," *C.R.A.S.*, Vol. 246, No. 16, April 21, 1958, p. 2340), attempting to explain the observed phenomena by the combined effect of the wind and building cannot be accepted.

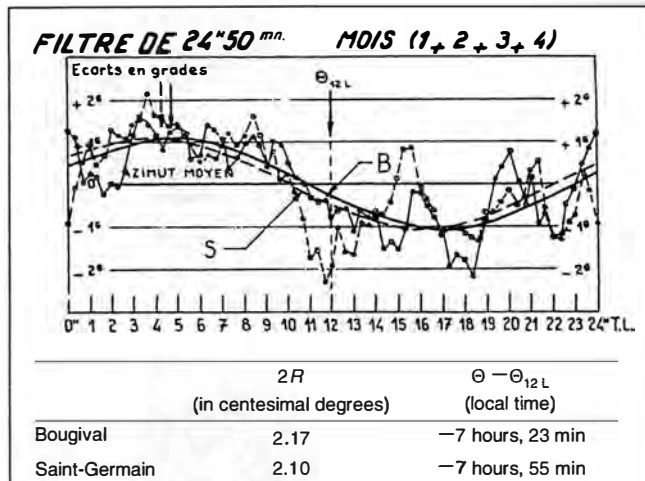


Figure 8
SIMULTANEOUS EXPERIMENTS AT BOUGIVAL AND SAINT-GERMAIN CONFIRM THE ANALYSIS

Shown are the results of harmonic analysis (Buys-Ballot filter) using a period of 24 hours, 50 minutes, for both month-long, simultaneous experiments (July 1958). Deviations are in centesimal degrees. Solid lines represent tests at Bougival; dashed lines represent tests at St. Germain. Of these, the thin lines represent mean cycles; the heavy lines represent adjustment sinusoids.

(1) Alone, the practical identity of the periodic effects of 24 hours, 50 minutes, observed at Saint-Germain and Bougival permits the elimination of any explanation by a casual cause.

(2) In the same way, the practically invariable temperature conditions realized in the Bougival laboratory permit the elimination of any thermal effect.

(3) The parallelism of the periodic effects observed at Bougival and Saint-Germain leads to the elimination of any effect based on the influence induced by the building or on that of any superficial cause.²

(4) The relatively large variability with time observed in the amplitude of the periodic effects permits the elimination of any explanation based on the actually admitted laws of gravitation.

Thus, the results of my experiments (July 1958) confirm, in a striking manner, my earlier argument leading to the conclusion that there exist in the motion of a paraconical pendulum on an anisotropic support anomalies of the periodic character which, at this point of the discussion, cannot be tied to any known phenomenon.

Did you miss other articles on Allais's work?

"The Experiments of Dayton C. Miller (1925-1926) and the Theory of Relativity"

"On My Experiments in Physics, 1952-1960" by Maurice Allais
both in *21st Century*, Spring 1998

"Undermining the Foundations of Relativity" by Rémi Saumont
A review of Allais's book, *L'anisotropie de l'espace*
(The Anisotropy of Space) in *21st Century*, Summer 1998

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Alexander Gurwitsch And the Concept Of the Biological Field,

Part 2

by Michael Lipkind



Alexander Gavrilovich Gurwitsch (1874-1954)

A student of the great biologist discusses the importance of Gurwitsch's thought and work.

From archives of L. Belousov

EDITOR'S NOTE

In part 1, which appears in the Summer 1998 issue of 21st Century, p. 37, virologist Michael Lipkind presents the history of Gurwitsch's work, and his development of the theory of the biological field, from successive models describing the development of specific tissues during embryogenesis, to the formation of dynamic molecular constellations. Lipkind also describes Gurwitsch's discovery of the emission of coherent photons from cells in mitosis, which could trigger mitosis in other neighboring cells.

In part 2, Lipkind sets forth Gurwitsch's postulates of the biological field theory, and raises again the question of what organizes the unique properties of living systems. "What accounts for the evident fact that chemical processes in living systems proceed differently than those in vitro (outside living systems)?" The field theory acts as a guide to experimentally answer this question, and Gurwitsch demonstrates that the biological field is vectorial and anisotropic, which creates singularities within living systems.

Lipkind also addresses Gurwitsch's approach to the singularity of the function of the brain cortex, and the failure of the classical neuron theory to explain the "break of continuity" between receipt of stimuli and the generation of thought.

The author is currently a research professor of virology at the Kimron Veterinary Institute in the Volcani Center for Research in Agriculture in Israel. Lipkind also works at the International Institute of Biophysics in Neuss, Germany, whose main research focus is biophotonics, which is a continuation of Gurwitsch's mitogenetic radiation, and is a member of the board of directors of the Institute.

Future 21st Century articles will report on current research in the field of biophysics. Lipkind's two-part series was edited by Colin M. Lowry and David Cherry.

POSTULATES OF THE THEORY AND NATURE OF THE FIELD

The basic postulates of Gurwitsch's theory of the vectorial biological field are these:

1. Each cell is a source of the field.
2. The field is vectorial in nature and the vectors are directed centrifugally from the source.
3. The generation of the field is associated with processes in the nucleus, related to transformations of chromatin (DNA). The choice of chromatin as a source of the field relates to its strict continuity throughout the life cycle, and its transfer by heredity, as well as its incredible stability in vivo as a substance, compared with all other material components of the living system.
4. There are elementary "flashes" of the generated field, which are connected with certain events in the metabolism of the chromatin. It is suggested (without strong obligation) that these events involve interactions of the chromatin with certain kinds of proteins. The total number of flashes per unit time, designated as field intensity, depends immediately on the intensity of chromatin metabolism and on general cell metabolism.
5. The elementary flashes of the generated field associated with chromatin metabolism can occur only within the already existing field. Essentially, this is the expression of the succession of processes in living systems, or the proclamation of the princi-

ples declared by William Harvey ("omne vivum ex ovo") and Louis Pasteur's rejection of the spontaneous generation of life.

6. The field vectors originating from the nucleus result from the distribution of elementary field flashes at any given moment. Therefore, the field intensity is a completely dynamic, fluctuating parameter, which reacts subtly to metabolic changes.

7. The field is spatially anisotropic, and this is the main postulate. This means that the isodynamic surface at which all the vectors are equal is not spherical, but ellipsoidal. The anisotropy of the ellipsoid can be expressed as a ratio among its three axes, and such ratio, being species-specific, is considered an invariant species constant. An infinite number of possible axis ratios covers all the potential species.

8. The field vector decreases in strength with increasing distance from the field source. It is reasonable to assume that the value (length) of the vector depends on the square of its distance from the source, but the true function is a matter of empirical examination. In spite of the decrement, the influence of the field is not limited by the cell boundary, but spreads beyond it.

9. Field vectors exert influence upon excited protein molecules, transforming a portion of the excitation energy into directed kinetic energy, and the direction of the movement is determined by the field vector. This is expressed either in the directed movement (flow) of the excited protein molecules along the vector, or in specific deformations of the protein molecule, especially when they are in a state of stable polymerization. This means that in the living state the field works against the chaotic movement of protein molecules.

10. The intensity of the field at a certain point (the length of the vector at this point) determines what share of the whole molecular excitation energy is transformed into the directed kinetic form. This can be represented as the ratio between the directed kinetic energy and the total excitation energy of the molecules. The intensity of the field does not depend on the amount of chromatin: It depends on its metabolic turnover.

11. The vectors from separate field sources can be composed geometrically, and the resulting vector will determine the direction of the kinetic energy at the point of composition. In a multi-celled embryo, there is an integral actual field resulting from the geometric composition of all the vectors issuing from all sources (nuclei). In such a composition, both the field intensity and the field anisotropy make contributions to the value of the resulting vector.

Although the nature of the biological field is not defined in these postulates, two comments concerning this problem are in order.

First, Gurwitsch's biological field cannot be reduced to any known physical field: It is an immanent property of living things. According to postulate 5, the elementary flash of the field is induced only by the existing field, so that it is successive and cannot originate de novo. This is the full expression of the vitalist principle.

Second, Gurwitsch's biological field is not energetic, which means that no special energy is focussed in the field source. The field vector transforms a portion of the metabolic energy accumulated in the excited protein molecules into directed kinetic energy, moving or deforming the molecules. The energy is not supplied by the field to the site of its action, instead the field vector employs the local energy accumulated at the site.





THE ANALYSIS OF ACTUAL INTEGRAL FIELDS

The above postulates express the logical basis of the conception of the vectorial biological field, which is presented as a universal, fundamental, biological (vitalistic) invariant principle.

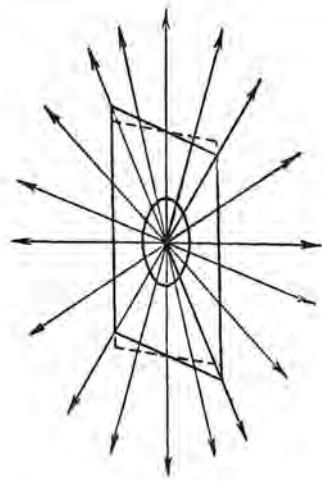


Figure 1
FIELD CONFIGURATION OF A CELL OF OBLIQUE SHAPE

The side walls of the cell are symmetric to the axes of field anisotropy, while the top and bottom walls are asymmetric to the axes. This causes the straightening of the cell (dotted lines).

Source: A.G. Gurwitsch 1944

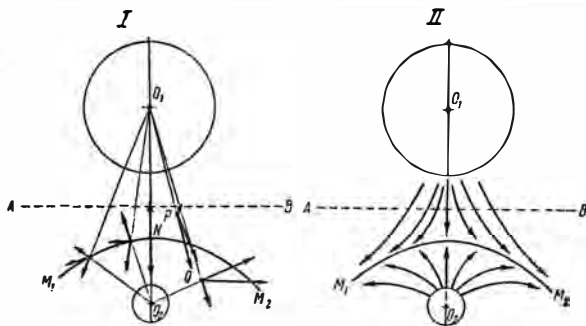


Figure 2
FORMATION OF THE NULL ZONE

The nuclei of adjacent cells, O_1 and O_2 , are the sources of isotropic fields whose intensities are proportional to the diameters of the circles. Drawing I shows the vectorial calculation for some particular points. Drawing II provides the general picture. The borderline between the cells is A-B, and M_1 - M_2 is the null zone. The resulting vector at point N is zero, and elsewhere along M_1 - M_2 the resulting vectors are tangentially directed; at points P and Q, beyond the null zone, the resulting vectors are directed towards the null zone.

Source: A.G. Gurwitsch, *Analytical Biology*, unpublished; the figure is reproduced from Belousov 1963

ple. In this form, the conception is balanced logically, and contains no internal contradictions or tautologies. However, Gurwitsch developed his theory further, having introduced a notion of actual integral field which serves as a working principle. Descriptions and some schematic illustrations of the formation and action of the actual fields at the molecular, cellular, and supracellular levels are presented here.

Molecular Level

In a single cell, if the nucleus is considered the field source, it will have a repulsive action on the excited protein molecules in the cytoplasm. This results in increasing the concentration of excited molecules towards the cell periphery. Simultaneously, a "counterflow" increases the concentration of non-excited molecules in perinuclear zones. Given such conditions, the most balanced position of the nucleus would be in the geo-

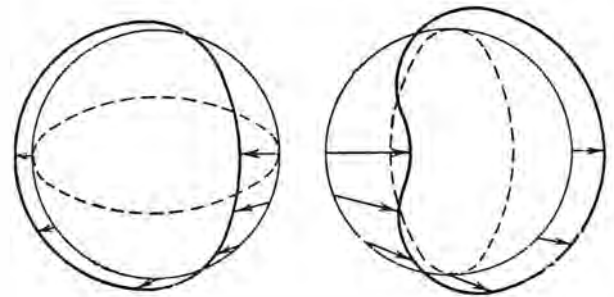


Figure 3
INTERACTION OF THE FIELDS OF TWO CELLS

The cells are initially of spherical form. The anisotropy of their fields is indicated by the inscribed ellipses. Mutually perpendicular orientations of the ellipses' long axes are shown.

Source: A.G. Gurwitsch 1944

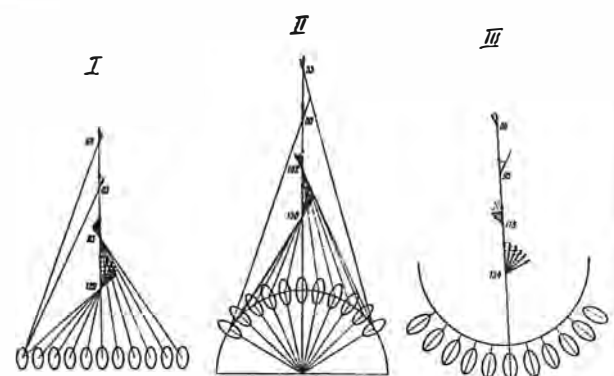


Figure 4
ACTUAL INTEGRAL FIELD FOR CELL LAYERS OF VARYING CONFIGURATION

Flat, convex, and concave configurations of cell layers. Values of the resulting vectors are given in relative units at four equally spaced points.

Source: A.G. Gurwitsch 1944

metric center of the cell. Any oblique shape, being unbalanced, would eventually become a symmetric one (Figure 1).

The interaction between two field sources (not only between the nuclei of adjacent cells, but also between chromatin-containing organelles like mitochondria and chloroplasts, or between the nucleus and centrosome within a cell) will result in the geometric composition of the opposing vectors. This leads to the formation of a "zero zone" where the value of the resulting vector is equal to zero. Since the excited molecules are driven together into these zones by the opposing vectors of the two interacting sources, the concentration of excited molecules will be maximal in these zones (Figure 2). Such "condensation zones," according to Gurwitsch, favor various molecular interactions.

However, the essential result of the field action is the formation of unbalanced molecular constellations. Insofar as the constellations form an unbalanced continuum in a defined space, the actual field within this space can have a complex configuration corresponding to the local geometry of field vectors, which, in turn, depends on the interrelations among the field sources. Therefore, the character of the unbalanced molecular constellations (their steric configuration) depends on the actual fields. On the other hand, the constellations are not only the result of, but also the object of, the actual field action.

The facilitation of the molecular reactions occurring within the "zero condensation zones" can promote the formation of stable submicroscopic structures (called vestigia by Gurwitsch) which may become visible by being constituents of intracellular structural formations. These structural "vestigia" can be

considered as traces of increased molecular activity in specific "hot" points of the condensation zones, with the specificity being determined by the particular configuration of the actual field.

The analysis of the formation of the actual integral fields and their actions at the molecular level seem rather speculative, although it is based on the concept of unbalanced molecular constellations, which, in turn, is based on the phenomenon of degradational mitogenetic radiation. However, the analysis of the actual field formation at the cellular level is supported by more experimental evidence, and is more easily demonstrable.



Cellular and Supracellular Level

Transference (movements) and deformations of cells and nuclei under the influence of the actual field vectors, should be considered as a result of the transference of the internal cell molecular content. Gurwitsch performed his analysis of the actual integral fields using the formal rules of the geometrical composition of the field vectors, and found some remarkable regularities.

The simplest case of the formation of the actual field is that presented by the interaction of two single cells (nuclei). It can be seen (Figure 3), that the mutual influence of the opposite vectors results in both the divergence and deformation of the nuclei of the cells. These effects decrease with the increase in distance between the interacting cells.

The formation and action of integral actual fields in epithelial layers and large three-dimensional cell complexes are of particular interest, because these developing parts are realized through morphogenesis. The remarkable peculiarity of the actual field of the epithelial layer is that the synthetic field in each of its cells is much stronger (the resulting vector is longer) than the field vector of the local single cell would be. Accordingly, the actual field outside the layer (external field) depends on both the extent and configuration of the layer (Figure 4). It can be seen (Figure 5), that the larger the extent of the layer, the stronger the external actual field (the longer the field vector at the same distance from the layer). This means that the actual field in this case is practically without decrement, and hence the notion of the long-distance effect of the actual field should be accepted (Gurwitsch's model of the "effective cone").

As to the actual fields of large cell complexes, there is a difference between flat and spherical cell complexes. In the former case, almost all the cells (except the marginal ones) have similar field conditions: The actual field in each cell does not depend on the coordinates within the complex. In contrast, within a spherical complex, the field vectors differ considerably, depending on the changing coordinates (Figure 6).

The models considered above describing some regularities of the actual field formation are static ones. Gurwitsch also considered some dynamic situations. In particular, he analyzed the mechanism of the curving of epithelial layers, one of the main phenomena of morphogenesis. Application of the vectorial composition shows that an apparently insignificant initial displacement of one of the cell nuclei relative to an adjacent one is sufficient to start the formation of a continuously growing concavity (Figure 7). A similar consideration can be applied to the opposite case, the protruding of the epithelial layer (for example, development of the sea urchin gastrula, Figure 8).

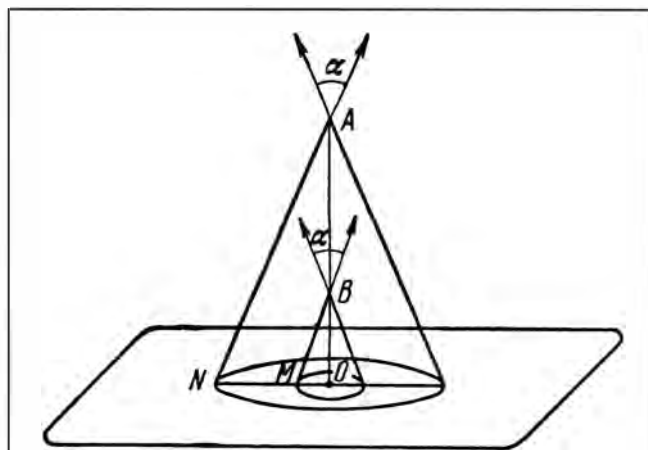


Figure 5
LONG-RANGE EFFECT OF THE
ACTUAL INTEGRAL FIELD

This depicts the long-range effect of the actual integral field from a cell layer of unlimited extent. Within angle α the field vectors do not deviate much from the perpendicular to the cell layer. At increasing distance from the layer in direction $B \rightarrow A$, the decline in field strength is compensated for by the contribution of field vectors from cells within a larger area, denoted here as the ring MN.

Source: A.G. Gurwitsch, *Analytical Biology*, unpublished; figure is reproduced from Belousov 1963

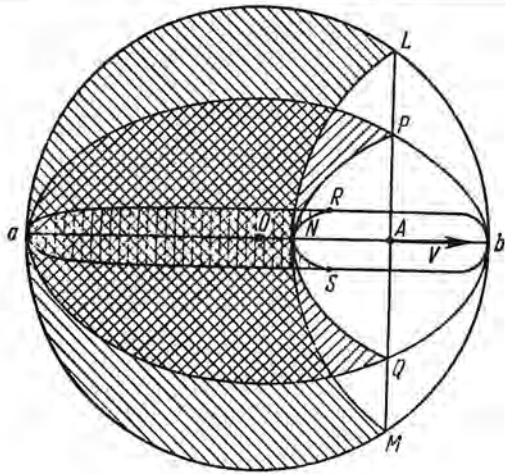


Figure 6

ACTUAL INTEGRAL FIELD OF SPHERICAL AND 'FLAT' THREE-DIMENSIONAL CELL COMPLEXES

In a spherical cell complex with surface $LaMb$, the resulting vector V at point A , being composed of cell vectors originating from the cells within volume $LaMN$, is directed toward the right: The field influences on A of cells located within two equal volumes, $ALNM$ and $ALbM$, which are equidistant from A , cancel each other out. In the ellipsoidal cell complex with surface $bPaQ$, vector V at point A results from the field influences of cells within volume $PaQN$. In the completely "flat" cell complex $aReS$, the field influence on point A comes from the cells within volume $RaSN$. Since volume $RaSN$ is greater than $PaQN$, which, in turn, is greater than volume $LaMN$, and since the center of gravity of the cell complex exerting influence from the left, moves away from point A , along with the "flattening" of the complex, vector V decreases. This means that, along with the "flattening" of the cell complex, a cell maintaining the same location relative to the complex center, "feels" its asymmetry to a lesser degree.

Source: A.G. Gurwitsch, *Analytical Biology*, unpublished; figure is reproduced from Belousov 1963

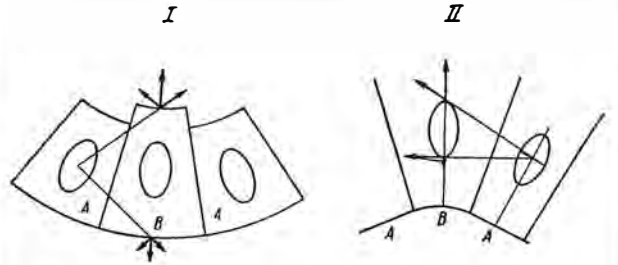


Figure 7

CURVING OF THE EPITHELIAL LAYER AS A RESULT OF FIELD VECTOR COMPOSITION

The influence of field vectors from the cells marked A on the larger cell B , is seen in drawing I: The resulting vector, directed toward the concave side of the layer, prevails over the opposite one. Further progress of the process is seen in drawing II.

Source: A.G. Gurwitsch 1944

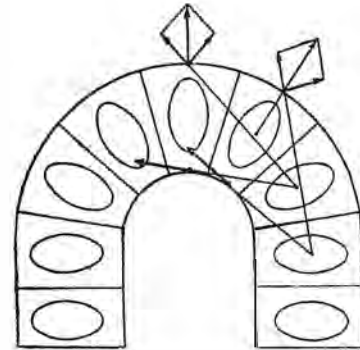


Figure 8

ACTUAL FIELD AT THE EXTERIOR SURFACE OF THE CONVEX LAYER

The vectors show the probability of the cell protruding.

Source: A.G. Gurwitsch 1944

The next model demonstrates the significance of the field anisotropy for the configuration of the actual field. It is evident that even small differences in the ratio of the ellipsoid axes, designated as an anisotropy index, can have a significant influence on the actual field.

ANALYSIS OF LIVING PHENOMENA WITH THE VECTORIAL BIOLOGICAL FIELD THEORY

According to Gurwitsch's epistemological principles, the fruitfulness of a theory lies only in its service as the basis for working hypotheses available to experimental examination. Gurwitsch carried out a tremendous attempt to make the theory of the biological field "work" by applying it to an incredibly wide scope of biological phenomena (Gurwitsch 1944). In addition to morphogenesis, the midwife of the field theory, the range embraced such differing biological problems as differen-

tiation and histogenesis, mitosis, metabolism, neuromuscular function, dynamic functional organization of the brain cortex, and some aspects of the psychic sphere (somato-psychic connections) including the philosophical problem of psychic indeterminism.

In the previously described morphogenesis of the triton phalanx (Anikin 1929), the cell coordinate-dependent deformations of cell nuclei were explained by means of an abstract invariant field construction suitable for this case (see Figures 12 and 13 in Part 1). The same morphogenic phenomenology can be analyzed by means of the vectorial field conception, which easily explains both the deformations and the movements of the cells (nuclei), the model of the interaction between the two cells (Figure 3) being an obvious illustration (compare Figure 12, Part 1, p. 47 with Figure 3). Construction of the actual field of the phalanx leads to the same results as Anikin's calculations from an abstract formula.

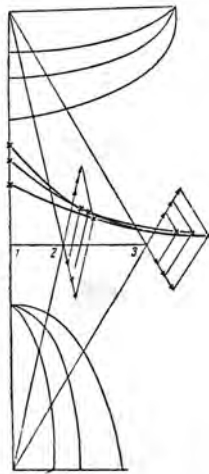


Figure 9

INFLUENCE OF FIELD ANISOTROPY ON THE ACTUAL INTEGRAL FIELD

Here two cells are shown with the long axes of their nuclei at right angles to each other. The influence of the integral field of the cells on points 1, 2, and 3 depends on the ratio between the long and short axes of the respective ellipses.

Source: A.G. Gurwitsch 1944

The most demonstrable example concerns the development of the cerebral vesicles from the initially smooth neural tube of the chick embryo. This model has much in common with Gurwitsch's classic work, "The Mechanism of Form Inheritance" (1914), in which the notion of "dynamically preformed morpha" was first introduced. From the construction of the external actual fields from the opposite epithelial walls of the tube, it was possible to predict the localization of the changes in the curvature of the walls, these points becoming more and more expressed. As a result of this, the division of the neural tube into the anterior, medial, and posterior brain proceeds (Figure 10). From the configuration of the actual field, all the described phenomena, such as the indicative turning of the axes of the nuclei, their reorientations, and cell movements could be very well described (Figures 2-7, Part 1).

Except for these two objects which served earlier for the development of his early field conceptions ("dynamically preformed morpha"), Gurwitsch carried out a vectorial field construction of the more universal early stage of development—gastrulation—using the sea urchin embryo (Gurwitsch 1944). Although the blastula of the echinodermata is ideally symmetric relative to all axes, the cells in the region of the future endoderm are a little larger than those of the future ectoderm, and correspondingly, their nuclei are located a little farther from the blastula surface than those in other regions. These differences are sufficient for the local invagination, which is determined to proceed according to the schemes grounded on the basic field postulates (Figures 7, 8, and 11). It is clear from these schemes that even a low degree of field anisotropy leads in this simple case to significant morphological consequences. After completion of the invagination, the mesenchymal cells migrate out from the endoderm, that is newly formed as a re-

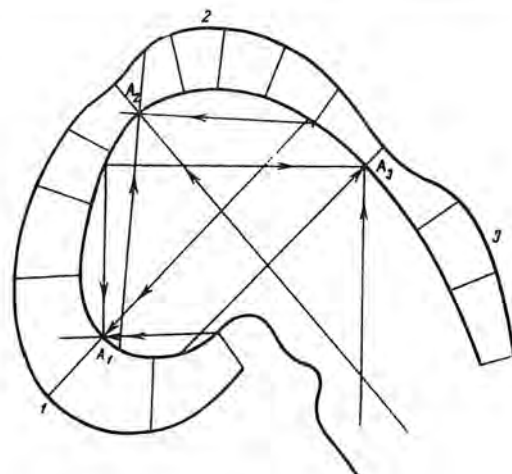


Figure 10

SIMPLIFIED DIAGRAM OF THE SYNTHETIC ACTUAL FIELD OF CEREBRAL VESICLES IN THE CHICK EMBRYO

The inner contour is a medial section through the brain of a chick embryo 40 hours old. The field interaction among areas indicated by points A_1 , A_2 , and A_3 is designated conditionally by three vectors: one is perpendicular to the point under consideration, and two are at 45° to the perpendicular. The values of the resulting vectors predict the external contour of the following stage, which divides the vesicle into anterior (1), medial (2), and posterior (3) brain.

Source: A.G. Gurwitsch 1944

sult of invagination. This is explained by the field influences of the neighboring cells (Figure 8). From this follows the further arrangement of the mesenchymal cells in the form of the ring located around the invaginated primary gut. Taking into account the asymmetric (inclined) arrangement of the axes of the invagination, it is possible to explain the further transformation of the spherical gastrula (Figure 11) into the bilaterally symmetric pluteus (a larval form of the echinodermata).

Differentiation and Histogenesis

The appearance of divergence in the development of embryonal cells belonging to the same cell complex (sometimes these are the neighboring cells) is designated as differentiation. The differences among the cells become more distinct, and lead toward specific cell types acquiring special functions. The whole course of the processes occurring in the differentiating cells, leading to acquisition by the cells of a certain tissue specificity and type, is designated as histogenesis.

The differentiation phenomenon presents insuperable obstacles for the preformist conception. Hans Driesch's principle of equipotentiality declares the dependence of the cell's fate on its position in the whole, meaning that any displacement of the cells within the whole will not change the final result, only the fate of an individual cell. This fate is realized especially through differentiation. Therefore, equipotentiality in this case means the "actuality" of the observed divergence between the



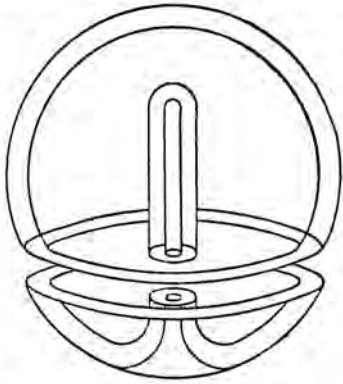


Figure 11

**SECTION THROUGH THE SEA URCHIN GASTRULA
AT THE LEVEL OF THE MESENCHYMAL RING**

Gurwitsch suggests that this section through the sea urchin gastrula corresponds to the "zero level" of the resulting vector of all the cells of the ectoderm and endoderm.

Source: A.G. Gurwitsch 1944

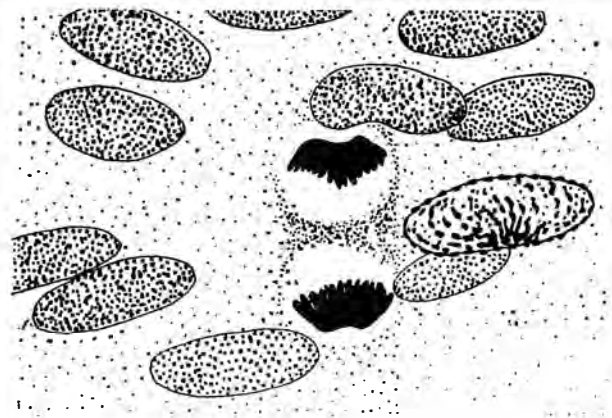


Figure 13

**SYMMETRIC TELOPHASE IN THE PRESENCE OF
A CELL IN PROPHASE (AXOLOTL)**

The long axis (heteropolar vector) of a neighboring cell in prophase, does not intersect the mitotic figure in telophase, which remains symmetric (axolotl cerebral vesicle).

Source: Puchalskaya 1947

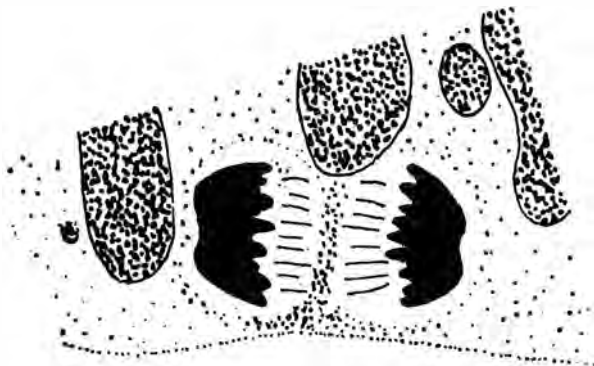


Figure 12

AN ISOLATED MITOSIS IS SYMMETRIC (AXOLOTL)

The mitotic figures are symmetric in this isolated mitosis in the cerebral vesicle of the axolotl.

Source: Puchalskaya 1947

differentiating cells (the absence of predetermined entities responsible for the observed differences).

Thus, the epigenetic principle in this case comes forward in the most enigmatic form, even more incomprehensible than that in the case of morphogenesis. The latter case could be realized through the action of some forces (vectors) moving the cells "mechanically" (that is also mysterious, but presents a simpler imagination of the mode of action of any hypothetical "organizing factor," even such an indeterminable one as entelechia). In the case of differentiation, the position within the whole is realized through the involvement of different intracellular processes determining the pathway of histogenesis.

The theory of the vectorial field describes the problem of differentiation by means of relatively simple assumptions (Gurwitsch, *Analytical Biology*). The "actuality" (in contrast to the

preformist determination) of the apparent divergence between the cells under differentiation is caused by continual evolution of the actual integral field of both the cell complex and each individual cell. Gurwitsch considers the actual field of each cell as a "microfield" composed of the neighboring cells, on which the "macrofield" of the whole complex is superimposed. Although the results of such interaction can be unlimitedly different, Gurwitsch considers the two main types of the actual field configurations: (a) the sharp prevalence of one vector (anisotropic character of the field), and (b) a relatively homopolar actual field. The former type of the actual field is compatible with the epithelial layers in which the cells are spatially bound, and the anisotropic character of the actual field can persist for a certain period of time. This is realized at the marginal zones of the actual "macrofields" (at the surfaces of the multilayer cell complexes) and, thus, zonal differences in the actual field of the complex can be expected. Accordingly, within the same zone there can be differences among the actual fields of the individual cells ("microfield") which are expressed in the appearance of "condensation (zero) zones" (Figure 2), with the high concentration of the excited molecules facilitating certain chemical reactions and the formation of irreversible "vestigia."

Thus, the actual fields of homogenous complexes consisting of equipotential cells can induce differences both at the level of cell layers and in individual cells, and these differences may become irreversible. Hence, the phenomenon of differentiation is described here from the epigenetic point of view, compatible with the experimentally proven concepts of equipotentiality and equifinality. The above considerations about the origin of the divergence as the cause of differentiation are supported by the evidence that both zonal and individual differentiation are observed in the marginal zones, for example, the differentiation of retinal rods and cones (zonal) and that of neuroblasts (individual).

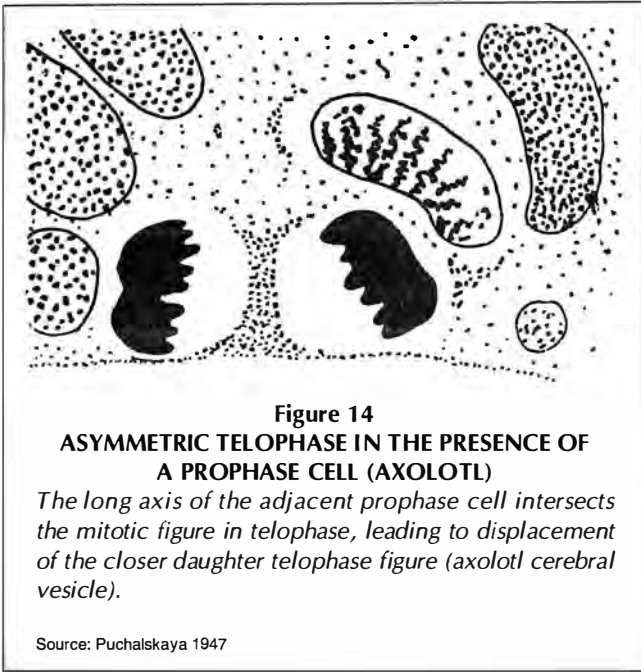


Figure 14
ASYMMETRIC TELOPHASE IN THE PRESENCE OF
A PROPHASE CELL (AXOLOTL)

The long axis of the adjacent prophase cell intersects the mitotic figure in telophase, leading to displacement of the closer daughter telophase figure (axolotl cerebral vesicle).

Source: Puchalskaya 1947

The most interesting phenomenon of histogenesis, according to Gurwitsch, is the increasing divergence from the cell principle (meaning that the phenomena are not simply the result of changes in individual cells) which is so evident during the early embryonal period, before differentiation. This divergence can be expressed in either an initial construction of a new type of cell organization, or the formation of extracellular structural elements (for example, collagen fibers).

The basis for the description of the latter case by the theory of the biological field, is demonstrated by one of its main postulates, declaring the spreading of the cell field vectors beyond the cell borders. This postulate is strengthened by the conclusion that there are long-distance field effects from the epithelial layer (Figures 4, 5). The actual fields in the extracellular areas may form not only the "zero points" but "zero lines" and "zero surfaces," which, being condensation zones, promote the synthesis of the peptide chains oriented according to the directions of the condensation surfaces. Gurwitsch emphasizes that all of these considerations seem to be "very simple," but they permit us to understand the strict regularity in the orientation of the fibrils in bone plates, the cornea, and different cuticular and skeletal formations of invertebrates.

As to the construction of the cell organization, Gurwitsch accepts the assumption that there may be more than one field source in certain types of cells. This assumption is supported by evidence for the presence of chromatin-containing structures (field sources) in the cytoplasm, such as mitochondria or chloroplasts, or the centrosome (considered a nucleus-derived structure). The presence of additional field sources within the same cell leads to the formation of the intracellular actual field, which breaks the stability of the settled "macrofield" and becomes a factor of further irreversible evolution within the intracellular range, while the whole complex is completing its morphogenetic development. This helps explain the continuous cellular changes occurring during the process of histogenesis.

Mitosis

The best example of the field analysis applied to the subcellular level was the adequate description of mitosis which presents a highly complicated chain of events realized in an incredibly strict sequence and coordination in space-time. All the stages of the "miraculous phenomenon of karyokinesis" (Gurwitsch 1941) were analyzed by Gurwitsch in every detail by means of the vectorial field postulates, and described in his unpublished work, "The Theory of Mitosis" (1954). However, these model constructions were supported in a brilliantly illustrative way by the studies performed by E. Puchalskaya, under the direct guidance of Gurwitsch.



The studies were carried out on cerebral vesicles of amphibian embryos, meristems of onion roots, and microsporocytes of larch (*Larix* sp.). It was found that in a high number of the mitoses in the late stages, such as anaphase and telophase, the karyokinetic figures are asymmetric. The asymmetry was expressed in distortion of the mitotic spindle which is "normally" rectilinear, and in displacement or rotation of the mitotic figures in late anaphase and telophase. Further observation of the asymmetry showed that in some of the cases, there were mitoses in the neighboring cells, but at an earlier stage (prophase and metaphase), while in the case of isolated mitoses, these were usually symmetric (Figure 12). The existence of mitoses at an early stage in the neighboring cells was not always a condition for the occurrence of asymmetry. However, the asymmetry was found to depend on a certain specific steric orientation of the prophase or metaphase figures in the neighboring cells (Figures 13 and 14).

An "ordinary" explanation would be that the observed asymmetry is the result of mechanical factors: The cells with earlier mitoses have a higher turgor which would be a cause for mechanical pressure. As to the amphibian brain cells, the asymmetric displacement of the mitotic figure was not usually followed by any changes in the cell boundaries, but the absence of strict cell boundaries, and the small size of the cells, made it impossible to totally exclude the mechanical factor. However, in the plant cells, especially in the meristems of the onion roots, with their thick, rigid cell walls, clear-cut cell contours remained unchanged in the cases of heavy asymmetry, which permits the exclusion of the "mechanical" hypothesis. The important fact was that the existence of neighboring cells with prophase or metaphase mitotic figures was not the only condition for the induction of asymmetry: the mitotic figures of the prophase and metaphase cells were specifically oriented relative to the cells in anaphase and telophase in which the mitotic asymmetry was observed.

The analysis of this puzzling phenomenon by means of the vectorial field postulates, was based on the following working hypothesis. The field anisotropy, expressed as a specific ratio of the ellipsoid axes of the elementary field flashes, relates also to the vectors originating from the nucleus as a field source. Similarly, the same anisotropy principle is applicable to any chromatin-containing derivatives which can be field sources, and the mitotic figure is an example of this case.

Calculations show that if one takes into account the specific horseshoe-like form of the chromosomes in prophase and metaphase, the resulting field vector of the cell will pass through its geometric center, and through the "navel," the place between the arms of the horseshoe-shaped chromo-



somes. Accordingly, this vector is characterized by heteropolarity, which means that, although it is oriented along the axis of the metaphase cell, the vector is considerably stronger (longer) in one preferred direction, coinciding with the "navel" site of the chromosomes. Also, chromatin metabolism substantially increases during mitosis, as the DNA in the chromosomes becomes condensed and tightly packed, reaching its maximum at metaphase, and declining considerably during anaphase and telophase. Therefore, insofar as the value of the field vector depends on the chromatin's metabolic activity, the

prophase and metaphase cells produce very strong field sources. Thus, because of both the anisotropy law and the high intensity of the chromatin metabolism, the resulting vector of the metaphase and prophase cell is a strong heteropolar vector "shooting" preferentially in one direction. This working hypothesis was used by Puchalskaya (1947), with the following results.

It was observed that the asymmetry in anaphase and telophase cells was found in those cases in which the prophase or metaphase figures in the neighboring cells were oriented in such a way, that the direction of the resulting heteropolar field vector crossed the anaphase and telophase figures (Figures 14-23). All of these illustrations, obtained in different objects,

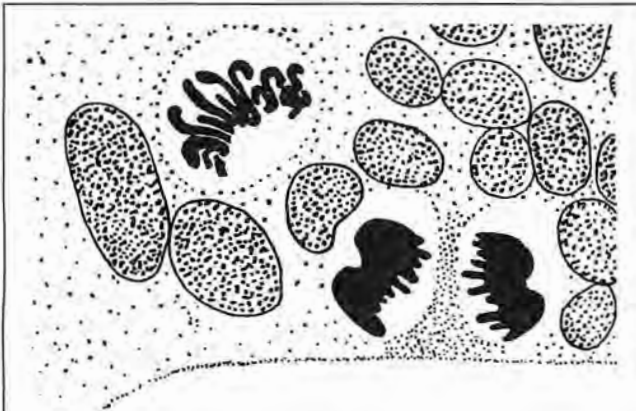


Figure 15
ASYMMETRIC TELOPHASE IN THE PRESENCE OF A CELL IN METAPHASE (AXOLOTL)

The long axis of the adjacent metaphase cell intersects one of the daughter mitotic figures, which corresponds to its displacement (axolotl cerebral vesicle).

Source: Puchalskaya 1947

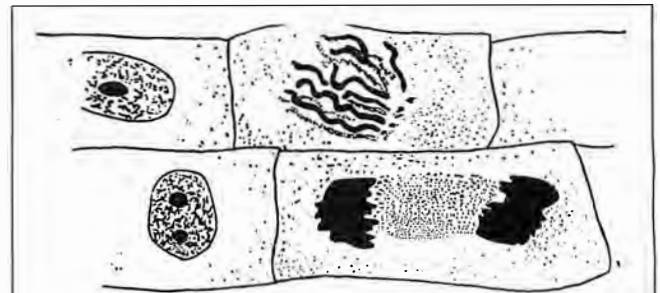


Figure 17
INFLUENCE OF PROPHASE CELL ON A TELOPHASE MITOTIC FIGURE (ONION)

The heteropolar long axis of the cell in prophase intersects the telophase mitotic figure: One of the daughter figures is displaced (onion root).

Source: Puchalskaya 1947

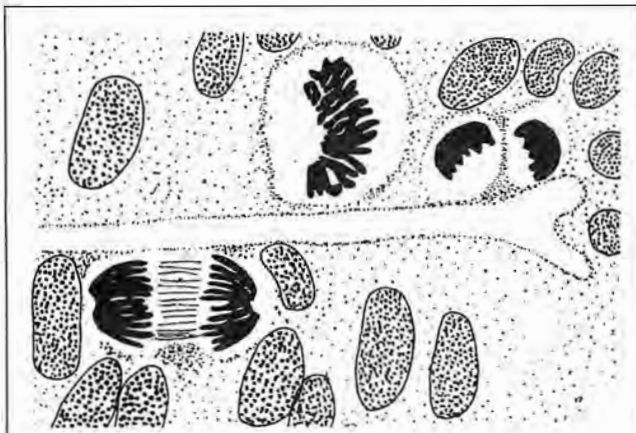


Figure 16
ASYMMETRY AND SYMMETRY IN TELOPHASE AND ANAPHASE (AXOLOTL)

An asymmetric telophase is intersected by the axis of a cell in metaphase (above); a symmetric anaphase (below) is not intersected by the same axis (axolotl cerebral vesicle).

Source: Puchalskaya 1947

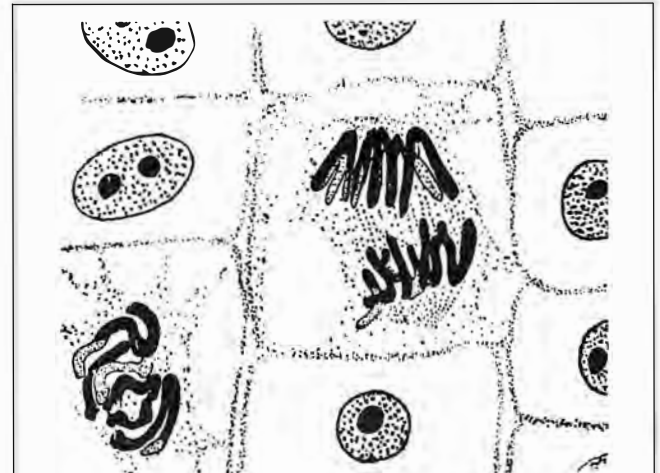


Figure 18
INFLUENCE OF PROPHASE CELL ON AN ANAPHASE MITOTIC FIGURE (ONION)

The heteropolar long axis of the prophase cell (left) intersects the anaphase figure: One of the daughter figures is displaced (onion root).

Source: Puchalskaya 1947

demonstrate the same regularity. On the contrary, in all cases where the prophase or metaphase figures in the neighboring cells are oriented such that the resulting vector does not intersect the anaphase and telophase cells, there is no asymmetry, even though these field sources are in close proximity (Figures 12, 13, and 21). Figure 21 points toward the triumph of the working hypothesis: It shows two prophase figures in adjacent cells, whose resulting vectors are "missing the target," with the telophase figure remaining perfectly symmetric.

The statistical treatment of data obtained from onion root meristems produced the following results: (a) from a total of 339 cases of isolated mitoses, 35 were asymmetric (10.3 per-

cent); (b) from the total of 115 cases in which the direction of the resulting vectors of the neighboring prophase and metaphase cells intersected the later mitotic figures, 113 were asymmetric (98.3 percent); (c) from the total of 303 cases in which the direction of the resulting vectors of the neighboring prophase and metaphase cells did not intersect the later mitotic figures, only 2 showed asymmetry (0.7 percent). Similar data were obtained for the other objects studied.

These results present demonstrative evidence supporting the principal postulates of the vectorial biological field conception concerning the correlation between field intensity and that of chromatin metabolism. Dramatic changes in morphology of the mitotic figures are remarkably explained by the repulsive action of the vectorial field of prophase and metaphase cells, which have a strong resulting vector, resulting from the high intensity of the chromatin metabolism, and the sharply expressed field anisotropy.

These unique data, which were published in Russian in a small collection of articles on mitogenesis and the theory of the biological field (Puchalskaya 1947), have escaped all attention of Western science.¹

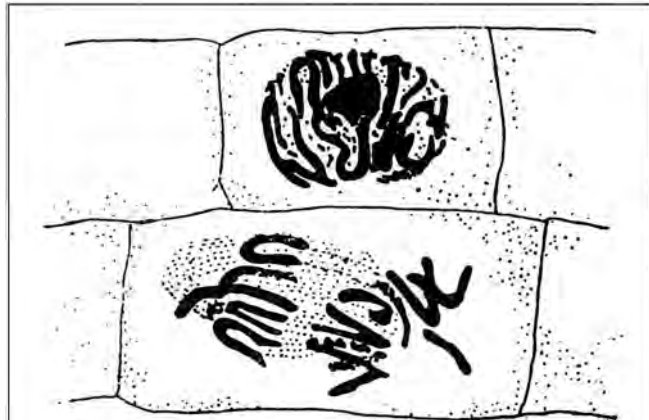


Figure 19

MORE DRASTIC INFLUENCE OF PROPHASE CELL ON AN ANAPHASE MITOTIC FIGURE (ONION)

The heteropolar long axis of the prophase cell (right) intersects the anaphase mitotic figure, which corresponds to its displacement (onion root).

Source: Puchalskaya 1947

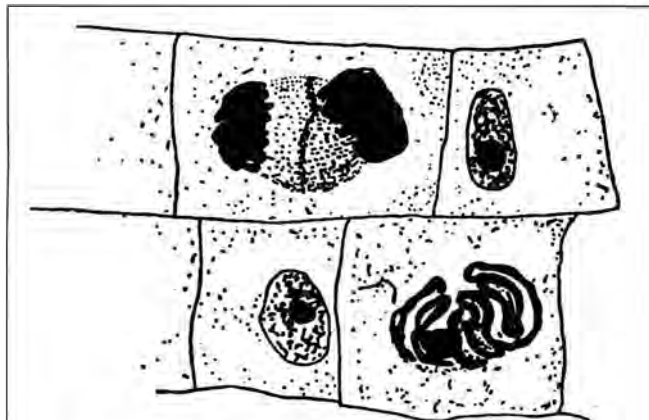


Figure 20

INFLUENCE OF PROPHASE CELL ON A TELOPHASE MITOTIC FIGURE (ONION)

The long heteropolar axis of the prophase cell intersects one of the daughter telophase figures, which corresponds to its displacement (onion root).

Source: Puchalskaya 1947

Reversible Physiological Processes

Although Gurwitsch's elaboration of the biological field theory was based on fundamental problems of developmental biology, the reversible processes had to be intently considered, insofar as the theory began involving all of the levels of biological organization, including the molecular level. Gurwitsch's keen interest in the processes of nervous excitation and regularities of brain cortex function had appeared earlier (Gurwitsch 1929): It was part of his general interest in reversible re-

1. Experiments by Herbert A. Pohl, in the early 1980s, measured the dielectric field strength at the exterior of living cells, and found that the field intensity was greatest during mitosis, specifically metaphase. This result clearly supports Gurwitsch's hypothesis (H.A. Pohl, ed. 1987). —Eds.

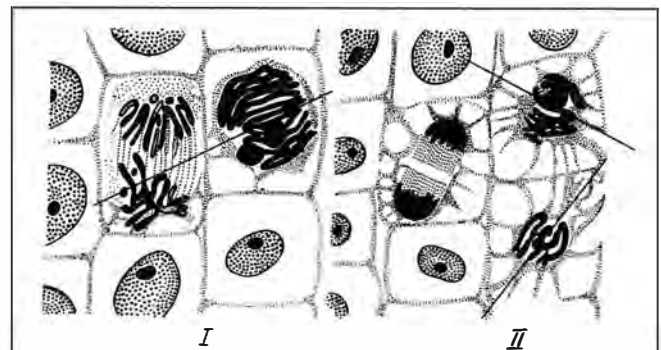


Figure 21

INFLUENCE OF SPATIAL ARRANGEMENT OF MITOTIC FIGURES ON THEIR MORPHOLOGY (ONION)

The long heteropolar axis of the prophase cell intersects one of the daughter anaphase figures, causing distortion (I). The long heteropolar axes of two adjacent prophase cells (II) do not intersect an adjacent telophase figure, which remains perfectly symmetric (onion root).

Source: Puchalskaya 1947; reproduced from Belousov 1963



actions as physiological processes, which he tried to comprehend on the basis of the same supreme principles of equipotentiality and equifinality. The discovery of degradational mitogenetic radiation (A.G. Gurwitsch 1937b, L.D. Gurwitsch 1937a) gave an experimental basis for the conception of unbalanced molecular constellations, which appeared to be the main "working" principle for the application of the vectorial biological field theory to reversible processes.

The logical thread of Gurwitsch's considerations in this area is as follows.

In the individual life cycle, "unrestrained" embryonic development, resulting from interactions of continuously evolving actual synthetic fields, finally fades away, and gives way to a stabilization of the resulting field of the whole. Thus, progressive, irreversible processes gradually cease and are exchanged for stationary, reversible ones. Parallel to this, the actual synthetic fields cease evolving, and identical and invariant individual cell fields become independent and dominant. This is not a "field background" for the reversible processes proceeding independently, but the field is a species-specific invariant factor that determines the conservative character of the current reversible "acts" or reactions.

Central Metabolic Processes

Because metabolism is one of the central problems of both classical biochemistry and modern molecular biology, it is the very image of the tremendous advances made by the analytical trend dominant in the biological sciences. At first sight it seems to have no deficiency in its theoretical basis, and there is doubt whether all of the above-mentioned "supreme" principles can be applied to the metabolic processes. Accordingly, enzymology, which serves as a basis for metabolic biochemistry, is one of the most elaborated branches in biology. The modern undisputed dogma "gene → enzyme" seems to serve as a magical bridge between the higher sphere of determining (and regulating) factors and the inferior layer of executive agents.

The situation is not, however, so harmonious. Indeed, the whole edifice of metabolic biochemistry rests on the fundamental notion of the enzyme as a highly specific biological catalyst, which is believed to provide at the molecular level all the complicated specificity of the observed living phenomena. However, the enzyme's high specificity, to correspond to the observed living phenomenon, must be projected onto a highly complicated network of the enzyme-directed metabolic pathways. The schemes of these pathways are composed on the basis of the results of studies of each particular enzyme reaction. However, any particular living phenomenon proceeding at a higher level (cellular or supracellular), if resulting from events occurring at a lower (molecular) level, must be determined by a high number of enzymatic reactions highly coordinated in space-time. It becomes evident that precisely this coordination is what determines the observed specificity of the living phenomena.

The conditions of the enzymatic reactions defined in purely chemical terms are absolutely insufficient for explaining the specificity of the living phenomenon observed at the higher level. Thus, any attempt to infer the coordination of enzymatic acts from the conditions of the same molecular level is a failure, and evidently needs the involvement of factors of quite another kind. An attempt to ascribe the coordinating condi-

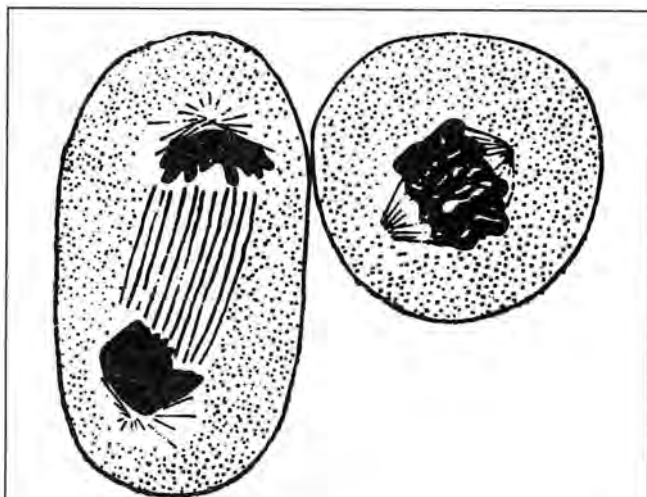


Figure 22
INFLUENCE OF ORIENTATION OF MITOTIC FIGURES ON THEIR MORPHOLOGY (LARCH)

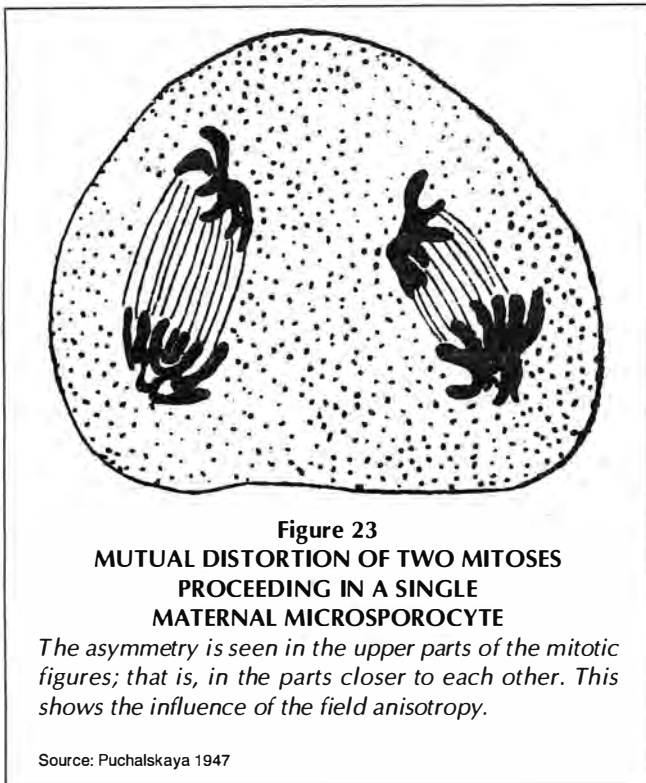
In the case of two maternal microsporocytes, one of the daughter telophase figures is intersected by the long axis of the other cell nucleus in early anaphase, and is displaced.

Source: Puchalskaya 1947

tions to cell membrane structures or surfaces (Golgi body, endoplasmic reticulum, cytoskeleton, and so on), meets the same logical obstacles. The specific "architectonics" of the membrane structures which are to provide the specific spatial arrangement of the chemical processes in vivo does not pre-exist in a completed form, but itself is constituted as a result of some specific synthetic reactions.

The involvement of the genomic level does not solve the problem either, because the problem of the coordination of the enzymatic reactions is replaced by that of the coordination of on-off switching of the respective genes, with the same logical dead end. Thus the problem is merely transferred to a more and more remote level, so that it begins to look like one of the eternal nature-philosophical questions; that is, beyond scientific analysis: Further inquiry would seem simply indecent (like vain discourses about finite or infinite divisibility of elementary particles), since it would inevitably lead to a tautological answer. However, very often the tautology may be imaginary or temporary, and such a situation was clearly illustrated by Gurwitsch in his *Analytical Biology*:

To the question: What accounts for the evident fact that chemical processes in living systems proceed differently than those in vitro? The answer will be that: This is because of special conditions existing in the living systems. To the next question: What is the essence of these conditions? The answer will be: The conditions are the result of not yet ascertained, but in principle ascertainable, particular combinations of molecules in living systems. To the next question: What brings about these particular combinations of the molecules? The only possible answer, from the conventional point of



view, will be: The special conditions in the living systems.

In such form the tautology is quite evident, but it follows from the immovable conviction that everything which can be observed in living systems results in the final instance from canonic properties of the involved molecules. Any other assumption beyond the limits of this assertion is declared to be tautological, because according to the definition, it cannot be reduced to a molecular scheme. The vicious cycle of such argumentation is evident: Although being non-conventional, the disputed assumption, if defined in a restrictive way, can escape the tautology. It will seem incomprehensible only from the canonic point of view.

The "non-conventional disputed assumption" defined in a restrictive way, and not reduced to the canonic properties of the molecules, is the field factor, which coordinates the (enzymatic) processes within the molecular level and "subordinates" the coordinating conditions of the molecular level to the field conditions at the higher levels (cellular and supracellular). Using the glossary of the theory of the vectorial biological field, the specific conditions for the chemical processes in living systems are realized through the unbalanced molecular constellations (Gurwitsch 1944). The constellations include excited protein molecules whose specific orientation within the complex is determined by the resulting vectors of the actual synthetic field. The specific orientation of chemically non-bound molecules within the constellations provides the following special conditions:

1. Parallel orientation (along the resulting field vectors) of the excited protein molecules within the constellations, initi-

ates common energetic levels. Accordingly, a quantum of energy absorbed by one of the molecules belonging to the constellation circulates within the limits of the whole constellation. This means that all the quanta of energy absorbed by the excited molecules flow into the common energetic pool. (Precisely this energy is needed for the continuous maintenance of the unbalanced state of the constellations, and hence this energy is liberated in the form of degradational mitogenetic radiation after the constellation breaks down.) Obviously, these common energetic levels can substantially favor the realization of certain reactions.

2. The specific orientation of the excited molecules within the constellations can cause specific (and multiform) steric conditions for facilitating or hindering certain chemical reactions, which in vitro are either of low probability, or per contra, proceed without limitation.

3. As a result of the realization of certain enzymatic chemical reactions in vivo, due to the specific spatial orientation of the excited protein molecules within the constellations, certain stable compounds and structures are formed ("vestigia," according to Gurwitsch) which play a role in the regulation and coordination of chemical reactions. For example, they regulate the specific intracellular distribution of various membrane-bound enzymes providing a large number of coordinated chains of enzymatic reactions.

The above-mentioned consequences of the field-driven orientation of the molecules within the unbalanced constellations ("unbalanced molecular orderliness," according to Gurwitsch) are essentially expressions of those notorious specific conditions which determine the particular path of chemical reactions in living systems, which are not due to the canonic properties of the molecules involved. Here the notion of "specific conditions" is devoid of any tautology, because it has a restrictive spatial parameter.

The substantiation of the competence of the vectorial field conception for the analysis of the reversible processes is different from that for the analysis of morphogenesis. In the latter case, the criterion for the applicability of the field conception is based on data of the direct geometric configurations of different parts of the developing embryo which can be modelled using the basic vectorial field postulates. In the case of the reversible processes, the argumentation is based on the applicability to the problem of the concept of the unbalanced molecular constellations, which is inferred from the experimental evidence of degradational mitogenetic radiation. In this case, the postulated field action follows as a necessity, as well as this definition: The existence and renewal of the unbalanced molecular constellations is possible in the presence of a factor which is external to the constellations, and is not their intrinsic property. The character of the actual vectorial field and the dependence of the field intensity in turn on metabolic activity makes the actual field a powerful tool, which not only is a "leading factor" of morphogenesis, but also is a coordinating and regulating factor in the realization of the reversible metabolic processes.

These considerations open a *terra incognita* for experimental studies on the coordination of metabolic processes in connection with the non-equilibrium state of the molecular substrate in living systems.





NEUROPHYSIOLOGY AND GENERAL REGULARITIES OF THE BRAIN CORTEX FUNCTION

The field concept was applied by Gurwitsch to the neurophysiological sphere for the first time in his paper, "Der Begriff der Äquipotentialität in seiner Anwendung auf Physiologische Probleme" [The Concept of Equipotentiality in its Application to Physiological Problems] (1929). Later on, his interests in neurophysiology were closely connected with the progress and achievements made in the studies of mitogenetic radiation. The methods used to study mitogenetic radiation, especially the mitogenetic spectral analysis, turned out to be powerful tools for the analysis of the molecular substrate of the neuromuscular system, using the vectorial field conception. It was precisely this field which became the favorite of Anna Gurwitsch (A.G. Gurwitsch's daughter), who became a recognized leader in "mitogenetic physiology."

All of the developments in the application of the field conception to the analysis of the neuromuscular system will be considered in detail in a later section. Here, some general considerations concerning the vectorial field conception, as applied to the function of the brain cortex, will be elaborated in brief.

In Gurwitsch's 1929 paper, the notion of "brain continuum" was suggested with incredible profundity. According to this concept, the cortex presents a three-dimensional continuous non-structural constellation, and all the structural histo-elements are immersed in it, and impregnated by it. The functional state of the continuum is determined by its own immanent characteristics (related to it as a whole) on which current afferent excitations are superimposed. However, the final results, such as volitional impulses or reflex actions, are determined by the state of the continuum, which, thus, reacts as a whole.

In the case of the optical functional complex, each state of the cortex continuum in the visual area of the cortex is a correlate of visual perception. Gurwitsch writes:

However, the continuum state is determined by the excitations of the related neurons only to a certain degree, since the excitation corresponding to the perception of the whole, or the image perception (Gestalt), cannot be considered as an associative connection of the excitations of single neurons. The evidence is that the elementary excitations flow into the continuum as a common reservoir [Gurwitsch 1929].

The above abstract conception of the brain continuum was revived and concretized when the theory of the vectorial biological field was established (Gurwitsch 1944). In light of it, the dynamic cell field spreading beyond the cell borders to extracellular space, continuously constitutes a current connection between the cells, and the resulting integral field is a single, general, indissoluble, continual whole, interspersed with "points of condensation" or maxima, which are intracellular areas of the cell fields. The actual integral field in brain areas is now the expression of the above abstract continuum. It has constant (invariant) characteristics which, it is suggested, determine the general character of the individual organism, including psychological phenomena.

The Psychic Sphere

Strictly speaking, the psychic sphere, although closely related to the physiological activity of the brain cortex, does not belong to reversible processes as other functional activities of the brain or any other physiological system. Indeed, irreversible psychological "maturation" continues throughout the lifetime of the individual.

According to Gurwitsch, the attempt to make a biological analysis of the psychic processes provides a touchstone for the limits of biological thought (*Analytical Biology*). The analysis used the concepts derived from observations of living systems. The fact that Gurwitsch performs such an attempt, using the same "working" principle as was used for the analysis of metabolism and mitosis, shows the unprecedented universality of his vectorial field conception as a working instrument.

According to Gurwitsch's basic principle, the psychic sphere can be the object of biological analysis only so far as it depends on somatic processes. The goal of the analysis is to establish unequivocal connections between both spheres. Progress along this research path will depend on the lucky choice of the "acts" (phenomena) of the psychic sphere which are to be analyzed. Gurwitsch chooses two such activities. The first is the connection between the external stimuli and the psychic phenomena which can be designated as feelings. The second concerns the incessant stream of chaotic thoughts which is a certain background for all the other psychic activities. These two evidently different phenomena have a common basis, which is as follows.

Analysis of both cases inevitably reveals what is designated by Gurwitsch as "the break in continuity" or "the gap in the entirety"; these are, perhaps, imperfect translations of the notion introduced by Gurwitsch in Russian in the original manuscript of *Analytical Biology*. This "break in continuity" is meant to be found while analyzing the somato-psychic and psychosomatic chains of processes: Such a chain is considered to be continuous as soon as at least one parameter is common to both its parts. Both the "classical" point of view and Gurwitsch's own viewpoint accept as evident "the break in continuity," but differ in principle in the further analysis.

From the classical point of view, all of the events within the somatic part of the chain—from the excitation of the receptor up to the last event just before the "break in continuity"—do not differ in principle from each other. The same consideration can be applied to the psychic part of the chain in the opposite direction: psychic feeling → effector reaction of the corresponding organ. Accordingly, the task is to establish unequivocal relations between the content (matter) of the last event in the somatic part of the chain and the essence (content) of the corresponding feeling at the psychic end of the chain (and vice versa). In such a case, the somatic part of the chain can be reduced to just the conduction of the stimulus from the receptor to the place of the "break in continuity." The latter is so drastic that, in Gurwitsch's opinion, there is no basis for any hope to establish the unequivocal connections between the two spheres, so that the above-formulated task is a mere declaration.

On the contrary, Gurwitsch considers that, intuitively, we suspect that the processes of the somatic part of the chain get more and more complicated, and the last one before the "break in continuity" must be fundamentally different from the earlier

events. However, in the arsenal of physico-chemical notions, there is no adequate means for the description of this fundamental difference. Precisely here the theory of the vectorial biological field can offer the adequate non-classical notions. Gurwitsch confronts the classical definitions concerning the essence of feeling as a psychic act in its causal connection with somatic stimulus. The classical formula is: "We feel (are conscious of) the origin, rise, and proceeding in our brain cortex of certain somatic processes which, in principle, are analogous to the other known processes occurring in the organism." Gurwitsch's formula is: "The processes in the brain cortex which we feel (are conscious of) are different in principle from any other processes in the organism, and can be designated by a non-tautological definition." The substantiation of this assertion by Gurwitsch starts from the analysis of the general structure of the brain cortex as the somatic ground for the psychic activities.

Characteristics of the Cortex As a Whole

The analysis is based on the attempt to distinguish the basic characteristics of the cortex as a whole, as opposed to the principle of its reduction into elements. Accordingly, Gurwitsch takes into account the following unique characteristics of the brain cortex organization:

1. The number of cells in the cortex area corresponding to a certain receptor considerably exceeds (perhaps by several orders of magnitude) the number of nerve fibers connecting it (through a set of intermediate centers) with all the elements of the receptor.

2. The cortex is characterized by complicated specific architectonics, which includes regular spatial arrangement and orientation of the neurons (elements); this leads to the conclusion that interrelations among the cells are characterized by spatial (geometric) parameters.

3. The different types of cells in the cortex have peculiar specific configurations of the cell body and cell projections (axon, dendrite).

4. The cells of the cortex are rich in chromatin-containing organelles (mitochondria), which can be found in the most distal parts of neuron fibers.

5. The cortex is highly sensitive to toxic agents and to oxygen deficiency, which cause severe disorders at concentrations which do not strongly affect other systems of the organism.

All of these data are employed by Gurwitsch in his theoretical considerations, while the classical conception does not employ such cortex characteristics as specific configurations of different cell types, nor the architectonics of the cortex as a whole. Instead, it pays almost all of its attention to synapses, which became the basic point of the classic neuron theory. Therefore, the classical conception is grounded upon the specific anatomic connections corresponding to functional complexes. The latter, studied by physiological methodology, has led to a situation where many discrete acts are under research, and the problem of conduction became the central one in experimental efforts. Thus, the main content of the intrinsic cortical processes, which obviously does not consist in conduction of impulses to and from the cortex, escapes consideration in classic neuron theory. The idea of cortex function is reduced to interactions and interrelations among neurons (elements) by means of strictly determined connections.

In contrast, Gurwitsch accepts the inseparable, irresolvable something of the cortex considered as a whole, and constructs his conception of the psychic functioning of the cortex, using the postulates of the vectorial biological field, in the following way.



1. Each neural cell is the source of the field, and as a result of their vectorial interactions, the actual integral field is established.

2. Geometric parameters of the field of each individual cell depend on its configuration, including the cell projections, as they contain cytochromatin (mitochondria), which is a potential source of the elementary field flashes. Architectonics (stereometrical configuration) of the actual field of the cortex is the result of three parameters: the number of cells, their spatial arrangement, and the characteristics of their own cellular fields.

3. The field of the cortex is of high intensity. In particular, this is indicated by the extraordinary richness in cytochromatin (mitochondria), which is known to produce a high rate of energetic metabolism.

4. As a result of the wide and dense distribution of the dendrites which are rich in cytochromatin (mitochondria), the actual field in any point of the cortex is of a stabilizing nature, because of the field's high intensity. This means that there is a high degree of vectorization of molecular processes; that is, a high degree of the non-equilibrium state of the molecular constellations.

The whole complex of these conditions constitutes the state of the "field tension." Such a state would correspond to a fictitious situation in which the cortex "is left to its own resources" (very stationary metabolism), as if isolated from any external stimuli. However, in reality, the cortex is under diverse, continuous, excitational influences, coming from extero-, entero-, and proprio-receptors, causing changes in the state of the corresponding cortical neurons. The important thing is that these changes are superimposed on a momentary state of the cortex actual field, which is a quasi-stable (dynamic) independently existing factor.

The vectorial field conception presents a dualistic confrontation between the field sources and the substrate of their influence. In this respect, the interference of the impulses coming from the receptors may have two possible consequences: (a) The impulses interfere only with the state of the substrate, causing a disharmony between the field and the state of the substrate; (b) The impulses also influence some field parameters, so that the changes in state of the substrate causing the disharmony are the result of both the immediate influence of the impulses and the impulse-caused modification of the field.

The final conclusion from these considerations is as follows. In the somato-psychic chain of processes, the last event in the somatic part of the chain before the break in continuity, after which the feeling (psychic part of the chain) becomes evident, may be defined in two ways: either as the origin of the disharmony in the field substrate, or simply as the momentary state of the actual field of the cortex. We "feel" the states of the actual field of the cortex. Similarly, the chaotic stream of incoherent thoughts can be imagined as the feeling of the quasi-stationary state of the actual field (continuous fluctuations of the field tension), not depending on any discrete excitations or volitional acts.



However, the basic thesis that “we feel the state of the cortex actual field,” may seem too general and dim (perhaps a bit mystifying), not giving the satisfaction of understanding. Therefore, Gurwitsch gives it a more limited interpretation and confronts it with other conceptions.

Returning to the cortex architectonics, Gurwitsch emphasizes its high regularity (mostly absent in the histological organization of the subcortical centers) expressed by the three parameters: homogeneous structure and configuration of the cells prevailing in a given area (pyramid cells, for example), lamellar character of their spatial arrangement and, especially, strictly parallel orientation of the cell axes. The combination of these three parameters is specific for certain cortical areas (cytoarchitectonic areas) characterized histologically and physiologically (functional connections with certain receptor or effector zones). Therefore, the actual field of such areas is designated a macrofield by Gurwitsch. The macrofields of the various cytoarchitectonic areas constitute the general actual field of the whole cortex.

Although any sharp changes in the momentary states of the macrofields of certain cytoarchitectonic areas affect the macrofields of the neighboring areas, causing changes in the general cortex field, the general field, being conservative, acts counter to (“smooths out”) the changes in the macrofield of the excited area. This conservative character of the general cortex field, influencing its parts (macrofields of cytoarchitectonic areas), can be correlated with a personal disposition, to which the notions of decomposition and “more-less” estimation are not applicable. At the same time, the disposition influences the individual feelings and acts, which agrees with the idea of the general cortical field influencing the macrofields of the cytoarchitectonic areas.

The idea of a common indication in the individual’s behavior and the cortical processes related to the cortex as a whole, is not alien to the classical conception. However, Gurwitsch exposes a difference in principle between the two conceptions.

In the classical conception, interactions, connections, and associations—apart from the anatomical connections between single cells and cell complexes—are comprehended as a spreading of the state of excitation from the primarily affected cells to the more remote cells. Certainly, the directed spreading of the excitation, which essentially is a process of conduction, is an established fact, but Gurwitsch emphasizes that only that which has been decomposed can be conducted. Therefore, in order to bind the conducted excitation with the feeling at the other (psychic) end of the somato-psychic chain, the first act of conduction toward “feeling formation” must be followed by the stage of joining up the conducted elements of that something which was decomposed, and to which the final feeling at the psychic end corresponds. However, in the classical conception, there is no adequate apparatus for joining up the elements: This would be possible if one accepted the existence of qualitative differences between the excitations of each cell, but this contradicts the clear equipotentiality of the cells within each cytoarchitectonic area.

Alternatively, the vectorial field conception: The conservative indivisible whole (general cortical field) composed of the macrofields, and the local discrete deviations of microfields

caused by afferent impulses, are responded to by the whole architectonics with certain gradients.

The final confrontation of the two conceptions in an abstract mode is as follows: (a) The integral feeling is a result of the composition of discrete elementary excitations into a certain whole (the classical conception); (b) The integral feeling is a modification of the pre-existing whole under the influence of the discrete excitations (Gurwitsch’s conception). The important inference from this confrontation is that, according to the classical conception, the brain cortex is an exclusively reacting apparatus which is compatible only with those feelings which are bound to the acts as reactions to the impulses. Thus, there is no apparatus for any other feelings; for example, those associated with mental operations not bound to the observed acts. On the contrary, the general actual field of the cortex, in Gurwitsch’s expression, “has its independent life,” and its state—regardless of current perturbations brought by the afferent impulses—may be designated as unbalanced labile tension. Fluctuations of this tension caused by the complexity of the cortical field architectonics, are expressed (are felt) as a chaotic stream of incoherent thoughts.

A special problem considered by Gurwitsch concerns vestigia (vestiges), or traces of feelings which are preserved in the cortex and can be reproduced. Thus, the vestigium is a kind of preserved mold from that configuration of the local actual microfield which existed at the moment when the feeling was generated. Evidently, this problem is closely related to the problems of memory and recollection. The analysis is limited to those feelings which are immediately connected with receptor activity (afferent impulses).

All the above schemes concerning somato-psychic chains of events originating in receptors and (through the break in continuity) ending with feelings, were based on the complete reversibility of the processes considered. However, the notion of the vestigium demands that the scheme must include a new parameter, a certain seldom realized value, which results in irreversibility of the last event, which is the vestigium. The arsenal of classical biology offers two possible ways for the realization of this scheme on the molecular level: either chemical chain reaction or conduction of the electric potential. Neither one, however, is compatible with the inference about the qualitative diversity of the excitations in the same neural fiber. Purely chemical and electrical parameters are not sufficient for an adequate description of the enormously variegated types of excitations differing in their content. Therefore, Gurwitsch comes to a conclusion (on the basis of data on the mitogenetic analysis of the nerve impulse) that the chain processes spreading along the neural fiber are not limited to chemical parameters, but are also characterized by steric parameters. These parameters are thought to operate as follows.

Certain molecular “functional units” in the neural fibers are assumed to be peptide molecules of certain sizes. As members of non-equilibrium constellations, the molecules acquire certain specific (mutual) orientations and undergo reversible steric deformations which are transferred along the somato-psychic chain. As opposed to chemical variants, the degree of the deformation and the diversity of the deformations are practically unlimited. Thus, the nature of the impulse moving from the receptors to the cortex is associated with the wave of deformations spreading in the neural fiber along the somato-psychic



Gurwitsch's laboratory in Moscow in June 1948. Gurwitsch is second from right in first row. The third from right is his daughter, Anna.

From archives of L. Belousov



chain. If this chain passes through an area with a high field intensity (for example, an area with a high density of neurons) the deformations may undergo some changes. On the other hand, the wave of deformations can involve some cellular components including cytochromatin, which would cause changes in some field parameters.

As a result of such conjugated and interdependent processes, in certain rare cases some deformations may become steady and irreversible, and these are vestigia. Activation of the vestigia is thought to be a molecular analogue of the psychic phenomena of recollection and reminiscence. The act of activating the vestigia is assumed by Gurwitsch to be connected with the process of their self-reproduction. The same assumption is employed by Gurwitsch in interpreting the mechanism for conducting various excitations in the same nerve fiber. This is an unprecedented assumption, having no analogies in biology and chemistry, but it does not contradict the fundamentals of the physics of energy, since the deformed protein molecule has a higher energetic potential that can be transferred to a non-deformed molecule with a lower potential. Insofar as such a transfer proceeds within the vectorial biological field, it would transfer not only the energy, but also the deformation.

The intensity of the self-reproduction of the deformations may vary, so that in the case of low intensity, the newly formed vestigium exists for a short period and then vanishes; in the case of a moderate intensity, the vestigium persists in a latent state (memory), and in the case of high intensity, the latent vestigium can be activated by an impulse analogous to the initial one (recollection). In the case of high intensity, the activation leads to changes in the macrofield expressed by a corresponding feeling.

In further analysis, Gurwitsch changes the notion "latent" (vestigium) to the more specific "subliminal." It should then be accepted that the subliminal vestigia, stored and continually accumulated in the cortex, exert influence on certain parameters of the corresponding local microfields. These slight, negligible changes slowly and progressively lead to still slower but inevitable changes in the macrofield. The slow changes do not lead to the feelings which result from the sharp discrete changes of the macrofields, but they may exert influence on feelings by imparting to them additional tints. Therefore, such subliminal vestigia slowly change the architectonics of the general field of the cortex. Insofar as the state of the latter is associated by Gurwitsch with the totality of psychic phenomena, including individual disposition, the above considerations permit us to describe the slow, progressive evolution of the individual disposition (psychic maturation) as the evolution of the cortical field depending, in turn, on the accumulation of the latent subliminal vestigia.

Psychic Indeterminism

The problem of psychic indeterminism seems to go beyond the purely biological prerogative, and grows into the philosophical sphere associated with its basic problem: the spirit-matter relationship. The involvement of "exact sciences" such as physics in this problem (limited to a purely speculative level) can be seen from the utterances of such eminent thinkers as Niels Bohr, Erwin Schrödinger, and in general, the ideas on the connection between psychic indeterminism, on the one hand, and the indeterminism and "free will" of the elementary particles, on the other, are widely discussed in the literature on the philosophy of mind (Rensch 1976). As to the ability of the biological sciences to address this problem,



complete feebleness is all that can be demonstrated, even on the speculative level. Classical neuron theory is not capable of even attempting to explain the visibly indeterministic phenomenology.

As opposed to the purely speculative character of the problem itself, Gurwitsch's analysis is founded on histo-morphological and physiological grounds, to which he applies the theory of the vectorial biological field (Gurwitsch 1944). First, true to his peculiar approach in attacking a scientific problem, he tries to formulate a particular definition of psychic indeterminism which would permit a non-tautological analysis of this immanent, eternal problem. He raises the following question: Can any impulses be transmitted from the cortex to the effector organs if all the receptors of the organism are absolutely blocked? Although such an experiment is not possible, the presumably positive answer to the question does not seem to be absurd or nonsensical.

However, Gurwitsch attempts to formulate the question in another form. If one supposes that an individual is under stimulation by a monotonous afferent impulse, and his reactions to this impulse (acts) are continuously registered, there are two alternative possibilities, corresponding to the existence or absence of indeterminism. In the first case, all the registered reactions (acts) of the individual are statistically equally probable, without any prevalence of either of them (true indeterminism). In the second case, a specific kind of reaction prevails, and deviations from this kind will be arranged according to the Gaussian distribution (the absence of indeterminism). Although the performing of such an experiment in pure conditions is also beyond real possibility, there is hardly any doubt that the second alternative is the case (assuming the sanity of the individual under study). Therefore, true indeterminism in the sense of the definition given above should be rejected. Its resemblance to Gurwitsch's view results from certain probabilities for different variants, meaning the absence of "obligation" for the most probable of them.

However, in biological reality, the hypothetical possibility of psychic indeterminism is understood as the question of whether there is an unequivocal connection between an incoming afferent impulse and the following effector act. Precisely this notion of indeterminism was used by Gurwitsch for the analysis. Certainly, insofar as psychic activity is postulated to be associated with the processes in the brain cortex, this question does not concern a simple stimulus-response cerebro-spinal reflex arch, whose deterministic nature is beyond any question.

From the classical point of view, the absence of the unequivocal connection between afferent and efferent impulses, is explained as a result of the extraordinary complexity of the processes in the cortex, which is essentially an evasion.

The vectorial biological field concept gives the problem a new, non-tautological description. The proclaimed "extraordinary complexity" of the processes in the cortex, which obscure and pervert the postulated unequivocal connection between the afferent and efferent processes, can be considered the result of the total actions of the highly numerous, simultaneous, and immediately preceding impulses, including a great many of those coming from enteroreceptors not reaching the consciousness. These obscuring impulses prevent the dominant impulse from being fully displayed, and hence, prevent the

demonstration of the deterministic nature of the psychic phenomena. However, classical neuron theory does not indicate with what morphological apparatus or substrate these obscuring sideline impulses come into contact.

Indeed, taking into account the multiplicity and diversity of the sideline impulses, it is impossible theoretically to relate them to a different effector apparatus (and there is no histo-anatomical evidence for it). The only model somehow manifested by reality is connected with the organization of the central nervous system of many invertebrates, which is constituted of a general non-segmented ganglionic center into which all afferent impulses flow, and from which all effector impulses flow in turn. However, this model is not suitable for the case under discussion, since it leaves no place for the postulated prevailing connections responsible for the typical reactions.

The theory of the vectorial biological field helps to establish a certain hierarchy in the functioning of the afferent and efferent chain processes, in the following way. Although the anatomical neuronal connections are dominant, they are not isolated within the brain cortex. The incoming afferent impulses (the corresponding chain processes) interfere with the chain processes spreading in the unbalanced molecular constellations, whose configurations are determined by the corresponding local microfields and area macrofields, by their intensity and configuration. The influence of the interfering chain processes on the initial receptor-caused afferent impulse can obscure and distort the initial impulse. The resulting field-induced deformations of the substrate, which will finally determine the specificity of the effector act, may appear to be numerous and quite different, so that a number of different acts in response to the same afferent impulse will become manifest, compatible with the indeterministic conception.

Taking into account the purely speculative background of the problem of psychic indeterminism, Gurwitsch's analysis, made from the intrinsically biological point of view on the basis of rational scientific methodology, can be considered an unprecedented, courageous attempt.

Embryogenesis of the Psyche

The statement of this problem is based on the following considerations by Gurwitsch. There is an immanent (continuous) connection between the psychic and somatic spheres, and the former develops in parallel with the embryonal development of the soma. This thesis sounds quite innocent, until it is sharpened by its simple logical extension, which now takes the form of an audacious postulate: Psychic elements are present at any stage of the embryo's development. However, an important reservation is made about what type of elements is meant. It is clear that the psychic elements of the developing embryo are thought to be rather rudimentary, and evolve (or develop by jumps) along with the embryo's development.

If, in general, the psychic sphere is the totality of current transient feelings, continuously changing, mixed in their content and only partly dependent on the environment, all these fleeting feelings originate and proceed on a certain background (also slowly developing) which can be designated as our individuality. Gurwitsch's postulate about somato-psychic immanent connections concerns only this background. Accordingly, Gurwitsch considers as inscrutable the idea that this "background" originates at a certain stage of embryogenesis "out of nothing,"

without a rudimentary source. The path of the analysis is to create a concept of this source by examining the embryonic stages in reverse, and imagining a gradual involution of the psychic sphere up through any conceivable rudimentary state. However, such an idea in itself may seem rather utopian, since the notion of the rudiment means preservation of the main analogies between "feeling" as a fully developed psychic phenomenon of the adult organism, and its embryonic counterpart.

While confronting both (the mature form and its rudiment) one often resorts to comparison by means of estimations such as "more-less" and "simpler-more complex." Are there any kinds of feelings, as psychic phenomena, which permit such estimations? Gurwitsch assumes that a positive answer to this question is possible if such a psychic phenomenon as "knowledge" is concerned. Indeed, knowledge is that basis of the psychic sphere which develops, grows, and becomes complex starting just after birth. However, if such a conceivable analysis of psychic involution can be described by means of comprehensible notions, it would be logical to continue it further by including intrauterine life. Moreover, strictly speaking, it is impossible to stop this mental operation, and to indicate any final point in the retrospective analysis which would be the "point of origin of the psyche."

Gurwitsch uses the concept of knowledge in a limited sense, identifying it, essentially, with the notion of "feeling," and avoiding the usage of the notion of "consciousness" as more equivocal and uncertain. Then, according to such a concept of knowledge, the latter means knowledge about one's momentary state, and its changes, and this notion of knowledge is identical to the state of feeling.

However, as described previously, feeling is the first event after the "break in continuity" that is compatible with the last event before the break, which is the state of the actual field of the corresponding cortex area. This consideration permits one to offer the following preliminary definition of the rudimentary psyche at any stage of embryogenesis: The rudimentary psychic feeling of an embryo is limited to the knowledge of the momentary state of its actual field.

However, together with the feelings, the psychic sphere includes what can be called "actions" or "deeds." Does this notion permit their reduction to the rudiment, as with the notion of feeling? Gurwitsch accepts that the psychic concept of "action" is difficult to define, even in the "normal" case, so that the definition of the rudimentary case might not be possible. Nevertheless, Gurwitsch suggests the following definition of "action": If a certain observed phenomenon appears as the last event from different chains of events, this phenomenon is a result of action. Thus, the essence of the problem is associated with the "act of choice" of one of the possible paths (chains of events) among a number of them, where the other paths are also possible. Gurwitsch applies this to the processes of embryogenesis, emphasizing that it is not evident a priori that the embryogenetic processes can be designated as "actions."

However, Driesch's concept of equipotentiality of the embryonic elements, based on his experiments on harmonic regulation, leads to the conclusion that the behavior of the embryonic elements under experimental conditions suits the above definition of "action." Together with this, as Driesch himself noted, it would be unnatural to think that embryos display actions only when they undergo gross experimental interference:

If actions of the embryo are manifested under extraordinary circumstances, it must be concluded that under "normal" conditions, it also acts in reaction to all the inevitable fluctuations of the parameters of development.

Accordingly, the final concept of the embryonic rudimentary psyche is defined as follows: The embryo "knows" the state and changes of its actual field and "acts" in order to smooth the tension arising from the changes.

However, Gurwitsch admits that his idea of embryonic psychic actions essentially coincides with Driesch's general concept of "harmonic regulation," which concerns the same phenomenon of embryonic behavior in response to experimental interference. Perhaps, it may be answered, the designation of the known phenomena of harmonic regulation as psychic acts is simply a battle over terms. Indeed, the problem of the biological basis of the "normal" psyche exists whether we like it or not, and it may only be our attitude toward the problem that is arbitrary, such as that any rational investigation is utterly impossible. Or it may be said that the problem of the embryonal psyche is just a mental construct, aiming to relate the facts of embryonal regulation to the sphere of psychic phenomena.

Gurwitsch convincingly demonstrates that the problem of the embryonic psyche is not just a far-fetched play on words. First of all, Gurwitsch's analysis, based on the principle of "reduction to an absurdity," leads inevitably to recognition of the objective existence of the embryonic psyche. Second, the possibility of applying the same concept of the tension of the actual field to such different phenomena as embryonal regulation and psychic feelings of the mature individual, seems to be fruitful.

Moreover, the consecutive analysis of the processes of embryonal regulation, leads to the same conclusion about the "break in continuity" as in the case of the somato-psychic chain. The only difference is that in the latter case, the first event after the break relates to "feelings," while in the case of embryonal regulation, the first event relates to "acts." Therefore, the assumption that the embryonic "acts" are determined by the immediately preceding "feelings" may seem to be arbitrary. However, insofar as the embryonic "acts," according to the definition given above, originate in the embryo's "choice," it must be a certain "factor of choice" which essentially is designated by Gurwitsch as related to "feelings."

The last objection confronted by Gurwitsch (his stylistic peculiarity was a kind of dialogue with the devil's advocate) was that the identification of embryonal regulation with psychic "feelings" does not introduce any new notion beyond Driesch's classic formulations, and hence, the whole conception of embryonic psyche is futile and vapid. However, this is not true.

The point is, that the essence of embryonal regulation was defined by Driesch as an urge towards return to a "norm." However, in this case, the notion of the "norm" coincides with the whole totality of that which, in fact, is the organism itself, so that the definition of the "norm" is tautological. A non-tautological definition must contain some limiting parameters, and such parameters are formulated by the conception of the actual field.

Indeed, notions like state or tension of the actual field, which are employed for description of the embryonic psyche, do not coincide with the notion of the organism or embryo. Therefore, the association of the notion of psychic feeling





with the state of the actual field escapes tautology. The comparison between two definitions which follow is quite demonstrative: "The embryo 'knows' the momentary state of its actual field" and the paraphrase definition of Driesch, "the embryo 'knows' its momentary state." The latter definition cannot be applied to everyone's individuality, because everyone "feels" only particular partial states, not seizing the psychic sphere in all its totality. Gurwitsch's conception of the actual field, in its application to the embryo psyche, has the same limiting significance.

CONCLUDING REMARKS

Gurwitsch always emphasized that living phenomena of any sort, and at any level of organization, belong to systems which, at any moment of observation, are at some stage of the ascending-descending curve of their life cycle. Contemporary biologists have usually missed this, or at least, not used it in their theoretical conceptions. The principal purpose of biology is to elucidate the regularities of the processes which constitute the life cycle. According to "classical" biology (and to the overwhelming majority of biologists), the life cycle is a phenomenon of a quite unequivocal "iron regularity" (Gurwitsch's expression) laid in the egg, but current attendant circumstances continuously distort its realization, and it remains hidden. Such an "iron regularity" is realized through the rigid, unequivocal connections among all essential processes, and the main task of scientific analysis is to cast away all contingencies, in order to reveal these connections in their naked purity.

Hence, the classical point of view is that the "norm" coincides with all the possible minimal and maximal deviations. Indeed, the undoubtedly intrinsic observable property of the life cycle is its conservativeness and, according to the dominant views, it is precisely this conservativeness that is an expression of the postulated unequivocal regularity determining the life cycle. However, the facts related to developmental mechanics (Roux and Spemann), harmonic regulation (Driesch) and the influence of centrifugation on egg cleavage (Gurwitsch) testify against rigid, unequivocal connections. The concept of "normating," introduced by Gurwitsch, presents a factor organizing the specificity of the processes at all levels, leaving a considerable degree of freedom in the behavior of the individual elements included in the realization of these processes.

As an illustration of the action of such normating factors, Gurwitsch uses a metaphor conceived by Virchow who, in his famous theory of cellular pathology, considered the organism (the whole) as a cell republic (Virchow, 1858). The main condition for the optimal functioning of any republic is to elaborate a constitution which combines order and stability of the state as a whole, with the minimum possible limitation of the freedom of all the citizens as individuals. This definition exactly reflects the concept of normating. Continuing with this allegory, one should state that the republic's constitution is based on certain principles of society which are its lawful notions, such as rules, codes, and customs. Similarly, the normating principle in biology should also "work" on certain specific parameters (which are to be normated) common to different biological phenomena, otherwise this notion becomes a mere tautology, and loses any value. Therefore, Gurwitsch clearly deter-

mines these lawful parameters upon which the normating principle acts: These are purely spatial (vectorial) parameters of cell behavior, and this is, essentially, the basis of the constitution of the cell republic. However, by definition, any factor acting within the limits of steric parameters and, hence, making the elements' behavior depend on their coordinates within the whole, is a field factor.

In this connection, it should be emphasized that the notion of "field" introduced into biology by Gurwitsch, was used by others in the 1920s and 1930s, without any strict definition of the concept, and often without common sense. In certain cases involving demonstration of equipotentiality of the elements, the presence of a field was just declared in a vague and emasculated form (see review by C.H. Waddington, 1966). Evidently, such groundless declarations of the presence of a field were not a step forward from the original conclusions of Driesch, and hence, the usage of the concept of field in such cases was just a matter of semantic tautology.

The field conception developed by Gurwitsch, was based first on the elaboration of particular models of morphogenesis using specific invariant laws (dynamically preformed morpho) and then on the development of the unitary vectorial field conception, using specific, strictly defined postulates. This marked substantial progress towards the creation of the epigenetic conception of development as a working principle. This, in itself, is a great advantage as compared to the other general conceptions concerning embryonal development, such as the classical genetics of Mendel, and the developmental mechanics of Roux and Spemann.

Driesch's conception (considered logically beyond reproach by Gurwitsch), based on remarkable experiments, was led by its author to a deadlock by introducing the concept of *entelechia*, which was beyond rational scientific analysis. Therefore, the great achievement of Gurwitsch was that he brought his theory from the heavens of an immaculate logical structure to the grounds of a "working" instrument, helping to explain the phenomenology displayed at all the levels of biological organization. It is precisely the concept of actual fields that can serve as such a working tool.

The relationship of Gurwitsch's field to physical laws, and the principles of field action, were comprehensively discussed in Gurwitsch's last work, which was published in Russian 37 years after the author's death, and is still practically unknown in the West (Gurwitsch, *Principles of Analytical Biology and the Theory of the Cellular Field*, 1991). The following quotation from this work is worth noting.

The dominating conviction is that different chains of events in the analysis of observed living phenomena will, in some distant future, boil down to the level of those data and notions which are used in physics and chemistry. In opposition to this conviction, our suggestion is that the confluence will occur at a higher level, specific to the living phenomena, which means that biology can possess its own specific fundamental notion, not contradicting the fundamental notions of physics and chemistry, but also not reduced to them. The field theory is an attempt to formulate such a fundamental notion. . . . The field conception is not based on physico-chemical notions, but on physico-chemical possibilities. These possibilities are

designated by physical terms, and the theory of the biological field using these terms makes from them an unparalleled combination. Yet it does not contradict the basis of physical thought and experience which underlies all the constructions for sequences of events of various observable, phenomenologically independent processes of embryogenesis, as well as of repeated (periodic or aperiodic) processes continuously proceeding during the whole life cycle.

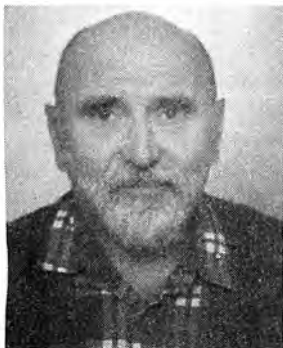
However, even though we attribute to the field the significance of a basic "fundamental notion," specific to living systems, to which, hence, a property of universality is imparted, the whole conception is alien to an idea that everything occurring in living systems is unequivocally determined or even depends on the field. Such a primitive idea would be equivalent to a mere tautology. On the contrary, the field definition is strictly outlined and limiting. The field . . . has a significance of a normating invariant factor of steric parameters on processes proceeding in living systems at a molecular level.

Thus, the succession of developments of the field conception, reviewed above, from the first abstract models describing single morphogenetic phenomena, to the general theory of the vectorial biological field, covering, by its explanatory power, all the levels of organization of the living organism, is one of the superb efforts of the human mind in the attempt to comprehend the fundamental regularities of the development, organization, and function of living systems.

Returning to the question posed in the introduction, whether there is any connection between Gurwitsch's theory of the biological field, and modern trends of contemporary theoretical biology, we come to the conclusion that there is a deep discrepancy between the two. Gurwitsch's theory of the biological field is practically unknown in the West. However, finding a consonance between Gurwitsch's ideas and modern theoretical constructions could be a fascinating task.

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Michael Lipkind was born in Moscow in 1934, and was personally acquainted with Gurwitsch in his youth. Gurwitsch's brilliant intellectual power, original scientific and philosophical vision, humane personality, steadfast honesty and generosity during a cruel period of Russian history, strongly influenced Lipkind, who considers himself as Gurwitsch's disciple.

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Remarks on Gurwitsch's Method

Part 2

by Lyndon H. LaRouche, Jr.

An economist comments on the importance of Gurwitsch's method for physical economy.

EDITOR'S NOTE

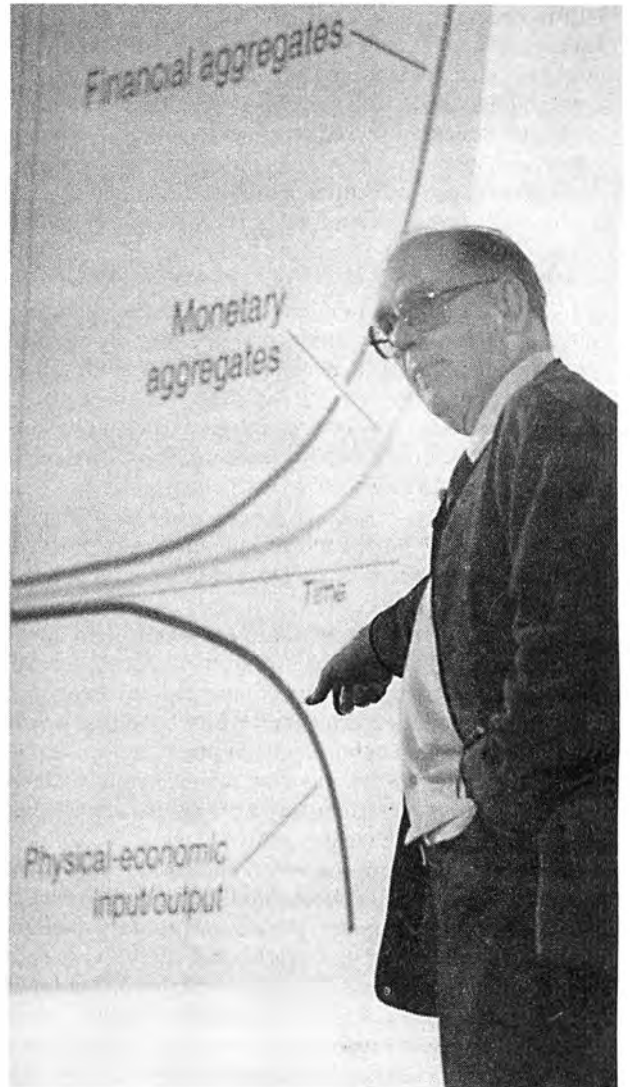
Part 1 of LaRouche's comments appeared in the Summer 1998 issue of 21st Century, p. 52. As noted there, LaRouche's remarks were written on March 15, 1987, when Michael Lipkind's work on Alexander Gurwitsch was being discussed and edited for publication in Fusion magazine, the predecessor of 21st Century. Fusion was summarily shut down in April 1987 and put into forced bankruptcy by a corrupt faction of the U.S. federal government, as part of their "Get LaRouche" campaign. We are happy to present this long-delayed commentary on Gurwitsch's work.

In Part 1, LaRouche discusses the fact that healthy living processes are characterized by a kind of harmonic ordering, as known since the work of Luca Pacioli, Leonardo de Vinci, and Johannes Kepler, and as developed in the work in mathematical physics by Carl Gauss and Bernhard Riemann.

Here, LaRouche reviews the connection between the biological origin of human mentation and the successful growth of the physical economy. Readers are also referred to LaRouche's more recent comment, "The Astrophysics of Gurwitsch Radiation," which appears on page 16 of this issue.

The Transfinite As Ontologically Existent

Alexander Gurwitsch apparently first elaborated the approach of most specific interest to me in a 1929 paper, "Der Begriff der Äquipotentialität in seiner Anwendung auf Physiologische Probleme" (The Concept of Equipotentiality in Its Application to Physiological Problems). In this, Michael Lipkind emphasizes, "the notion of 'brain continuum' was suggested and considered with the incredible profundity so characteristic of Gurwitsch."¹



Stuart Lewis/EIRNS

LaRouche discussing his triple-curve economic collapse function at a January 1998 meeting in Washington, D.C. Real physical production is declining hyperbolically, at the same time that financial and monetary aggregates are soaring hyperbolically.

"According to this concept," Lipkind writes, "the cortex presents a three-dimensional, continuous, non-structural constellation and all the structural histo-elements are immersed in it and impregnated by it." He then quotes Gurwitsch:

However, the continuum state is determined by excitations of the related neurons only to a certain degree, since the excitation corresponding to the perception of the whole or the image perception (*Gestalt*), cannot be considered as an associative connection of the excitations of single neurons. The evidence is that the elementary excitations flow into the continuum as a common reservoir [Gurwitsch 1929].

This is precisely what is readily demonstrated for the function of creative scientific discoveries within the developmen-

tal processes of entire economies. This can be no mere coincidence, since it is precisely the highest order of brain functions which determine this relationship of microcosm to continuum (macrocosm). Lipkind continues:

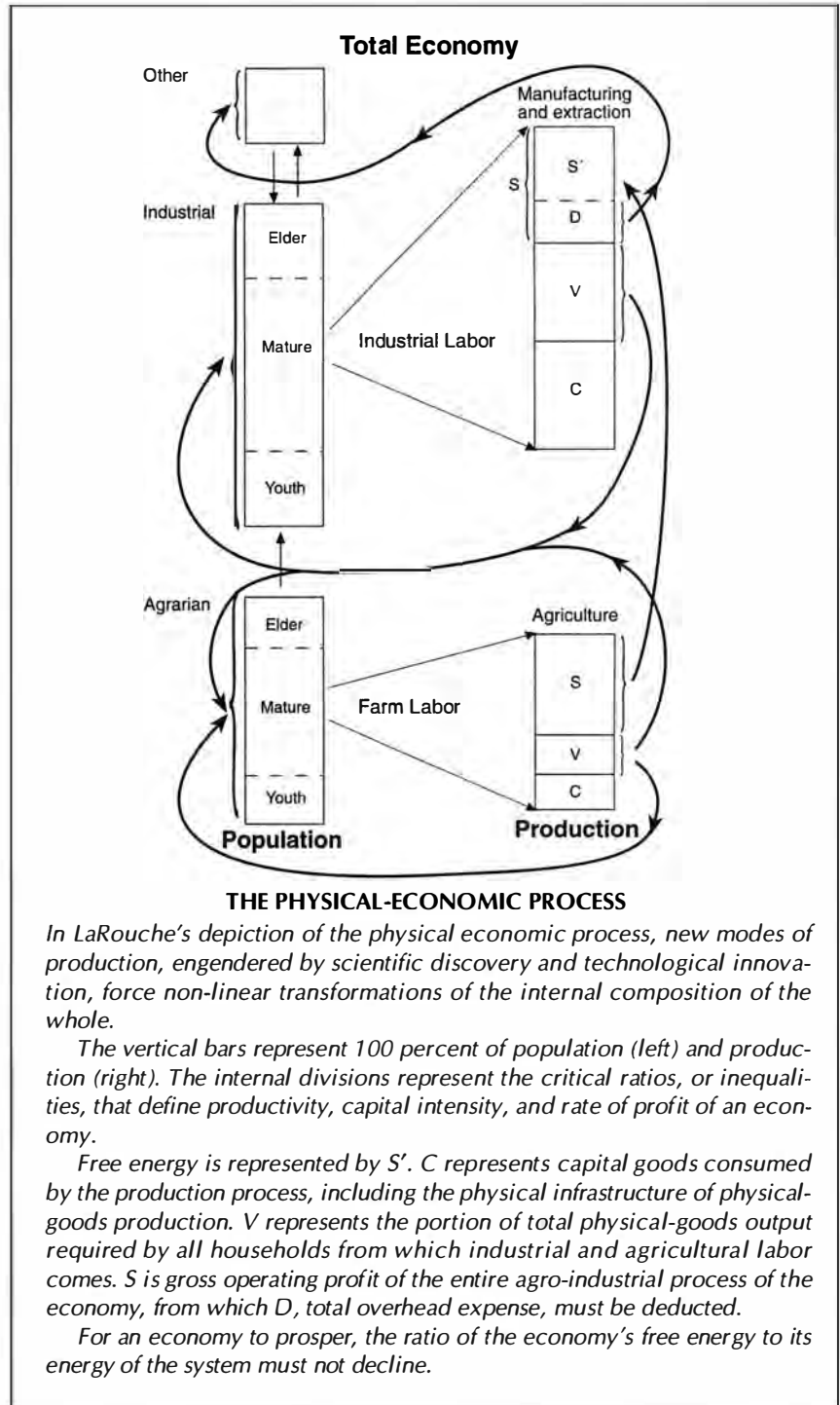
The above abstract conception of the brain continuum was revived and concretized when the theory of the vectorial biological field was established (Gurwitsch 1944). In light of this idea, the dynamic cell field spreading beyond the cell borders to extracellular space, continuously constitutes current connection between the cells, and the resulting integral field, is a single, general, indissoluble, continual whole, interspersed with "points of condensation," or maxima, which are the intracellular areas of the cell fields. [An interesting observation, respecting recent researches into AIDS dementia.] The actual integral field of brain areas is now the expression of the above abstract continuum. It has constant (invariant) characteristics, which finally are suggested to determine the general character of the individual organism, including physiological manifestations.

My own epistemological investigations into memory and the Riemannian physics of ordering of technological advances, suggests that human memory is essentially geometrically holographic, rather than "digital." We do not "recall" a particular memory, but, rather, regenerate (reconstruct) that which is presented as a recollection, holographically. This brings us to another of Lipkind's key points:

Strictly speaking, the psychic sphere, although closely related to the physiological activity of the brain cortex, does not belong to reversible processes, as do other functional activities of the cortex or any other physiological system. Indeed, irreversible psychological "maturation" continues throughout the lifetime of the individual.

From my standpoint in physical economy, Lipkind's description of Gurwitsch's concept echoes my own knowledge of the role of culture in the technological progress of society. The individual's development is shaped by culture, but the individual who contributes or otherwise distributes valid scientific-technological progress, modifies the culture of the society in that respect and degree. The individual's ability to modify the culture in this way is conditioned by the culture; the modification of the culture so effected, determines the behavior of the society thereafter.

Cultures which are transformed in a way corresponding to increase of potential population-density manifest what might



appear to be a directed series of cultural transformations, each associated within a corresponding enhancement of potential population-density. Culture defined in terms of such interaction of microcosm and macrocosm, corresponds to the unifying morphogenetic principle of Gurwitsch. Culture is to society, in this respect, what Gurwitsch's principle is to the continuum of the brain-function.

Lipkind emphasizes that the empirical study of brain functions from the vantage-point of Gurwitsch's principle must take into account two distinguishable classes of phenomena.



The first is the connection between the external stimuli and the psychic phenomena which can be designated as feelings. The second concerns the incessant stream of chaotic thoughts, which is a certain background for all the other psychic activities.² These two, evidently quite different phenomena have a common basis, which is as follows.

Analysis of both cases inevitably reveals what is designated by Gurwitsch as "the break in continuity" or "the gap in the entirety"; these are, perhaps, imperfect translations of the notion introduced by Gurwitsch in Russian in the original manuscript of *Analytical Biology*. This "break in continuity" is meant to be found while analyzing the somato-psychic and psycho-somatic chains of processes: Such a chain is considered to be continuous as soon as at least one parameter is common to both its parts. Both the "classical" point of view and Gurwitsch's own viewpoint accept as evident "the break in continuity" but differ in principle in the further analysis.

Here I introduce an important qualification. Where Lipkind writes "the gap in the entirety," I read "singularity" in the sense of Riemannian physics. Where he writes "the break in continuity," I read "discontinuity" in the sense of Dirichlet's principle of Gaussian topology, and as defined by Weierstrass: another aspect of the singularity.

One of the convenient measures of "negentropy," as I choose to define it in physical economy, is as an increase of the density of discontinuities per interval of action. The relevant Cantorian theorem, on enumerability of discontinuities within an arbitrarily small interval of action, applies; this Cantorian theorem must be read not only from the standpoint of Weierstrass, but as a proposition in Riemannian potential theory, as viewed, generated from radically constructive Gaussian synthetic geometry.

This has a simple demonstration in physical economy, where the structure of the division of labor becomes richer in singularities in correspondence to raising of the level of technology and productivity, and where the density of such singularities of process-structure diminishes under the influence of economic devolution.

The remainder of Lipkind's account of this matter, respecting Gurwitsch's work, speaks for itself. With one important exception, to be stressed next, my views are already implicitly identified above, or else the report is of such a nature that I should add no embellishments to it. There is one subsumed point, on the subject of "feeling," in which Lipkind's account oversimplifies the problems to be considered.

The Matter of 'Feeling'

The classical Greek recognizes two distinct qualities of "feeling." This is typified by the use of two different terms, "eros" and "agape," to correspond to the domain of one English term, "love." In reality, a purely contemplative form of knowledge does not exist. All thought pertaining to the quality of rational knowledge involves what are potentially extremely strong degrees of emotion. All thought is a disposition either for action, or relative inaction. It is the "feeling" aspect of thought which supplies the quality of action or inaction. The most important feature of this connection of thought to "feelings," is the proper discrimination among the two qualities of feeling available.

The woman challenges her lover, "Do you love me for my body or my mind," and should be quite sorely disappointed—sooner or later—if either option is strictly the case. "Male chauvinism" is a product of the preponderance of the former, "eros," and nothing but "agape" brings the woman's recommendation that her mate might be happier in celibacy.

A certain combination of both is required, but such that the former feeling is altogether dominated by the latter.

This issue bears most directly on Lipkind's portrayal of Gurwitsch's views, when we pose the distinction in a more universal frame of reference. The domination by a compulsion akin to "eros," is the prototype of irrational behavior, just as efficient action promptly subsumed by rational thought, is the hallmark of the rational, socially responsible personality. The relevant question, is whether the individual locates his emotional sense of personal identity more efficiently in "eros" or in "agape." This has direct bearing on reading the account of Gurwitsch's treatment of "Psychic Indeterminism." My point here, is to show that what appears a moral distinction, must also be a physiological distinction, bearing upon the self-developing continuum-principle of morphogenesis of development of the human mind.

The rational person is, first of all, a patriot, but also a "world-citizen," without there being any contradiction between the two. The mortal individual's circumstances are such, just because his mortal individual existence is a brief and fragile one, that he must depend upon his society to foster, and give meaning to the good he contributes through his life's work. He also requires, that as he, as microcosm, should be a positive factor in the relevant macrocosm, that his nation, as microcosm, finds true meaning in its contribution to the advancement of civilization. Thus, the proper policies of his nation, assure the merit of world-citizenship to the outcome of his otherwise fragile, individual existence.

To be a person for mankind's advancement, causes a shift in the sense of personal identity, from the erotic individualist, to the agapic sense of patriotism and world-citizenship. The person who retains an infantile sense of personal identity, the erotic one, will select his feeling for certain choices of action, and of personal self-development, accordingly. The same is true of the person who rises out of the infantile-erotic sense of identity, to the agapic. These are two distinct kinds of continua of morphogenetic development of the personality. As such, each must have its own peculiar physiological substrate.

"An ordered succession of higher-order phase-spaces is itself a continuous function, but one 'transfinite' with respect to each and all of the discrete manifolds associated with the successive phase-spaces."

I read the account of Gurwitsch's "psychical indeterminism," to signify that the morphogenetic process is "non-linear" in the Riemannian sense, as the notion of a "Riemann Surface," for example. This signifies, axiomatically, that no mechanistic determinism prevails, for reasons already stipulated by Riemann in his 1854 inaugural dissertation, "On the Hypothe-

ses Which Underlie Geometry." Or, as in the case of the famous 1859 paper, "On the Propagation of Plane Air Waves of Finite Magnitude," the driving of a process to its apparent discrete-manifold limit, defines a singularity which transforms the terms of statement of the continuing action relative to the discrete manifold. Both Riemann references are essentially equivalent, and are classic illustrations of truly non-linear processes.

This may be restated. The emergence of higher physical states, generates behavior which is not comprehensible, determined in terms of a discrete-manifold representation of the preceding state. This does not imply "indeterminacy" in the familiar sense of Bohr-Heisenberg, but only that higher states of discrete manifold are not comprehensible in terms of the lower ones. This seeming paradox is removed, by recognizing that an ordered succession of higher-order phase-spaces is itself a continuous function, but one "transfinite" with respect to each and all of the discrete manifolds associated with the successive phase-spaces.

In consequence of this fact of ordered states, we must shift causality from the discrete manifold to the higher domain which continuously subsumes the successive lower, discrete-manifold states. This shift in the elementary location of efficient causality demands that a corresponding shift in the location of ontological reality, away from the discrete (Cartesian or quasi-Cartesian) manifold, to the continuous, transfinite manifold. This admits of empirical demonstration, just as the Riemann Surface has empirical demonstrations.

There is nothing mystical in the notion of "vitalism" attributed to Gurwitsch. If the matter is stated in the proper terms

of Riemannian physics, the definiteness of its causal and ontological efficiency is located in the well-defined transfinite domain.

A most attractive feature of Gurwitsch's reported work deals with the nature of the kind of "memory" which guides an embryo to produce the proper form of its species. This is not a discrete memory, simply genetic-mechanical, but rather some developmental impulse within the living process which follows a least-action pathway in respect to its relationship to its own previous development and its setting. This, again, is precisely what we find in physical economy.

Conventions of language oblige us to use either such terms as "potential" and "equilibrium," or to resort to such qualifying neologisms as "meta-potential" and "meta-equilibrium.. The phenomena are more or less readily demonstrable, and their demonstration obliges us to find new, more precise terms to distinguish these phenomena. Perhaps, if we but define the proper, Keplerian-geometric meaning of the phenomenon of "negentropy," and construct our functions and experiments to reflect such Gauss-Riemann definitions of negentropy as the proper definition of a universal principle of least action, the formal representation of these conceptions were better accomplished.

Economist Lyndon H. LaRouche, Jr., is a member of the scientific advisory board of 21st Century.

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SPIRAL EDDIES

The Discovery That Changed the Face Of the Oceans

by Dr. Robert E. Stevenson

The ocean's surface is a vast, nonlinear array of spiral eddies, which defies all attempts at modelling by averaging techniques. Here, America's pioneer space oceanographer tells how the Skylab and Shuttle observations revolutionized our knowledge of the oceans.



We've just seen the biggest oil slick you could possibly imagine—off the coast of Argentina. It has spectacular iridescent colors in the Sun's reflection, and there are eddies and all kinds of meanders. It must be at least 1,500 miles long—it extends as far as we can see.
—Skylab-4, November 1973

This observation, which appeared in Johnson Space Center's weekly "Skylab Updates," in early November 1973, was transmitted by the crew of Skylab-4. The astronauts had obviously observed a massive bloom of phytoplankton in the Falkland Current—a conclusion shortly made by the Skylab crew, Cols. Gerald Carr and William Pogue, and Dr. Edward Gibson. It was the first major plankton bloom observed from space, it lasted continuously throughout the 84-day mission, and it gave the first verification of shearing eddies along a current boundary.

◀A low-oblique photograph taken by Capt. Robert "Hoot" Gibson, Spacecraft Commander of the Endeavor, looking northwest across the western Black Sea, toward Turkey and the Bosphorus. This spiral-eddy field was in that location throughout the mission, and was caught in several photos over three days, although individual eddies could not be identified one day to the next. There is no explanation for the absence of eddies in the waters east and northeast from the Black Sea mouth of the Bosphorus.

The observations of "eddies" in the Falkland Current so impressed the Skylab-4 crew, that in December 1973, Col. Carr transmitted an "oceanography lecture" from Skylab. Featuring real-time views of the bright chartreuse Falkland Current, with its meanders and eddies, the lecture provided evidence of the creation and extent of current-boundary eddies.

This "breakthrough" information piqued the interest of two Navy oceanographers, Paul Scully-Power and me, both of whom were involved in attempting to unscramble unusual acoustic signals from underwater and mobile acoustic surveillance platforms. If there were eddies routinely "spun-off" along the edges of major ocean currents, the solution of these questionable signals would be obvious.

While Skylab was still in orbit, a long-ranged U.S. Navy *Orion* aircraft was flown from Jacksonville, Florida, to the western Caribbean Sea. Flying on the western boundary of the major Caribbean Current, the air crew dropped expendable temperature probes along a prescribed track beneath the orbiting space station. From the temperature data, and from space, it was clear that eddies were being spawned from the current's edge.

The solution for the unusual acoustic signals was evident. Of greater importance, however, was the probability that eddies were formed along the shearing boundaries of every significant ocean current around the world! My paper, published shortly thereafter, in 1974, expressed that concept.

THE OCEAN EFFORT DURING THE APOLLO-SOYUZ TEST PROJECT

The concept that eddies, with diameters up to 100 kilometers, were being created continuously along the edges of ocean currents greatly intrigued the Navy's oceanographic and acoustic communities. As a result, the oceanographic support program for the Apollo-Soyuz Test Project was large. We selected four significant ocean sites, and the Apollo flight crew was trained thoroughly for the observations, as were the crews of ships and aircraft from the U.S. Navy, the Royal Air Force, the Royal Australian Navy, and the New Zealand Defense Establishment.

Although extraordinary data were obtained, the clear "breakthrough" came from the magnetic tapes of infrared imagery provided by the meteorologist aboard the *U.S.S. Kennedy*, transmitted from the Defense Meteorology Satellite (a U.S. Air Force system).

The *Kennedy* was in the Mediterranean Sea at the time, and taped the imagery that covered the sea from Italy out into the eastern Atlantic Ocean. The satellite center aboard the aircraft carrier did not have the capability of resolving imagery from the Defense Meteorology Satellite's infrared sensors. For that reason, the tapes were sent to the new satellite-receiving facility of the Navy Weather Service, at North Island, San Diego. There, Chief Petty Officer Robert Writner prepared, for the first time in history, thermal infrared images of the sea's surface; in particular, the sea surface west and east of the Strait of

Gibraltar. These images not only fit perfectly with the photography of the Gulf of Cadiz, taken by Brig. Gen. Tom Stafford, Apollo commander, but also provided the first ever information of eddies in the western Mediterranean Sea. (The images, and the accompanying data, were published in my *Huelva Front and Antipodal Seas* papers, 1977, 1979.)

Knowledge of Eddies Proliferates:

During those winter months of 1974-1975, the images were brought to the attention of Dr. Robert "Buzz" Bernstein at the Scripps Institution of Oceanography. Buzz was working on the intra-annual and inter-annual variability of the California Current, and it seemed logical that he should obtain infrared imagery of those waters off the western United States. The USAF Space Division agreed, and gave permission to the Navy's North Island Facility to provide Buzz with imagery whenever possible.

Observing Sea-Surface Dynamics

The Sun's reflection from the surface of the sea, referred to as "Sun glitter," has proven to be the most valuable tool in the visual observations of the ocean from space. Not only can the fine details of near-shore turbulence be examined, but Sun glitter is the only method by which dynamics in the open ocean and around islands can be observed.

In the golden center of the Sun's reflection, a smooth sea surface reflects brighter than a sea roughened by waves. The Sun is reflecting directly to the observer, or into a camera's lens, as it would from a mirror. This is known as "forward reflection" and permits the scenes with which we've all become familiar.

Sea slicks, either caused by surfactants or by the water moving with the wind, reflect brightly, whereas water flowing against the wind, resulting in choppy waves on the sea's surface, has a diffuse, dull reflection. Not only are these reflective differences easily seen, but they photograph well. They are also the means by which weather satellite scanners and space-borne synthetic-aperture radar image the movements in the surface ocean.

On the edge of the Sun's reflection, the golden colors change to blues. In this part of the glitter pattern, smooth water has a dark color and the roughened water has a light blue cast. The glare into the lens (of both the eye and the camera), is far less on the edge of the reflection than in the very center. As a result, fine details of the sea surface turbulence, sometimes lost in the central glare, are best observed on the edge of the reflection field.

It was soon apparent that the California Current was far more complicated than anyone had previously imagined. Furthermore, it seemed to Buzz and me that there were eddies in the eastern Pacific Ocean out to the Hawaiian Islands—as far as the imaged “view” from the Defense Meteorology Satellite reached from the “line-of-sight” transmission to North Island. It was important, however, that other physical oceanographers be aware of what we perceived, especially those who were facile in the field of oceanographic theory.

At a “brown-bag” lunch meeting at Scripps in February 1976, Buzz Bernstein made an informal presentation, with illustrations and ocean data, concluding with the comments that: “Mesoscale eddies, 100 to 150 km in diameter, appear to cover major areas of the oceans. These are distinctly different from the ‘pinched-off’ rings coming from the Gulf Stream and the Kuroshio Current off Japan.”

There were more than a few moments of silence. Buzz had made a rather staggering suggestion. Finally, Dr. Walter Munk, who had been at Scripps since 1940, and who was the scientist to whom we, and everyone in the oceanographic community, looked for “yes or no,” rose, folded his lunch bag, and remarked: “I don’t think that can really be the case. After all, if there were so many eddies, there’d never be any hope of modelling the ocean.”

(In that regard, Munk was perfectly correct. Even though General Circulation Models, GCMs, have improved by a few orders of magnitude in the past 20 years, for many reasons there is yet to appear a practical, predictive model. There are eddies, of scales from the “meso”—100 to 150 km—to the “sub-meso”—less than 50 km—in diameter. None are linear, and even trying to bypass them with Fourier transforms has not been satisfactory.)

The next week, I received a call from Walter Munk asking me to bring some of the space photos showing eddies for him to see. I quickly ascertained that Buzz had also been asked to bring his imagery, so we went together, that afternoon. Walter examined all of the photos and imagery, thoroughly, without a word. Then, leaning back from his desk, Munk asked, “Can you leave these with me for a few days?” We left them all with him, along with reprints of papers we had individually published.

As was—and still is—usual with Munk, there was no response, for some months. We just hoped that he was macerating eddies.

I don’t want to leave the impression that in the spring of 1976, Scully-Power, Bernstein, and I were standing alone against an army of non-eddyites. There were at least a dozen

practicing, descriptive oceanographers, about half that many theoreticians, and several dozen cadre of surveillance acousticians who were rather sure that ocean eddies, with diameters of several tens of kilometers, were more common than not. Each of us was becoming unacceptable to the modellers; particularly to those modellers at Princeton, Yale, and the Massachusetts Institute of Technology. After all, the data-point intervals of the models in those days were too far apart to do more than intersect an unknown eddy, which helped only to screw-up the computer run.



Dr. Walter Munk (left) and Rear Admiral J. Bradford Mooney at the Scripps Institution of Oceanography in July 1985. Munk was director of the Institute of Geophysics and Planetary Physics at the University of California at San Diego, and Mooney was Oceanographer of the Navy. Both are now retired, but remain active in ocean affairs.

Also, through an intelligence “back door,” we learned that open-ocean eddies were a “hot topic” among key oceanographers in the Soviet Union, under the leadership of Dr. Konstantin Fedorov, a pragmatic, inventive, and quite demanding physical oceanographer, who was the new director of the Space Oceanography Division, Soviet Academy of Sciences. Within the circle of our Navy oceanographers, there was the belief that Fedorov had learned about current-shearing eddies well ahead of us, and that the information was already in tactical use by Soviet submarines. Because we knew Federov to be

both ingenious and purposeful, we were not surprised that he was able to convince the Soviet Fleet; he was a strong, convincing person. From our point of view, the necessity of continuing our research was unquestionable.

(I learned, some 12 years later, that Konstantin was my second cousin, a grand-aunt of mine having married his grandfather.)

In early summer 1976, probably about mid-June, Munk announced that he would give an informal seminar at the Institute of Geophysics and Planetary Physics (IGPP) at Scripps, which he directed, in the large classroom, overhanging the coastal ocean of La Jolla. He indicated that he would offer some of his thoughts that he planned to report to the Joint Oceanographic Assembly in Edinburgh, Scotland, that coming August.

I need to set the stage a bit. Beginning in 1959, the Scientific Committee for Ocean Research of the Intergovernmental Oceanic Commission, had initiated Joint (that is, international) Oceanographic Assemblies to permit marine scientists to communicate with each other more directly, and more often, than in the past. Remember, at that time, communication satellites, E-mail, and facsimile machines were but dreams, and commercial jet-aircraft were yet to be in routine operation. There had been joint assemblies in New York, Moscow, and Halifax. Now was the propitious time for Edinburgh: The occasion would commemorate the 100th anniversary of the

Surfactant Films on the Ocean

Surfactant (natural) films are formed by hydrocarbons, fatty acids, aliphatic alcohols, ethers, and the like, which are produced by the decomposition of marine organisms. Carbohydrates and polypeptides also occur, but they are rather soluble in water and play little part in the formation of surfactants. Petroleum products, mainly in coastal waters, form films, but these differ greatly from natural oil films.

Under ideal conditions, when a small quantity of a chemically pure, nonvolatile, insoluble material is placed on a water surface, it either remains as a compact drop or spreads over the surface. A prerequisite for spreading is that the material's molecules have a greater attraction to water than to each other.

In spreading, the largest possible number of molecules tend to come in contact with the water. If the area of the surface allows it, a film that is one molecule thick (a monomolecular layer), is formed.

In real conditions, surface films are mixtures of different surfactants. They do not spread into monomolecular layers; instead, their thicknesses are on the order of several molecular diameters. Most of the organic films formed at sea are of substances that have extremely similar chemical composition, however, so their spreading action is close to that of the ideal material.

For this discussion, it is sufficient to note that surfactant films are formed only when tangential cohesion is great. The film molecules stick together in large, condensed formations, usually liquid and capable, therefore, of flowing freely over the surface of the water.

Perhaps the most obvious, and significant, manifestation of surfactant films on the ocean is the tendency toward extinction of capillary waves. The films not only dampen existing surface waves, but hinder wave generation. As John Miles, University of California at San Diego, pointed out 35 years ago, "a sufficiently inelastic surfactant film would result in an order of magnitude increase in the minimum wind speed necessary to generate waves." On the natural sea, however, films are usually torn apart by winds blowing at 5 to 7 m/sec.

The Visible Effects of Surfactants

Now, what do surfactants do for us observers?

The effect the surfactant film has on air-sea interaction is of most significance to remote sensing, or viewing, of the ocean from space. In addition to diminishing the response of the sea surface to the energy transfer from the wind, a film retards evaporation. In so doing, the micro-convection at the air-sea interface is either prevented, or reduced, preventing the formation of the cold thermal film that extends, in theory, to a depth of a few centimeters.

Were this the only effect of the film, a thermal infrared measurement of the sea surface would indicate a warmer than actual water temperature. But, the film also reduces the thermal emissivity from the surface, to the extent that a thermal infrared measurement is usually much less than

normal, so that it is a good indicator of the presence of the film itself.

It is in the visible and microwave portions of the electromagnetic spectrum, however, where films have the greatest influence on remote sensing of the ocean from space platforms. The optical effect of surfactant films is caused by the reduction of the capillary waves. From such a smoothed surface, the reflected light tends to be more elliptically polarized than flat. When viewed by eyeball, or in a photograph, slicks will appear bright in the center of the Sun's glitter, therefore, and darker than the surrounding water on the edge.

The extinction of the capillaries, and the corresponding decrease in surface roughness, lead to a decrease in the unit cross section of scattering, as measured in the microwave. This is because in resonant scattering, the scattering cross section in the direction of the receiver is proportional to the surface wave spectrum. Surfactant films enhance synthetic aperture radar images, but seriously limit the precision of microwave determinations of wind speed over the ocean.

Petroleum and Oil Films

In contrast to surfactant films, oil and petroleum films never spread down to a monomolecular layer. Instead, their thicknesses exceed molecular diameters by an order of magnitude. On the ocean, these oils may exist in the form of thick films, "ropes," "tar balls," or in emulsified (suspended) layers.

If petroleum products in the ocean were a significant fraction of natural surfactants, the pollution problem would be catastrophic. But, they are not! The best estimate is that about 0.25 percent of the annual production of 10 million tons of petroleum products end up in the open ocean. The greatest contribution is from tankers flushing their tanks, and passenger ships and freighters draining water ballast from their fuel tanks.

In coastal waters into which rivers discharge, the situation is quite different. The volume of petroleum products carried by rivers is more than three times the amount contributed by all ships, including accidental spills from tankers. These man-made materials are dumped from industrial plants, oil refineries and storage systems, as might be expected. The largest amount, however—double that from all ship disasters—comes from gasoline stations dumping into municipal sewage networks.

Other than confined arms of the sea, such as the Persian Gulf, coastal embayments, estuaries and their contiguous lagoons, and open coastlines where shipping disasters temporarily pollute the nearshore waters, petroleum oils are not significant in developing widespread surface films. Although they have measurable impacts on the water qualities in such areas and, therefore, do create difficult removal problems, oil films have a minimal influence on the sea-surface emissivity. The presence of films from petroleum products are of little concern in applying the various remote-sensing techniques to the ocean.

return of the *HMS Challenger* from its 3.5-year, world-circling oceanographic expedition. That monumental cruise had been the beginning of the field of "oceanography," and, as the return port had been Edinburgh, what better place for the anniversary celebration?

Everyone would be there—no one could possibly miss the occasion. All fields of oceanography would be represented, in the many and large classrooms of the university. For each field, the present-day "leader" would be the keynote speaker, presenting the totality of our oceanographic knowledge after 100 years of research. Walter Munk was scheduled to give the opening address to the physical oceanographers.

There were some of us who were looking beyond Dr. Munk's speech. Fedorov would be there, and would be elected the President of the Scientific Committee for Ocean Research. Maybe we could ply him with enough Guinesses to learn some details of the Soviet eddy studies (Although Fedorov did drink well after his election, he adamantly declined to discuss eddies.)

Now, back to June 1976, when Munk addressed about 50 oceanographers at Scripps. Munk began by expressing his appreciation to Buzz Bernstein and the Navy for providing the infrared imagery of sea-surface temperatures. He had also seen the photographs from Skylab and the Apollo-Soyuz Test Project, "that Bob Stevenson has been able to obtain." After going through a descriptive and theoretical "maze" of the upper layers of the ocean, Munk finally got to his punch line:

I really think it is becoming rather clear, you see.

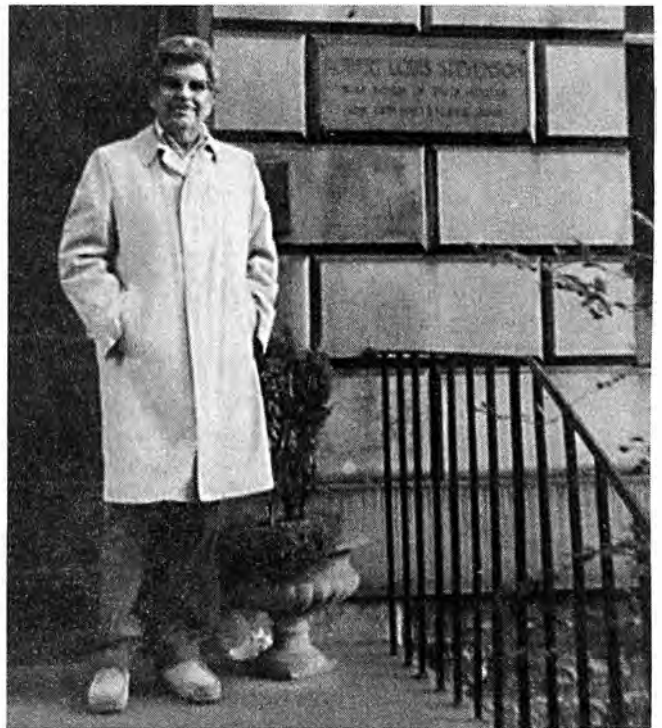
There are surely a lot of eddies in the ocean; more than just the rings pinching off the major currents. I think they probably represent a major part of motion in the near-surface ocean.

Walter then concluded, seemingly apologetically, "You know, I must tell this to all of the people in Edinburgh." Coffee-break time that afternoon was not quiet!

Edinburgh University, Aug. 10, 1976, 0805 Hrs

In the huge, banked auditorium, 600-plus oceanographers and guests sat crowded cheek-to-cheek. Dr. Walter Munk had been introduced and the clapping had subsided. In the last row, high above the room, I sat along with Buzz Bernstein, Paul Scully-Power, Dr. Denny Kirwan (former Navy oceanographer, now at Texas A&M), and Joe Reid (from Scripps). We all knew, basically, what was coming, and we were smiling, despite the early hour, as we looked over the crowd. You see, ever since the *Challenger* returned 100 years earlier, with new, profound information on the majestic ocean currents flowing through the world's oceans, and the flow of cold, dense water masses through the ocean deeps, the principal calculation of the kinetic energy of the ocean had been from measuring these grand motions. Most of the study of the physical ocean in the preceding century had centered around these ponderously moving masses of water.

Walter, with a tweed sports coat, worn over a wool sweater, and his usual khaki pants, had stepped to the side of the podium and leaned on it, slowly crossing his legs. (Denny chuckled, "He's in his pontificating stance. It's going to be good.")



The author in Edinburgh, June 1976, for the Joint Oceanographic Assembly, visiting the birthplace of Robert Louis Stevenson.

Smiling, looking over the assembled audience, first to the left, then to the right, with microphone in hand, Munk began:

Good morning, ladies and gentlemen. It is a great honor for me to be here today as we celebrate the 100th Anniversary of the *Challenger* Expedition. I have been reviewing the state-of-our knowledge about the ocean rather thoroughly over the past several months. To do this, I've had the support of many colleagues from around the world.

I want to start by telling you that it is now clear that 99 percent of the kinetic energy in the ocean is bound up in mesoscale eddies.

Munk stopped talking, as the shock of his statement began to register among the large audience. When the murmurs quieted, Walter went on: "Gentlemen, for the past 100 years, we have been dealing with a 1 percent problem!" Six hundred oceanographers sat bolt upright. Five of them, in the uppermost row of the auditorium, were grinning broadly, and shaking hands.

Munk could have said, then "Thank you, ladies and gentlemen," and departed the platform. He'd given the bottom line, shaken 600 of the world's leading oceanographers, and made his point. But, that was not his way. So, for the rest of the hour, Munk presented his data and analyses to the assembly in his inimitably thorough fashion.

The study of the world's oceans and seas would never again be the same. Munk's determination of the dynamics of the oceans was as much a watershed in oceanography as plate tectonics was to the fields of geology and solid-Earth geophysics.



NASA

Solitons, one of the other ocean phenomena first imaged from space, here in the Strait of Gibraltar, photographed by Dr. Paul Scully-Power from 190 nautical miles, with a 70-mm modified Hasselblad camera and a 60-mm lens. These solitary wave groups travel at speeds up to 10 km/hour, maintaining their form and integrity for hundreds of kilometers.

Remember, too, that at that time, no one knew of the occurrence, or even of the existence, of spiral eddies. Knowing today that these strange, ever-present, cyclonically spiralling waters occur in all oceans, we must consider the obvious: They represent a significant portion of the kinetic energy in Walter Munk's "eddies." Without question, therefore, to understand the dynamics of the upper ocean, it is essential that we understand the inherent characteristics of spiral eddies.

THE NONLINEAR SPIRAL EDDY SAGA

Of all the ocean features discovered by observations and photography from the Space Shuttle, spiral eddies in the open

ocean are the most surprising and of greatest importance to oceanography. Not only were they unknown prior to the "breakthrough" observations in 1973; they were not even suspected! Today, we know that spiral eddies are ubiquitous in the world's oceans.

Of course, the oceanographic literature was full of reports of spiralling whirlpools in straits, in entrances to bays, or streaming from islands or the submerged irregularities of a shallow sea floor. Those in the Strait of Messina between Scylla and Charybdis not only are well known from historical accounts, but their oceanography was described in detail by Albert Defant in 1940. And, in the 1980s, they were examined in detail by Dr. W. Alpers from some spectacular SEASAT (Oceanographic Satellite) imagery.

There is also Edgar Allan Poe's "Maelstrom" off Norway's Lofoten Islands, and the less famous, but equally impressive, "Old Sow" in the Bay of Fundy, between New Brunswick and Nova Scotia. The Bay of Fundy, owing to its shape and length, experiences the greatest tide range of any coast in the world. As the tide floods, the "Old Sow" whirls and foams with a malicious rumbling from which it gets its name. As Poe claimed for the Maelstrom, the "Old Sow" alternately engulfs and disgorges tree trunks, remnants of piers, and even boats, as it churns and roars. A cyclonic rotation, similar to, but far less intense than that in the Bay of Fundy, is formed from the large tidal exchange in the northern Gulf of California. It is known well to the Mexican fisherman in those waters, and has been observed and photographed from space.

All of the "whirlpools" and spiralling waters documented before 1981, however, are in narrow straits or passes. There the ebbing and flooding tides produce a large exchange of water through the confined channels, resulting in fast currents and extreme turbulence from the interaction with shore and bottom irregularities. Indeed, such features are so well known in oceanographic literature that the first spiral eddies observed from the Space Shuttle were thought to be formed from coastal and island interactions with local currents.

Then came the observations and photographs of spirals in the open ocean, and it was a "whole new ball game."

The Events of Discovery

It's worthwhile to recapitulate the events that led to the realization that spiral eddies in the open ocean are significant to oceanography; albeit, a surprise. It is strictly a story of observations by Shuttle astronauts.

In 1980, I was preparing an oceanographic primer for the U.S. Fleet units deployed in the Arabian Sea. The basic information available was infrared images from data taped aboard the National Oceanographic and Atmospheric Administration's meteorological satellites and prepared at the Scripps Satellite Facility in La Jolla. The data were "stretched" as much as possible to permit the best analysis of the relative temperature gradients across thermal boundaries, especially in the waters near the Arabian peninsula and in the Gulf of Oman. From the enhanced images, relative temperature differences of 0.1°C were apparent when the atmosphere was "moisture free"; mainly in the late fall, winter, and early spring.

During those months, an eddy appeared repeatedly in the Gulf of Oman, with rings representing temperature differences of 0.1°C . There was no rationale for the gulf waters, or any water for that matter, to be chopped into vertical slices of 0.1°C . The likely explanation was that the rings were from the changes in emissivity of the sea's surface caused by slicks. That was exactly the scene that Capt. John Young

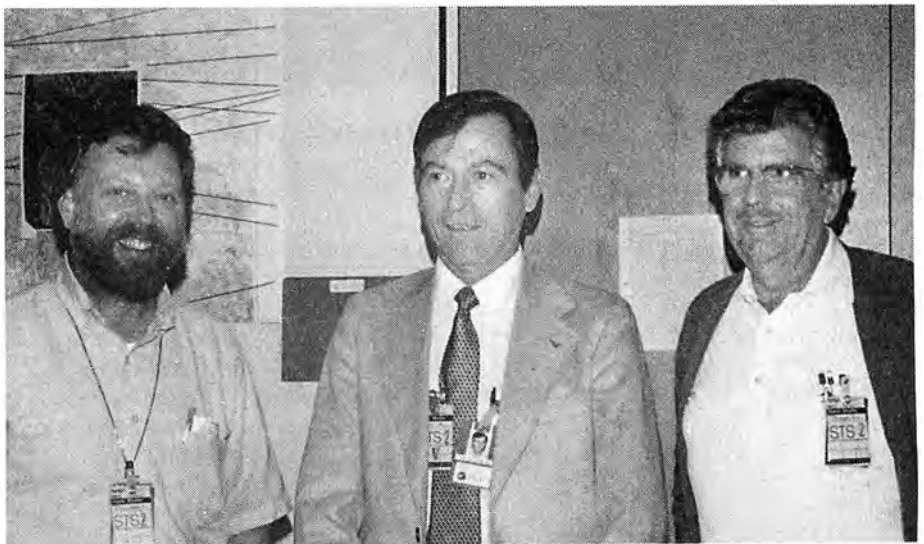
saw and photographed as the *Columbia* orbited down the Gulf of Oman in April 1981.

Although it was of some interest to confirm the thought that slicks were the tracers of the Oman Eddy, and were responding in the infrared, the existence of an eddy there was considered a natural reaction to the currents and shoreline configuration.

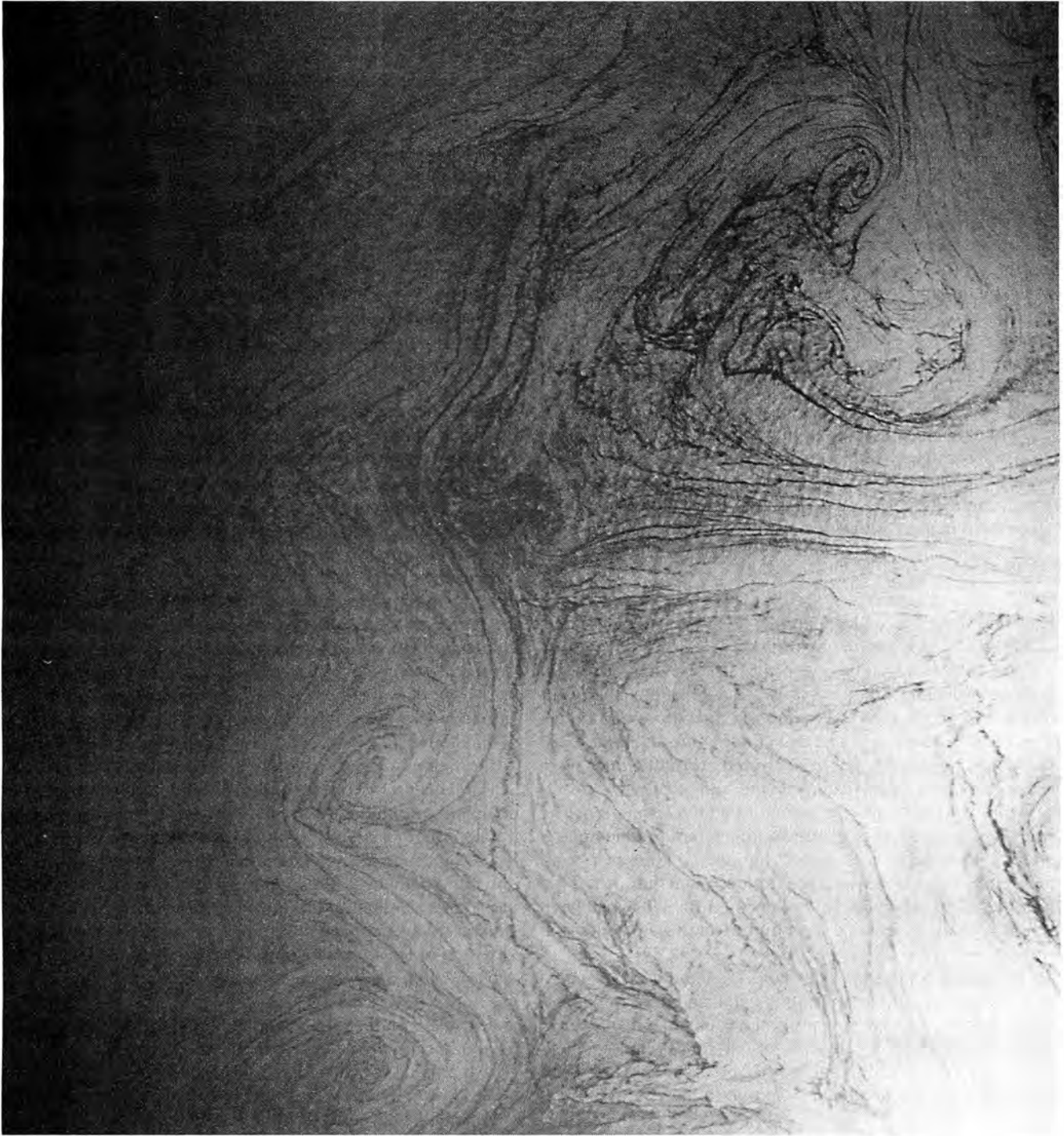
On its second flight in November 1981, the *Columbia* had a modified SEASAT, called SIR-A (Shuttle Imaging Radar-A, the first flown in the Shuttle), in the cargo bay. Designed as a geological experiment, with few ocean areas scheduled for radar imaging, the SIR-A plan was scrapped when problems with the Shuttle's systems required that the time on orbit be reduced from five to two and a half days. To get as much imagery as possible, the SIR-A was operated on lengthy passes, with the result that more imagery of the ocean was acquired than that of land.

Most of the ocean imaged was "flat," there being thousands of miles of sea surface that did not even exhibit ocean swell. But, in the Caribbean Sea, just north of Aruba, and in the channel between Cuba and the Bahamas, near Squaw Island, the SIR-A imaged spiral eddies. Both were about 15 km in diameter, and the one off Aruba had several slicks (dark on the radar image) rotating into a smooth central core. A lot of dark blobs on the image were interpreted as bilge dumps from ships heading towards Maracaibo, especially three in a line behind an obvious ship. It was logical to assume therefore, that there was plenty of oil around to help form the slicks in the eddy. And, as the eddy was so close to Aruba, the best guess was that it had probably spun off from the island.

An island eddy was also the likely origin of the eddy near Squaw Island, but the SIR-A image provided some intriguing information not seen before. Two stern ship wakes crossed the eddy. That part of the wake meeting an eddy slick was bent toward the center of the eddy, as if the slick was moving at a higher speed than the surrounding water. (That confirmed



Paul Scully-Power (left) and the author (right) with Capt. John W. Young, head of the Astronaut Office, at Mission Control, Johnson Space Center in November 1981, during the flight of STS-2.



NASA

The sea surface in the southwestern Indian Ocean, Sept. 2, 1983. This is the view noted by Capt. Richard Truly, showing well the clockwise rotation of the spiral eddies in the Southern Hemisphere. The long interlinking sea-surface slicks represent the flowing lines in the near-surface ocean as the waters flow in and out of the spirals. Capt. Truly's observations and his series of photos gave us the first firm indication that spiral eddies were influenced by the Earth's Coriolis effect.

some aerial observations made by Stevenson off southern California, of ship wakes crossing the streamlines of eddies spinning off Catalina Island.)

The SIR-A images were certainly interesting. Ocean features, including refracting swell and internal waves, could be studied from L-band (2-meter wavelength) radar images. But, unless ed-

dies in island wakes piqued your senses, the isolated spirals caught by the SIR-A were not going to create much of a stir.

Shuttle Flights STS-7 and 8

The emphasis of the oceanographic observations from STS-7, in June 1983, was placed on the tropical Pacific Ocean, from

Hawaii to the Equator, because of the effects a strong El Niño event was having on those waters. Spiral eddies were part of the crew's pre-flight briefings, but no more so than were the internal waves that could be expected around the borders of the South China Sea.

Photography and observations from the Pacific were great, and as expected. But, from the Indian Ocean, south of the Equator, came the spectacular "breakthrough" observation! Dr. Sally Ride and Col. John Fabian saw and quickly photographed two sets of spiral eddies, rotating cyclonically, clockwise! Although isolated, with no apparent interconnecting streamlines, the eddies were 1,000 kilometers from the nearest land, and in water depths approaching 7,000 meters. There was no chance of any topographic influence on their origin. They were clearly dynamic features of the open ocean and, furthermore, their cyclonic rotation indicated a response to the Earth's Coriolis effect!

I'm looking at the most complexed ocean you can possibly imagine. Tell those oceanographers that there are eddies just as far as we can see—all along the flight path in the Indian Ocean. They are all spiral eddies—we see them in the Tasman Sea and over in the Pacific east of New Zealand, too.

("Those oceanographers," Scully-Power and I, were then in England for the Navy. We learned the "news" in a telephone call from Mission Control in Houston.)

Capt. Dick Truly, commander of STS-8, in August 1983, reported to Mission Control in Houston later that the field of eddies was seen through the remaining three days of the mission. He said also that "as far as I can see" meant about 1,500 kilometers. It was the first indication that spiral eddies were not isolated, individual features in the surface ocean.

STS-8 was the first night launch of a Shuttle mission. The spacecraft would be over the southern Indian Ocean near midday, local time, with perfect lighting conditions to view the ocean. Everyone was eager to learn whether or not the sightings of spiral eddies in that ocean from STS-7 had been simply a chance view of a few short-lived, isolated eddies. It was not!

Throughout the last five days of STS-8, the crew observed and photographed a tremendous expanse of complex, spiralling turbulence. Covering the entire southern Indian Ocean, at latitudes north of about 30°S, spiral eddies rotating clockwise were connected to each other by long, parallel slicks (streamlines) with lengths of from two to three eddy-diameters.

The observations from STS-8 were as startling as those from STS-7. Not only were spirals reacting dynamically to the effects of Coriolis, but they could occur in huge fields of interconnecting eddies as well as single, isolated features. These observations stimulated a lot of computer time at NUSC (the Navy Underwater Systems Center), in Newport, in an attempt to fit interconnected spiral eddies with diameters of 15 to 20 kilometers into nonlinear equations; there was little success.

An Oceanographer's Observations from Orbit

Scully-Power reported from the flight deck during Shuttle mission 41-G to me in Mission Control, October 1984:

There are interconnected spiral eddies from one end of the Mediterranean to the other. They've been there every day of the mission. I've also seen them in many other parts of the ocean—on the edge of the Gulf Stream, in the South Atlantic, and off California and Mexico.

This was the first information that spiral eddies occur in more than one area of the ocean at the same time, and that they persist in those parts of the sea for at least a week.

Even though observations of spirals scattered through various ocean areas had come from the missions following STS-8, it was from Scully-Power that the next significant views were obtained. As the first oceanographer to fly in space, it was planned that he observe, catalog, and document the eddies in as many parts of the ocean as possible. The effort turned out to be a spectacular.

The entire Mediterranean Sea was covered with interconnecting spiral eddies throughout the mission. Similar eddy sequences, but covering lesser ocean areas than those in the Mediterranean, were observed along the north wall of the Gulf Stream, off the coast of Brazil, off southern California, and west of Mexico. In each area, the eddies were associated with possible shears, either along a coastline or the boundary of a major current.

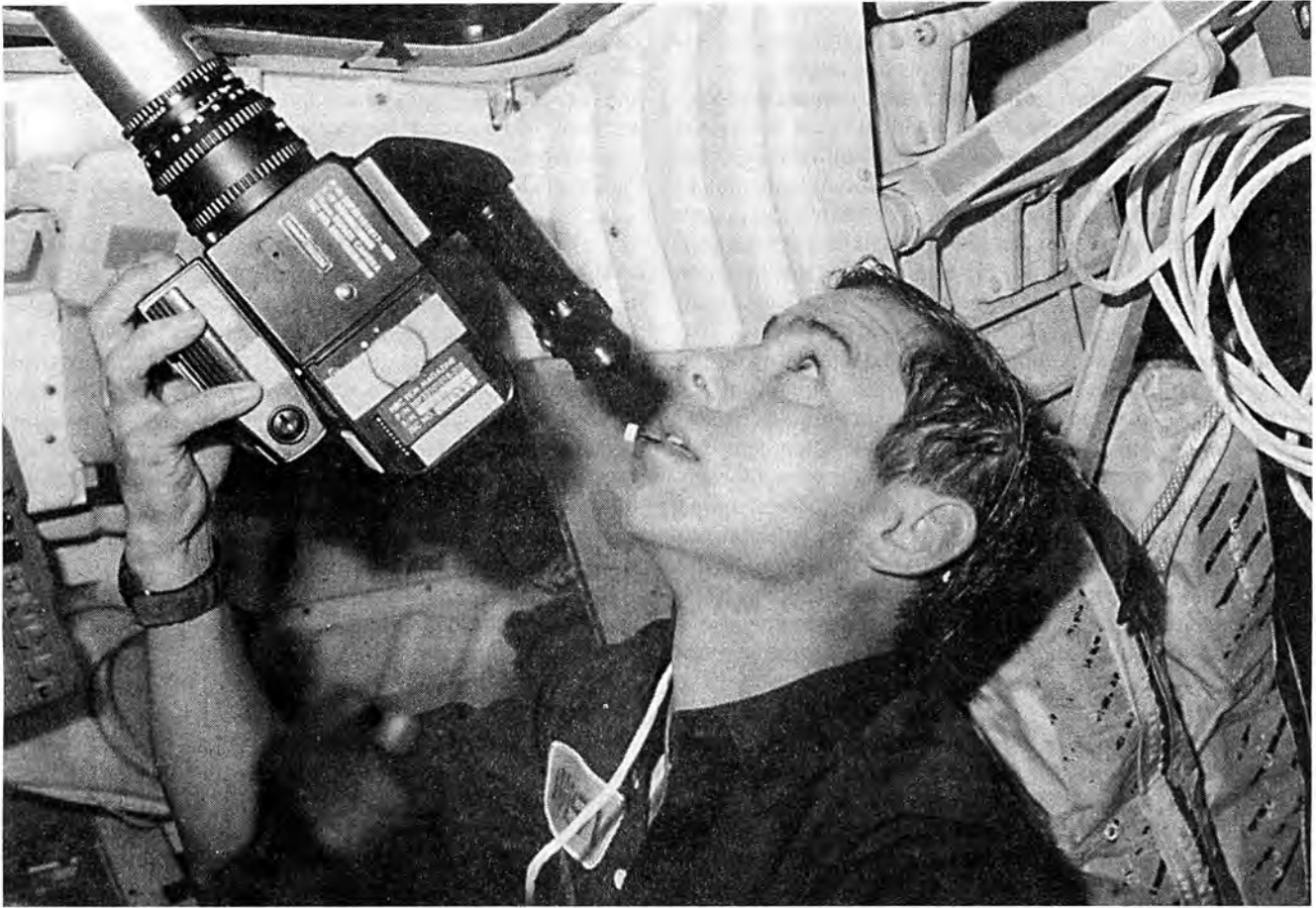
It seemed likely from these observations that the prime generating forces were strong horizontal shears, along coasts in marginal seas, and along currents in the open ocean. Spiral eddies probably exist, we concluded, in all seas where such shears take place. Furthermore, it was quite clear that surfactants (see box, page 60) spread over great areas of the sea's surface were essential to observations either visually or by L-band SAR.

From Scully-Power's cogent efforts, it was clear, too, that surfactants on the ocean surface were far more widespread than had been hitherto suspected. Consequently, microplanktonic and other marine biologic activity in the near-surface oceans must be greater than previously estimated. As a result, the Office of Naval Research initiated a substantial research program on biological productivity. And, the computers at the Newport laboratory of NUSC were continuously in use, addressing of the theory of spiral eddy dynamics. (No, to this day, in 1998, there has yet to be a suitable solution.)

I yelled for the pilot to get up here [from the Shuttle's mid-deck to flight deck] and grab the other camera. It was a fantastic sight—they just popped up suddenly—we'd been flying over a pretty flat, cloud-scattered North Atlantic—I never expected to see such a huge plankton bloom that far north.

This is from the post-flight discussion with the commander and pilot (Cols. Bob Overmyer and Dick Gregory) of Shuttle mission 61-B as they described the 400-kilometer patch of a brilliant plankton bloom, swirling in a spiral-eddy field at 45°N in the mid-Atlantic Ocean. It was the first observation of a major plankton bloom at such a northern latitude, and in the Gulf Stream Extension.

It was almost as if you could "see" the Mozambique Current roaring through the *venturi*, the restricted



NASA

Col. Brewster Shaw, USAF pilot of the STS-9, in November-December 1983, using a "space-modified" Hasselblad 70 mm-format camera, observing the Earth through the overhead window of Columbia's flight deck. Shaw retired from NASA after commanding four Shuttle missions, and now works for the United Space Alliance as head of Shuttle operations.

channel between Madagascar and the coast of Africa. There were some eddies to the north and a lot more south of the island. In the channel, though, the eddies were separated by long streamlines. I was surprised to see any eddies there at all.

This perceptive observation, by the commander (Col. Gordon Fullerton) of Shuttle mission 51-F, provided previously unknown information on the hydrodynamics of spiral eddies in currents flooding through broad channels.

Through the spring of 1985, we were comfortable with the concept of spirals forming along major vertical shears in the ocean. My paper describing our knowledge at that time, was finally published in early 1985. It was the first scientific report in which photographs and a discussion of the eddies were presented, and it concentrated on the observations made from STS-7 and STS-8. Later in 1985, Scully-Power's report of his observations from 41-G was published and distributed widely throughout NASA, the U.S. Navy, the Royal Navy, and all the large oceanographic institutions in the country.

Great enthusiasm came from both the Secretary of the Navy and Chief of Naval Operations. At their suggestion, Scully-Power went on to brief the NASA Administrator, the White House Science Advisor, the Chief of the CIA and his top staff,

various units of the Atlantic Fleet, and oceanographers at Woods Hole, Scripps, and other marine institutions. In the meantime, I was briefing the Commander of Naval Air Forces Pacific and his staff, the Commander of Submarine Forces Pacific, the Naval Oceanographic Center Pearl Harbor, the Anit-Submarine Warfare Air Wings Pacific, and pertinent personnel at the Naval Ocean Systems Center, San Diego.

Then Came the Eager Astronaut Observers

Not excluded from all of this excitement were the astronaut crews preparing for missions in 1985 and 1986, and all of the astronauts in the corps.

The idea that spiral eddies were restricted to those ocean areas exhibiting strong horizontal shears began to be questioned after the commander and pilot of Shuttle mission 61-B returned with photographs and observations of the sub-mesoscale features in the Philippine Sea, the western Gulf of Mexico, and the North Atlantic Ocean. Although the spectacular sequence in the North Atlantic was in waters likely influenced by the northern edge of the Gulf Stream Extension, the other observations were in seas where no currents of any substance were known to exist.

A dimly lit light seemed to switch on in the depths of our collective brains. Are spiral eddies common features of *all* sur-

face waters, we asked ourselves? Are they everywhere in the ocean, the observations limited only by the presence or absence of surfactants, and an appropriate Sun angle?

As the crews returned from mission after mission with photographs from nearly every ocean area that could be viewed, the answer became a comfortable "yes." Spiral eddies were observed in the sluggish, central gyres of the Atlantic, Indian, and Pacific oceans, the Sargasso Sea, the Caspian Sea, again in the South Indian Ocean and the slow, gentle Brazil Current. In fact, it was obvious. Spiral eddies, like the fictitious "Chicken Man," are everywhere! They are, essentially, ubiquitous!!

Ah, but with one exception—near the Equator, even despite the strong shearing action created from the equatorial currents. The best observation available had been made by Maj. Gary Payton during the Shuttle flight of 51-C when he caught at small, 5-km spiral 11°S of the Equator in the Indian Ocean.

So, arose the "closest-eddy-to-the-Equator" contest among the astronaut crews (spurred, in part anyway, by a first prize of a case of Coors beer, offered by me). From calculations Scully-Power and I made on the back of an airline ticket envelope, we predicted that spirals would reach no closer to the Equator than 6° of latitude, as the result of the disappearance of the Coriolis effect.

We were pretty busy the first three days of the mission. We made a few attempts to observe eddies near the Equator—without success. The Sun angle didn't give us any decent glitter pattern. We were supposed to land on the fourth day—yeah, you knew that—but anyway, we'd used all of our film by then. When we got extended for another day and a half, there wasn't much to do. So, everyone did as much observing as possible. We all saw them—we had no film left. Not even 35-mm stuff. I punched the computer for the position. That whole field of spirals was between 5 and 6 degrees south.

These were comments by the Shuttle commander (Capt. Robert "Hoot" Gibson) during the "quick-look" photo session after the Shuttle flight of 61-C, in January 1986. Four of the five-man astronaut crew (Hoot, Charlie Bolden, Steve Hawley, and Pinky Nelson) had seen the spiral eddies, but there were no photographs.

The tight Crew Activity Plan and the short flight scheduled for 61-C, combined to wipe out any photography of the tropical oceans. Responding perfectly to the routine pre-flight admonition, "Don't return with any unexposed film," all of the 70 and 35-mm film had been expended, as planned. But, the unexpected happened. Poor weather at Edwards Air Force Base delayed the landing for a day. Now with available time, and good glitter patterns at the Equator, particularly in the Indian Ocean, the whole crew participated in the "closest-to-the-Equator" derby.

Every member of the 61-C crew saw the eddy field. Fingers reached immediately to punch the on-board, computer for a precise nadir position. There remains a mystery as to whose finger was first on the button. With no unexposed film aboard, the crew members were relegated to the time-honored observational task: a written composition of the scene. Of passing

interest is that the three post-flight drawings available (the "artists" claiming anonymity), are nearly identical. Depicting an interconnected series of three (or four?) spiral eddies rotating cyclonically—clockwise—and centered around 6 degrees south of the Equator in the Indian Ocean.

(Everybody shared the case of Coors beer, including the Director, Flight Operations Division.)

Post-Discovery

The saga of the discovery of spiral eddies in the open ocean is an outstanding example of the oceanographic information that comes from close interaction between astronauts and space oceanographers, the keen perception of the observers in orbit, the precise attention by the Shuttle crews to the rapidly moving scene in the Sun glitter, the ever-growing expert photographic capability of the flight crews, the intensive interpretation and analysis by the space oceanographers, the timely turnover of the interpreted information to crews of upcoming flights, and the involvement of marine scientists from several disciplines in the oceanographic evaluations.

Spiral eddies continue to be observed, and photographed, from the flight deck of the various space Shuttles. They have also been photographed by U.S. astronauts, using U.S.-modified Hasselblad, 70-mm cameras, from the observation port of the Russian MIR space station. It is not known whether the Russian cosmonauts have observed and/or photographed the ocean features. There has been no international communication to that effect.

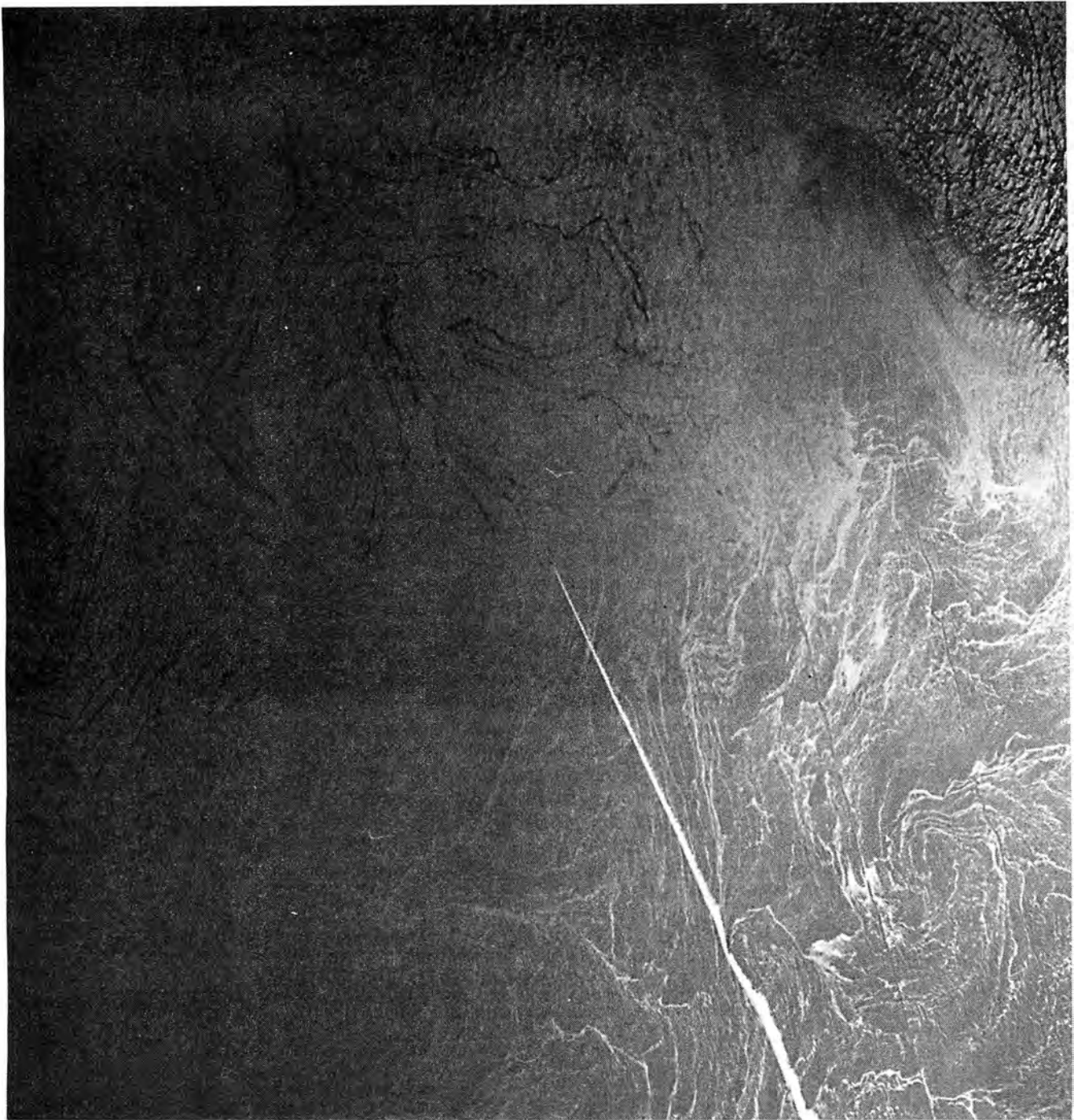
Such eddies have been observed in ocean regions where there have been ongoing, sometimes continuous, oceanographic expeditions. It seems certain, now, that in the open ocean, away from current boundaries, the distribution, interconnections and/or isolation of the spiral eddies are related to the underlying topography of the thermocline. They are confined to the "near-surface ocean," as defined by the late Konstantin Fedorov, which is clearly the domain of the ubiquitous spiralling eddies.

SPIRAL EDDIES TODAY

Most of what we know about spiral eddies comes from observations and photography by Shuttle astronauts. There are a handful of images from SEASAT's SAR and the SIR-A carried on STS-2 and the SEASAT images recognized in retrospect. (The currently orbiting SARs, on Canadian and European satellites, are used for landform investigations and, therefore, have not produced images of eddies.)

An equally small number of pre-Shuttle photographs caught spirals. Once again, it was only after spirals became obvious from Shuttle observations that we perused and interpreted them from Apollo and Skylab photography. From a sequential set of specially enhanced infrared images, unusual eddies were noted that later turned out to be spirals. Because of the unique algorithms used—at the Scripps Institution of Oceanography Satellite Facility—no other infrared images of which we know depict spiral eddies.

Oceanographic data of the eddies are few. Measurements from a Royal Navy experiment during a 41-G SIR-B crossing caught an upper-ocean shear that probably led into a spiral. The best information comes from a Norwegian expedition in



NASA

A low-oblique photograph, looking south toward the coast of Libya, taken Oct. 9, 1984, by Capt. David Leestma, USN, mission specialist aboard the Challenger. In this portion of the eastern Mediterranean Sea, a large, sea-going tanker ship was sailing to the east, leaving a bright stern wake in the Sun's glitter pattern from the discharge of the ballast tanks. The ship was just entering the "off-edge" of the Sun's reflection as the Challenger passed overhead. The bending of the ship's wake around a spiral eddy is easily noted.

the Greenland Sea, when simultaneous data were gathered from both a research vessel and an overflying aircraft. For the most part, therefore, the oceanographic evaluations of spiral eddies have been intuitive and deductive.

With those caveats in mind, therefore, here's what we know about spiral eddies:

(1) The diameters are less than 30 kilometers, the preferred range being between 5 and 15 km. Diameters smaller than 5 km have been measured from vertical photographs, although the determination of the boundaries is subjective, but no spiral eddies larger than 30 km have been observed in the open ocean.

(2) The rotation is invariably cyclonic; counterclockwise in the Northern Hemisphere, clockwise south of the Equator. No anti-cyclonic spiral eddies have been observed, or photographed, or imaged in any part of the ocean. Even where "interference eddies" are formed, as a current streams around an island, that eddy formed behind the left end of the island (looking downstream in the Northern Hemisphere), beginning as an anti-cyclonic rotation, becomes cyclonic within one or two eddy diameters downstream. There have been no observations of "von Karman" paired vortices anywhere in the ocean, in contrast to those in the marine atmosphere, downwind from oceanic islands.

(3) The dominant visual feature of the eddies is the streamlines of narrow slicks that outline the spiralling motion and are horizontal shears within the eddy. There have been no *in situ* measurements of the speeds of rotation, but a number of calculations have been made based on the magnitude to which ships' wakes have been displaced, especially along the streaming slicks. From such evaluations, it is clear that the rotation velocity ranges upward from 20 cm/sec and probably reaches 100 cm/sec in the streamlined slicks near the center of the spiral.

In one sequence of photos from the western Mediterranean Sea, where simultaneously gathered data from the NOAA-7 satellite showed a 5°C thermal boundary, the velocity difference across a streamline was estimated to be 200 cm/sec—again, from the displacement of ship wakes across the shear. On the other hand, an entire field of spiral eddies in the north-east Arabian Sea was observed being destroyed as it was overrun by a coastal current flowing at velocities in excess of 800 cm/sec, as determined by the oceanographer aboard the *U.S.S. Enterprise* as the aircraft carrier sailed through the interface.

(4) If the eddies rotate, they must have a depth dimension. Data are sketchy, but those that exist indicate that spiral eddies are not superficial surface features. The serendipitous measurements by the Royal Navy in the Bay of Biscay, October 1984, showed the current shear to a depth greater than 50 meters. Even if they extend no deeper than that, spirals are certainly significant to the kinetic energy of the near-surface ocean.

But, consider the extraordinary data from the Norwegian examination of a spiral in the Marginal Ice Zone off Greenland in April 1985. An eddy with a diameter of about 50 km was photographed and imaged with an airborne SLAR (side-looking active radar). Masses of pack-ice fragments permitted an easy recognition of the spiralling streamlines. From the accompanying research vessel, temperature profiles encountered a cold-core eddy extending to depths greater than 300 meters; as deep as the casts were made. The isotherms of the cold-cone of water became horizontal at depths between 75 and 100 meters, bending upward toward the surface into a shallow "bathtub" of warm, 4.5°C, water! There was no other water that warm within 200 km of the eddy! Despite the surface warm core, the rotational direction remained cyclonic.

(5) From manned spacecraft, spiral eddies have been observed in all oceans, and marginal and inland seas, from 45°S to 55°N. There is no "magic" in those latitudes; it is simply that the Sun's elevation and the Shuttle's orbital parameters have precluded suitable viewing at sites more poleward than that. They've been observed to within 6 degrees of the Equator,

but none closer than that, despite good viewing and photographic conditions.

Spiral eddies may dominate the near-surface ocean. They may appear as vast fields of interconnecting eddies, covering the entire surface of a marginal sea—the Mediterranean, Gulf of Mexico, Gulf of Oman, Black Sea, Japan Sea, or even the land-locked Caspian Sea. In the ocean, similar fields have been observed frequently, as well, in confined waters, such as, the Mozambique Channel and Tasman Sea.

In the open ocean, well away from any land configuration, and in waters too deep for any influence by sea-floor topography, there are extensive spiral-eddy fields. In those parts of the ocean where major shearing action from currents is unlikely, in the central areas of the great oceanic gyres; for example, spiral eddies are there. Once the astronaut crews became familiar with the typical sea-surface expressions of the eddies, photographs and observations come routinely from every mission.

There is no question about the ubiquity of spiral eddies. Wherever the sea-surface characteristics were suitable; such as, winds speeds less than 4 m/sec and even a minimal presence of surfactants, and there was a useful Sun-glitter pattern, spirals are seen and photographed.

(6) The oceanographic conditions under which spiral eddies are generated are not known, although it seems certain that they must be initiated by some horizontal shearing action. Because of their size, less than 30 km, the spirals would not respond to the Coriolis effect if they conformed to linear-wave theory. Yet, they do. Attempts to model them using nonlinear equations have yet to be successful.

We know virtually nothing of the "life histories" of the spirals. Although they are seen repeatedly in many areas, with one- to three-day observational intervals, the "same" field is observed, but never the "same" eddy, or its recognizable twin. It is reasonable that the spirals, once formed, have lifetimes of days, as in the case of the Greenland Sea eddy. They surely remain relatively fixed for the 10 to 15 hours of a ship's transit from the innumerable photographs of wakes through the eddy fields.

THE DYNAMIC, COMPLEX OCEAN

It became clear, in 1984 (from the space observations by Paul Scully-Power), that the ocean is far more complex than previously thought. As Scully-Power and I wrote in 1987:

No longer can the ocean be considered to be homogeneous, or uniformly stratified; it is dynamic at all scales. Yet, although the ocean is not homogeneous, it is not uniformly complex. Furthermore, these complexities tend not to be static; they meander around the ocean. Therefore, on a day-to-day basis, particular areas of the oceans can be more complex than surrounding areas. . . !

Most of the "complexities" Scully-Power and I were discussing were spiral eddies. So, now that we know such features to be spread around the oceans, and the marginal and inland seas of the world, what do we make of their existence? Do we consider the kinetic energy bound up in the spiralling waters? We could then add the amount to that proposed by Dr.

Walter Munk in 1976. It is possible to calculate the kinetic energy of a spiral eddy, by making a couple of knowledgeable assumptions. The diameter of any eddy can be determined from a space photograph, or from a SAR image. There is enough serendipitous information to permit a logical depth to be assigned; it is not going to be deeper than the prevailing thermocline. It is also possible to calculate the amount of kinetic energy in a given field of spiral eddies at a given time. The "given field" is the one that has been observed, or photographed, at the particular time noted from orbit, or along the orbital track of the space Shuttle through several minutes of time.

Both of these calculations were made by Scully-Power and me: first, quickly on the back of a paper napkin over a Lone Star beer in The Outpost near the Johnson Space Center; then again, from a strikingly good computer simulation. The number of ergs of kinetic energy from each try were close enough—an interesting bit of esoterica, we thought. The total kinetic energy in them represents about 50 percent of the grand percentage noted by Munk in Edinburgh in 1976, even though he may have exaggerated a bit. Perhaps. Given the entire ocean, there are probably about 5 million (or thereabouts) spiral eddies rotating at any given time. The problem in using the energy numbers from spiral eddies is that the features are individually ephemeral, although the field of spirals may persist for days, weeks, or longer.

Consequently, to try and separate the contributions of spiral eddies from mesoscale eddies in any General Circulation Model not only would be fruitless, but senseless. The question of the spiral eddies' impact on the interactions between the oceans and the atmosphere is something else. Spiral eddies rotate cyclonically, in both hemispheres. They have cold-water cores, therefore, and the cold water is rising from depths. The rising waters are richer in nutrients than the surrounding ocean, fostering great growths of plankton. From both the physical and biological actions, the surface waters are somewhat depleted in both oxygen and carbon dioxide. For a single spiral eddy, the effect in any predictive computer model is like that of the flea on the elephant; not even a "butterfly in Beijing." For a field of spiral-eddies, such as that observed by Capt. Richard Truly on STS-8, 2,000 km wide, and extending across the Indian Ocean into the southwestern Pacific Ocean, the flux of heat and gases is huge.

At this moment in our history of scientific discovery, no one has a clue of how to make any calculation on the role of spiral eddies in any weather or climate predictive model; even though the influence must be major. Computer models, whether they are addressing weather, climate change, or the influence of man on the state of the "greenhouse," must know (1) precisely the initial conditions, in both the ocean and atmosphere, (2) the temperature-regulating capability of the ocean, (3) the amount and direction of the flux of gases and particulates relative to the ocean, (4) the scale and variability of these fluxes in time, as well as (5) quantifying the effect of sunspot activity and the changes in the Earth's orbit.

(You'll notice, perhaps, that I did not mention the "component of the equation" about which we are bombarded day after day: man-made greenhouse gases. Why? Because it is the smallest part of the "equation." The greenhouse gases of the atmosphere are 96 percent water, none of which we can control. The inputs by man, carbon dioxide and methane, and/or

freon, are so minor that no one can ascertain their function in the Earth's temperature-regulating function.)

In time, the scientific method may give us enough knowledge of the dynamics of the Earth's surface and atmosphere to permit us to construct consistent weather, climate, and ocean predictive models. We aren't there yet! A favorite comment by my close friend, Professor Ben J. Cagle, whenever we reviewed the progress of computer models is, "Once a scientist has the physical facts, his general knowledge will permit him to make an intuitive conclusion that is better than any computer model." The emphasis is on "scientist."

Robert E. Stevenson, an oceanography consultant based in Del Mar, California, trains the NASA astronauts in oceanography and marine meteorology. He was Secretary General of the International Association for the Physical Science of the Oceans from 1987 to 1995, and worked as an oceanographer for the U.S. Office of Naval Research for 20 years. A member of the scientific advisory board of 21st Century, he is the author of more than 100 articles and several books, including the most widely used textbook on the natural sciences.

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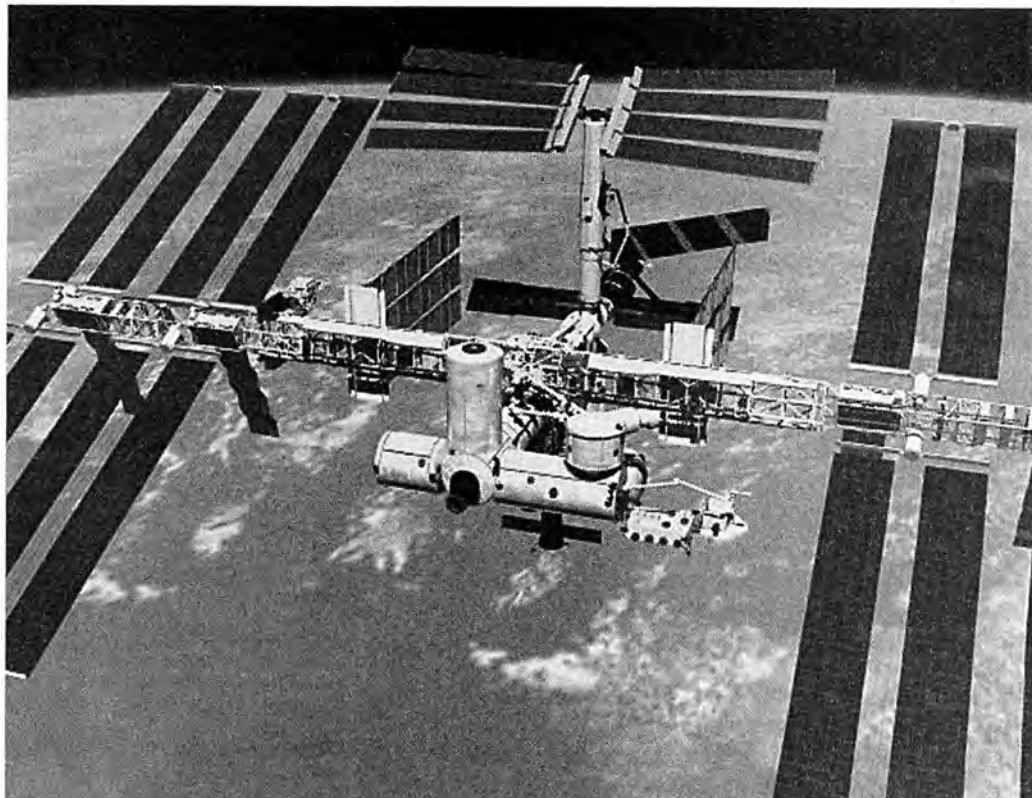
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Space Station to Open New Biomedical Frontiers

by Marsha Freeman

In the fight against disease, every weapon in the scientific arsenal must be marshalled. Since the start of the Space Shuttle program in 1981, the unique microgravity environment of space has added a new capability in the quest for understanding human biology and improving health. Short Space Shuttle flights, combined with longer-term stays on the Russian Mir station, have given scientists a glimpse of what will be possible when the International Space Station is operational—and it is an exciting future.

Michael E. DeBakey, M.D., renowned heart surgeon, and chancellor and chairman of the Department of Surgery of the Baylor College of Medicine, gave his view of the importance of space biomedical research in testimony before the House Committee on Science, Space, and Technology in June 1993: "The Space Station is not a luxury, any more than a medical research center at Baylor College of Medicine is a luxury. . . . Present technology on the [Space] Shuttle allows for stays in space of only about two weeks. . . . [On Earth] we do not limit medical researchers to only a few hours in the laboratory and expect cures for cancer. We need much longer missions in space—months to years—to obtain research results that may lead to the de-



All photos are courtesy of NASA

In November 1998, the Russian Space Agency is scheduled to launch the first element into Earth orbit to begin assembly of the International Space Station (ISS), being built by the space agencies of the United States, Europe, Russia, Canada, and Japan, with contributions from Brazil, Argentina, and hopefully many other nations. It is the largest and most complex international project ever undertaken. When completed at the beginning of the next century, the ISS will provide scientists the first full-time, year-in year-out world-class set of laboratories ever built in space.

velopment of our knowledge and breakthroughs."

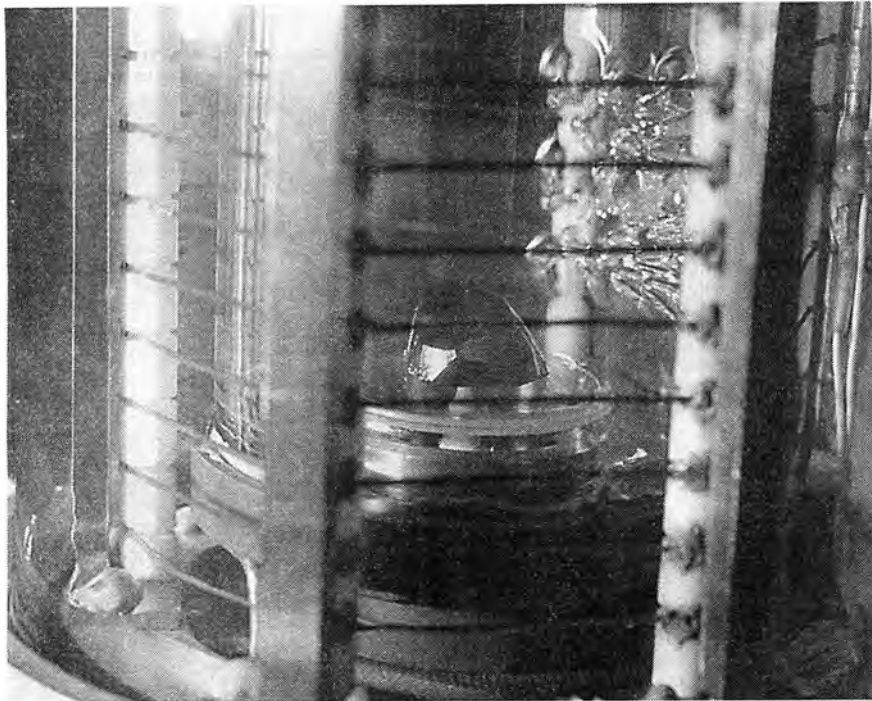
The International Space Station (ISS) will provide scientists with a full-time laboratory in space.

Unlocking Secrets of Proteins

There are more than 300,000 proteins in the human body, and scientists know the structure of fewer than 1 percent of them. Many are difficult to artificially produce and study on Earth, because the proteins' weight distorts their internal

structure, so researchers have gone into space to study proteins. Using the specialized equipment that has been developed for this purpose, researchers can grow crystalline forms of proteins and other biological substances there.

Under the guidance of the NASA Center for Macromolecular Crystallography at the University of Alabama in Birmingham, directed by Dr. Larry DeLucas, scientists have taken advantage of the microgravity environment of space, to



The ability of the Vapor Crystal Growth System equipment to grow protein crystals, seen here, was tested during the International Microgravity Laboratory Space Shuttle mission in early 1992.

produce superior protein crystals to aid in research on cancer, diabetes, emphysema, immune system disorders, and other ailments. In seven years of short-duration, space-based protein crystal growth experiments on the Space Shuttle, the structures of 30 proteins have been defined.

DeLucas had firsthand experience conducting experiments in space, as a payload specialist on the first U.S. Microgravity Spacelab mission in 1992.

The most advanced tool with which scientists study the structure of crystals is X-ray crystallography. When passed through a crystal, X-rays produce diffraction patterns that correspond to the locations of atoms and of clouds of electrons. By combining patterns from different angles, scientists can determine the structure of the crystal. If the internal structure of the crystal is disordered, as is often the case with ground-based crystals, a "fuzzy" pattern is produced.

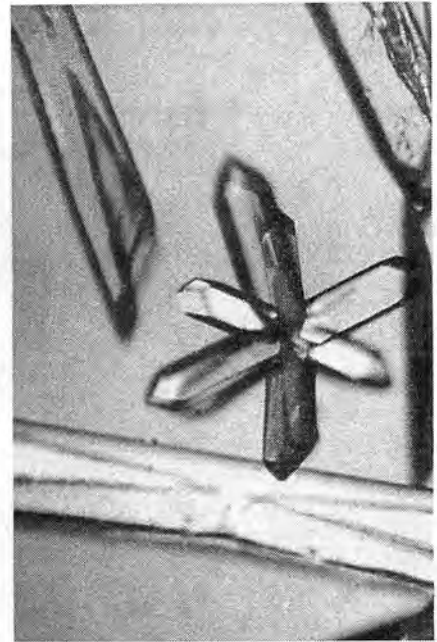
Insulin is one of the crystals that has been intensively studied in space, in order to produce a more effective drug for diabetics. Diabetes, the inability of the body to regulate blood sugar because of ineffective production of insulin, often leads to serious complications, and is the third leading cause of death in the

United States. An estimated 5 to 10 million Americans suffer with Type 1 diabetes, where the immune system directs the body to kill its own beta cells in the pancreas. (Beta cells sense sugar levels and produce insulin.)

The Hauptman-Woodward Medical Research Institute of Buffalo New York is working with Eli Lilly and Company, using data from space crystals of human insulin to design a drug that will allow the body to absorb insulin more effectively. They hope patients will only need to inject insulin every three days or so, instead of one to three times a day. It is expected that the "highs" and "lows" of blood sugar levels that diabetics suffer in between injections will be smoothed out, eliminating many of the debilitating complications from the disease.

"Space-grown crystals of insulin provide scientists with a view of its structure equivalent to seeing a grain of powdered sugar from 180 miles away!"

Space-grown crystals of insulin provide scientists with a view of its structure equivalent to seeing a grain of powdered

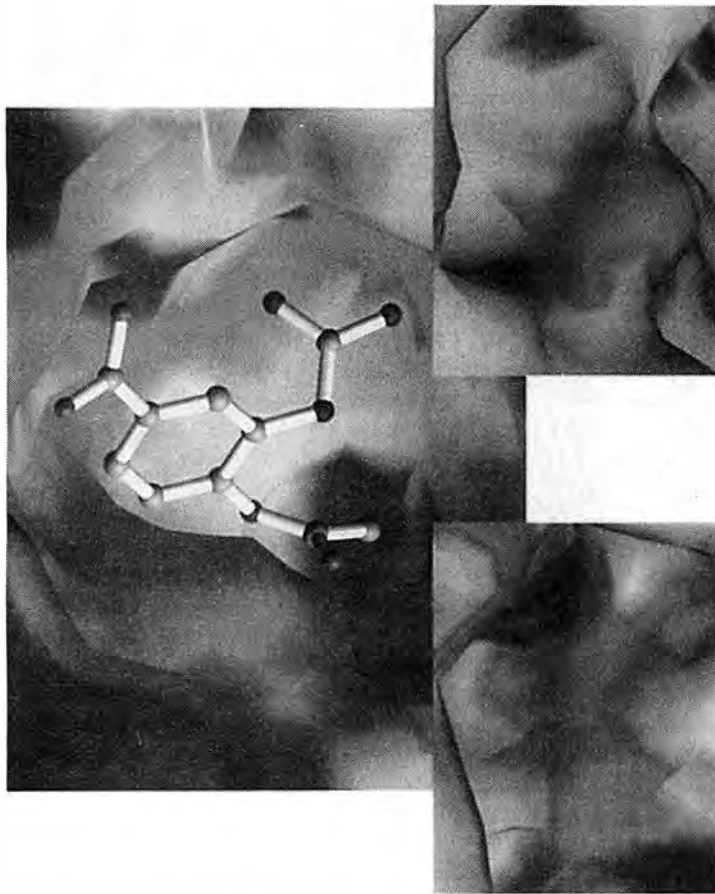


This high-definition crystal of insulin was grown in 1991, aboard the Space Shuttle. With a detailed map of this complex protein, scientists hope to design new treatments for this crippling disease.

sugar from 180 miles away! Details have been resolved down to 1.4 angstroms, less than 2-millionths the width of a human hair. NASA has grown human insulin crystals on two Space Shuttle missions.

"What we're looking for, long-term," Dr. Marianna Long, associate director of the Center for Macromolecular Crystallography, explains, "is a time-release formulation of insulin." Insulin comes in two forms, monomer and hexamer. The first is absorbed rapidly in the body but is not stable when stored. Diabetics inject inactive hexamer molecules, which gradually dissolve to deliver the monomers into the bloodstream to be absorbed. Insulin is so complex that even the hexamer form has three different configurations.

"Insulin has this phenomenal property called allosterism," commented Dr. G. David Smith from Hauptman-Woodward: it can change its shape spontaneously and still be the same molecule. One variation of insulin hexamer, T3R3, slows down the delivery rate to the bloodstream, and could spread out the delivery of the monomers over time, providing a stable blood sugar level for three or four days.



High mutation rates of the influenza virus have hindered the development of new drugs or vaccines. Using data from space-grown crystals, shown here, researchers have mapped the virus's structure, and are designing drugs to bind with the flu's surface proteins, to prevent it from spreading to other cells.

In 1994, on the STS-60 Space Shuttle mission, well-ordered crystals were produced during eight days in space. Working under grants from NASA and the National Institutes of Health, Dr. G. David Smith was the principal investigator of the experiment. X-ray crystallographic techniques produced an exceptionally detailed map of the molecule in the T3R3 hexamer form. Scientists plan to study the details of its structure, in order to design chemicals that will spontaneously generate T3R3 hexamers that are stable when stored, yet dissolve at just the right rate in the body.

At least three years of research and trials must follow before the new knowledge translates into improved therapies, DeLucas said recently. Ultimately, he said, "a more steady release of the insulin may decrease the complications due to diabetes."

Treating a Host of Infectious Diseases

In July 1997, NASA flew the Microgravity Science Laboratory 1 (MSL-1) mission, which was the 35th flight for the space protein crystal growth program. There were three protein crystal growth experiments on MSL-1, with a record number of 1,500 protein crystal samples. DeLucas was the principal investigator for the Vapor Diffusion Apparatus on the mission.

The facility processed 11 different proteins in 80 crystallization chambers. These included two proteins related to Chagas's

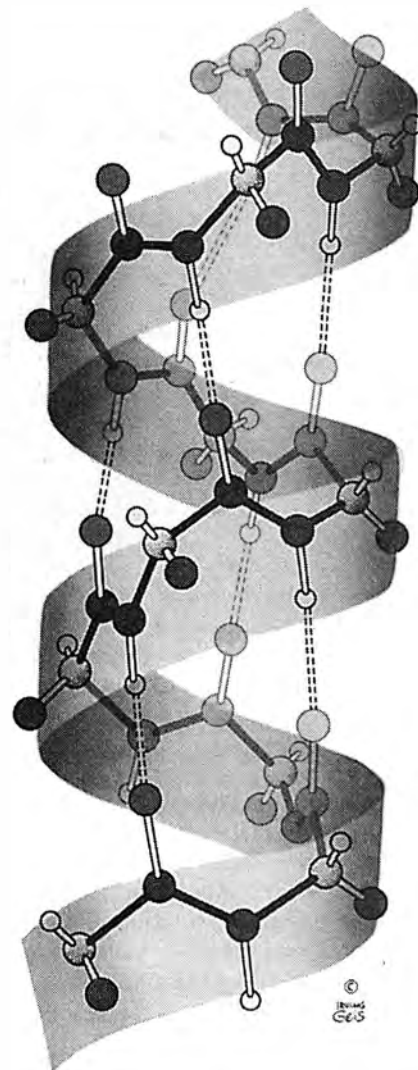


Figure 1

3-DIMENSIONAL PROTEIN STRUCTURE

Proteins are long chains of amino acids, and these chains can assume several secondary shapes, such as a helix, a sheet, or a loop. Depicted here is a protein chain in the secondary structural form of an alpha-helix. A protein may assume several different global shapes, but the secondary structure of its various domains remains relatively stable, and the variation in global shape results from the different possible ways of folding the domains together.

X-ray crystallography of proteins reveals the overall shape and three-dimensional structure, which may appear to be irregular. Within this irregular appearance, there are other geometrically regular levels of organization that influence the global structure.

Source: Courtesy of the estate of Irving Geis. Reproduced from *Structure and Action of Proteins* (page 29) by Richard Dickerson and Irving Geis; ©1969 by Irving Geis.

disease, a tropical disease that affects more than 20 million people in Latin America, and 150,000 people in the United States. The space-based research is in collaboration with scientists in Argentina, Brazil, Chile, Costa Rica, Mexico, and Uruguay.

Chagas is a crippling parasitic infection carried by the blood-sucking cone-nose ("kissing bug"), and is immune to treatment. It wastes muscle tissue until the patient dies. Scientists are growing crystals of chemical specimens found in the rain forests, to find a compound that blocks a key protein in Chagas.

Another disease targeted for drug design is influenza, which kills up to 20,000 people annually in the United States alone. Viruses have been described as "bad news wrapped in a protein," and one key to stopping a virus is to block its protein coating from allowing it to inject itself into a healthy cell, where it replicates and then spreads to other cells. Scientists have found two proteins on the surface of the flu virus that allow the virus to escape from the cell and attack other cells. Although the virus mutates, to change its appearance and fool the immune system, these two proteins remain unchanged.

Researchers are now developing an inhibitor that prevents the spread of the virus to other cells. It has been found to block every strain of the flu, but the amount of drug needed varies depend-

ing upon the particular strain that is targeted. The drug would not cure the flu, but it would prevent the symptoms from getting worse, allowing the immune system to mobilize against the disease.

Scientists have also studied space-grown crystals of *Staphylococcus aureus*, a bacterium that is immune to most drugs. It was found that this staph has several amino acids on its surface which allow it to attack a cell, and that if any one amino acid is disabled, the entire mechanism is disrupted. The next step in the research is to design a drug that will mimic the cell's collagen, and bind to at least one of the surface amino acids of the bacterium, which will keep it out of other cells.

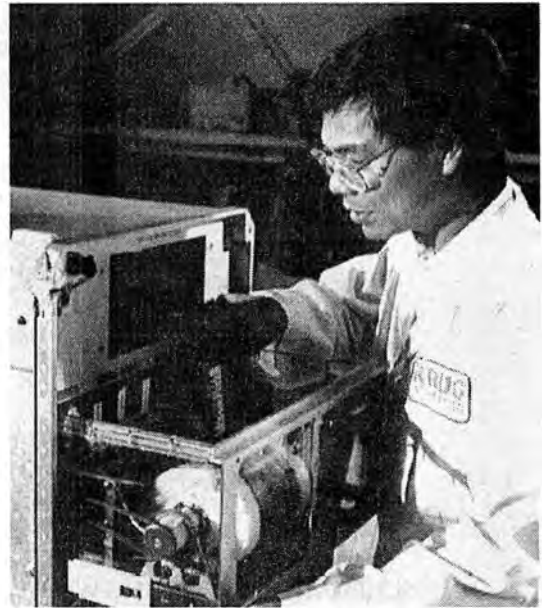
In a May briefing for reporters on the International Space Station, at the Johnson Space Center in Houston, DeLucas gave a status report on market-viable drugs developed from data provided by space-grown crystals. Drugs that are currently undergoing trials, and are expected to be available in the next two to six years if they pass Federal Drug Administration tests, would be used in the treatment of psoriasis, contact dermatitis, rheumatoid

arthritis, T-cell lymphoma, flu, and stroke.

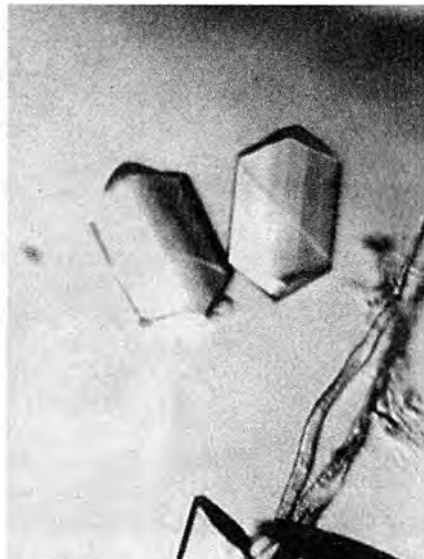
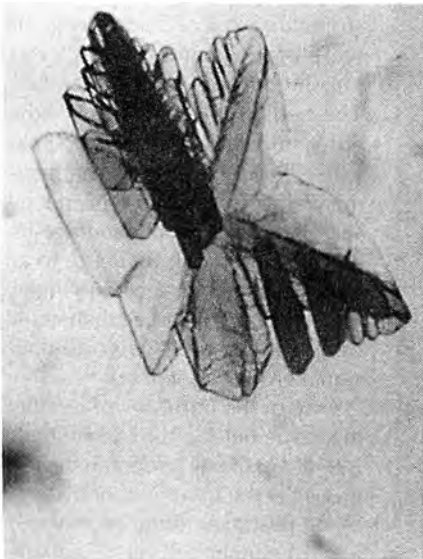
It took several flights, over a number of years, DeLucas explained, for scientists to learn the best methods for crystal growth. "Only 20 percent of the specimens flown succeed, partly because scientists are still learning the ideal growth conditions, which vary with each protein, and partly because a two-week Shuttle flight is only enough time for some crystals to just start growing. . . . To determine a crystal's structure," DeLucas said, "you need a continuous supply, maybe even for an entire year, and even more to design a drug that works with it. We need a constant supply of crystals to determine the three-dimensional structure."

The Opposition

The exciting results from the space crystallization experiments, and the great promise the fruit of that research holds for the near future, are not without political critics. The American Society for Cell Biology, based in Bethesda, Maryland, released a review of NASA's life sciences program, July 9, which stated flatly: "No serious contributions to knowledge of protein structures or to drug discovery or design have yet been made in space. Thus, there is no justification for a NASA protein crystallization program, and this committee strongly recommends that no further



Tinh Trinh reads the space bioreactor for its first trip into space in 1988. He is one of three patent holders for this technology.



The difference in complexity observable between space-grown (left) and Earth-grown (right) crystals, is clear from these images. The crystal is of protein isocitrate lyase, an enzyme that could be used to discover more potent treatments for crop disease.

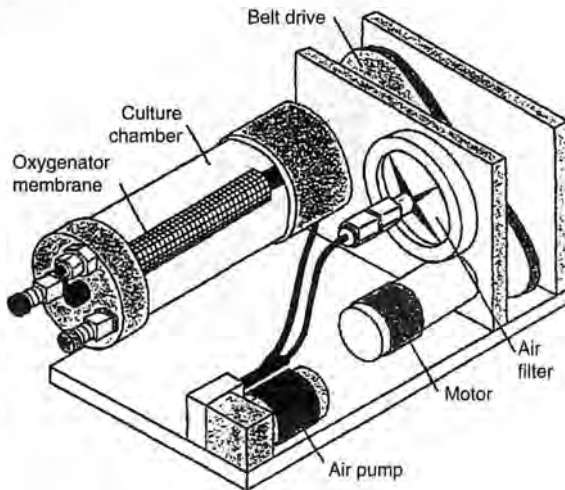


Figure 2
SCHEMATIC OF ROTATING WALL VESSEL BIOREACTOR

Shown is the electric motor that rotates the culture vessel, the pump drawing air from the chamber through a filter for the culture, the chamber where the tissue is grown, and the membrane-covered central shaft of the cylinder, which feeds the tissue and removes waste.

funds be spent on crystallization of proteins in space."

The timing of this incredible report was not accidental; it was released just prior to Indiana Democrat Rep. Tim Roemer's annual press conference to call for termination of the ISS, held this year on July 15. Scientists familiar with the situation believe that the only explanation is that the report was "politically motivated," because it was based on no data, and is outside the area of scientific expertise of the society.

Many scientists have refuted the society's attack. As DeLucas noted: "The key advantage of the ISS is the fact that we will be able to do science all year long. We won't have just a glimpse at it, as we do with the Space Shuttle. You put your experiment up there and for a long period of time we'll be able to do successive experiments, just as we do here on Earth. That's the only way to make rapid progress in any scientific field."

Growing 3-Dimensional Tissue

Until recently, scientists and medical researchers aiming to understand, treat, and cure, disease were limited to looking at tissue grown only in two dimen-

sions. Tissue and organs in the human body, of course, grow in three dimensions, and tissue grown otherwise does not replicate many of the most important differentiation, intercellular, and other characteristics of human cells.

The bioreactor, used for tissue culture experiments in space, has proven to be a



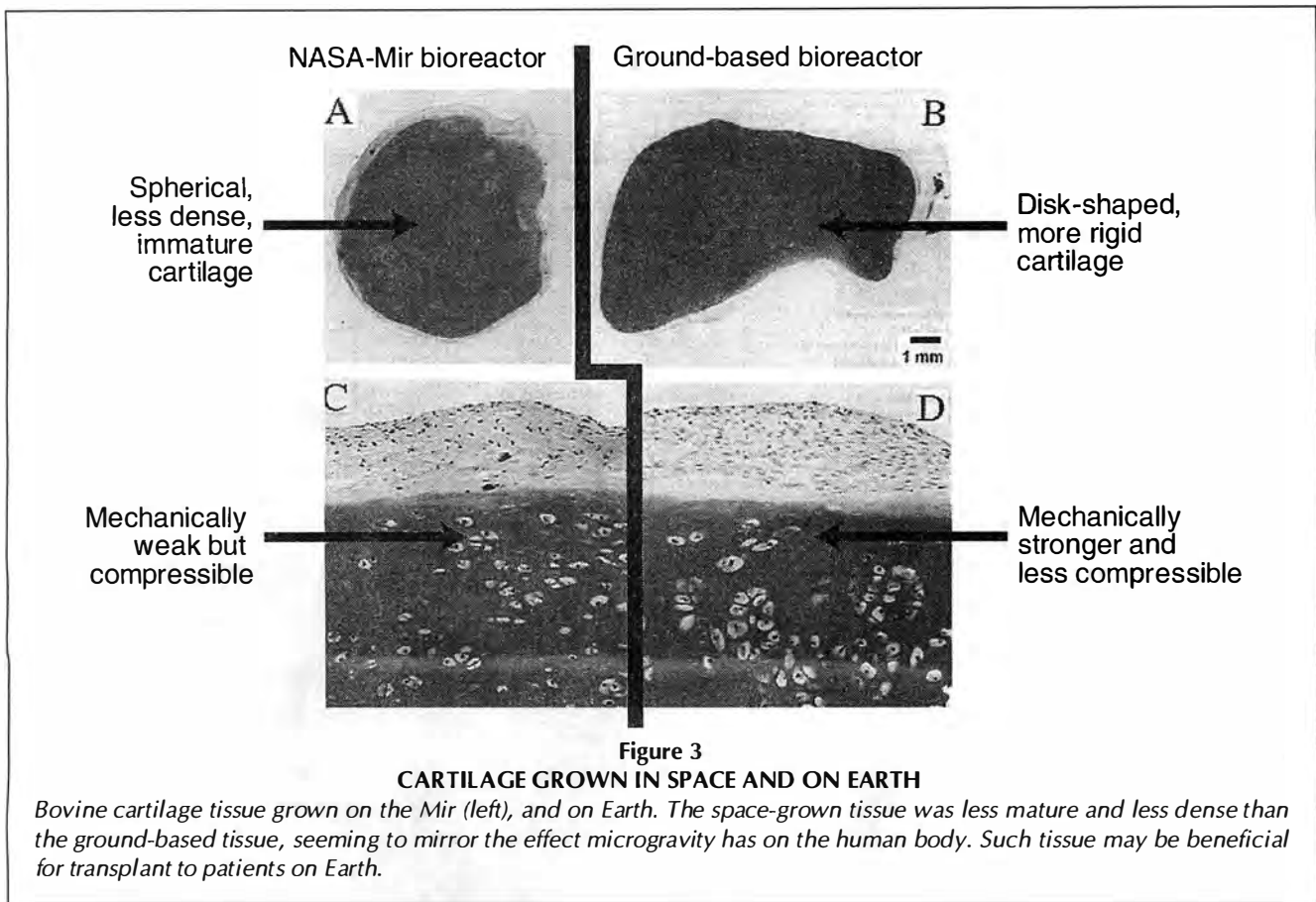
Astronauts Carl Walz and Jay Apt analyze a bovine cartilage tissue sample grown in a bioreactor on the Space Shuttle. The experiment was then transferred, along with astronaut John Blaha, for a long-term stay on the Russian Mir space station.

remarkable research device both in space, and in laboratories on Earth. The device was developed by a team at the Johnson Space Center, including astronaut David Wolf, and people in industry, initially to protect delicate cell cultures for space experiments from the relatively high shear forces generated by changes in the force of gravity during the launch and landing of the Space Shuttle.

In an interview with this author (*Executive Intelligence Review*, March 13, 1998), astronaut David Wolf explained that it was during the down-time in the Shuttle program, after the 1986 Challenger accident, (and seven years before he was an astronaut), that efforts of the team to simulate microgravity on the ground led to the development of the bioreactor. "Three of us came up with the approach to spin the [cell] culture on the ground," Wolf explained, "in a cylinder of culture media, like blood, and build a machine that acted as a heart-lung machine, a kidney, a digestive system—essentially building a rudimentary artificial [human] body to support the cells that were growing in this rotating, or spinning, cylinder." The ground-based device is called a rotating wall vessel.

The cells are suspended in a fluid medium that fills the culture chamber, with an inner co-rotating cylinder that has a membrane that allows nutrients and oxygen to pass to the cells, and waste products to be removed. Through rotation, the cells remain suspended, out of contact with the walls of the chamber, which creates a constant state of free fall. The cells rotate as a solid body, with minimal disruptive shear forces produced. Using the rotating wall vessel device on Earth, researchers have produced three-dimensional human tissue up to an inch and a half in size, with higher fidelity to *in vivo* tissue than could be produced in any two-dimensional growth container.

One of the purposes of producing tissue outside the human body is to aid in the development of new drugs for the treatment of disease. In the past, new drugs were tested against cancer cells grown on the ground in two dimensions on plastic, or in mice. But, as Dr. John Jessup, at the University of Pittsburgh Medical Center, notes, both these



media are "poor representatives of the human system. Drugs that kill cells on plastic may not kill cancer cells in the patient."

Jessup found that cancer cells grown in the laboratory in two dimensions do not produce the substances that many colon, breast, stomach, and other cancers produce *in vivo*, and because proteins and other substances bear on the way cancers spread throughout the body, better methods of tumor growth were required. His cancer tissue experiment flew on the Space Shuttle STS-70 mission in July 1995, which was the first flight of the bioreactor technology carrying human cells. In only a four-day flight, he found that the microgravity tissue was more viable than ground-based cultures.

3-D Model of Breast Cancer

Dr. Jeanne Becker, Associate Professor in the Department of Obstetrics and Gynecology at the University of South Florida, has been researching the characterization of three-dimensional models for breast and ovarian tumor growth using rotating wall vessel microgravity technology. She has been very enthusi-

astic about using the ground-based bioreactor technology, because both ovarian and breast cancers are extremely difficult to culture outside the human body. Models of tumor growth based on tissue grown in the rotating wall vessel reactor are now being evaluated for their usefulness in testing sensitivity to chemotherapeutic and biological agents, including hormonal therapy, which is particularly important as treatment for breast and ovarian cancer.

At a May 21 symposium sponsored by George Washington University in Washington, D.C., titled "NASA Research and Human Health," Becker reported that she is studying why and how drug resistance develops against cancer, which is the main problem with chemotherapy. She is also measuring the hormone responsiveness of tumors as they grow in the rotating wall vessel—an effect that cannot be studied in tissue cultured in two dimensions.

Becker has also made a most important discovery: She found that an ovarian tumor made up *in vivo* of heterogeneous mixed cancer cells, when

cultured in the bioreactor, replicated the mixture of cells from the original tumor tissue, thus providing scientists with a high-fidelity model of the actual cancer. Tumor cells grown in a conventional, two-dimensional flask, however, replicated only one kind of cell, and the complexity of the tumor was lost.

A bioreactor experiment that attempted to duplicate the growth of blood vessels in cancerous tumors was carried out on the last mission of U.S. astronauts to the Russian Mir space station, in the first half of 1998. Astronaut Andy Thomas was responsible for this Co-Cult experiment (growing more than one cell type together), which involved breast cancer cells and a fibroblast layer, made up of angiogenic cells that will form blood vessels. David Wolf said of the experiment: "These are two types of cells whose relationship is very critical. A tumor attracts blood vessels just to feed the cells, and this is a key area of cancer research." Interfering with the vascularization process in tumors could halt their growth.

Although a problem arose in Thomas's
(Continued on page 79)

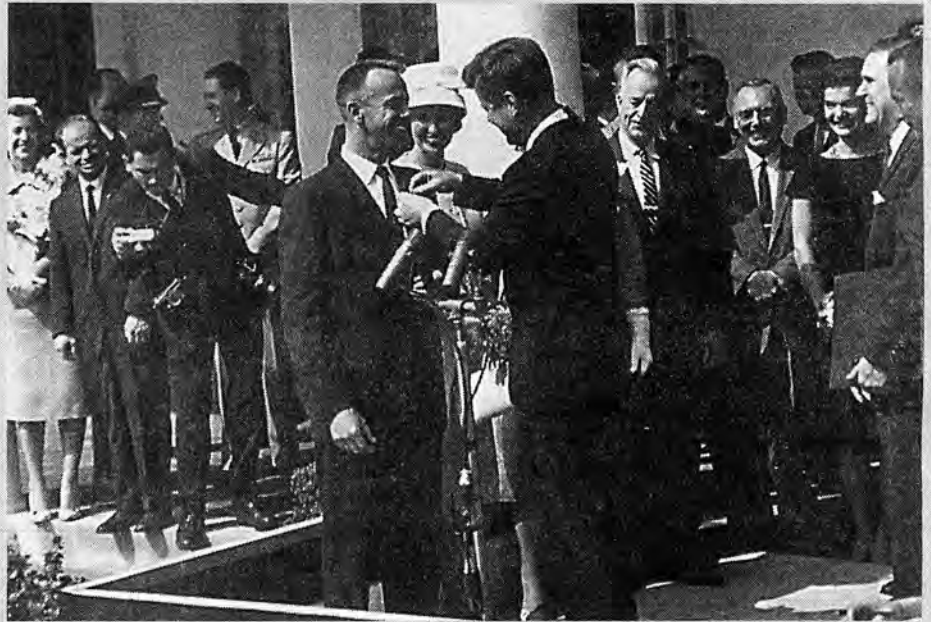
Astronaut Alan Shepard: First American in Space

by Marsha Freeman

Forty years ago, on Oct. 1, the National Aeronautics and Space Administration opened its doors as the world's first civilian agency with the mission to explore space. Thirty-nine years ago, seven men were chosen, out of more than one hundred who volunteered, to take America into the new space age. One of the seven chosen was Alan Shepard. Unlike the Soviet space program, which had beat the United States into space with the flight of Yuri Gagarin, April 12, 1961, Alan Shepard was going into space a month later in full view of the American public, and the world. With the assurance from program manager Wernher von Braun that the Redstone rocket was ready to carry a man into space for the first time, Alan Shepard climbed into his Freedom 7 capsule on May 5, in what current NASA Administrator Dan Goldin recently described as "an unbelievable act of courage." Shepard's colleagues have said that he was chosen to go first because of his intelligence, dedication, and composure. He exhibited these qualities throughout his life.

Never Say Never

Twenty days after Shepard's history-making 15-minute suborbital flight, President John F. Kennedy was confident enough in the capabilities and people of NASA to announce that, within a decade, the United States would land a man on the Moon, and return him safely to the Earth. The one-man Mercury missions would lead quickly to the next step toward



NASA

Three days after his historic space flight, astronaut Alan Shepard receives NASA's Distinguished Service Medal from President John Kennedy, and the thanks of a grateful nation.

Apollo—two men in orbit in the Gemini program. But while he was training for the first Gemini mission, Alan Shepard developed an inner ear ailment that grounded him.

Most astronauts, faced with the prospect of never being able to fly, have left the space program and gone on to other careers. Not Alan Shepard. Although greatly disappointed, Shepard took on the job of running the astronaut office at the Johnson Space Center, with the unhappy task of choosing and training *other* astronauts to fly. According to his secretary and other astronauts, he did not always handle the job gracefully, but he ran the office with fairness and an iron hand.

Then, in early 1969, Shepard learned of experimental surgery that held out the promise of correcting his

ear ailment. With his sole purpose to go to the Moon during the Apollo program, Shepard checked into the hospital under a pseudonym and underwent the surgery.

Back in the flight rotation, Shepard trained for the Apollo 14 mission to the Moon. And after the near-disaster of Apollo 13, it fell to Shepard and his crew to restore the confidence of this nation in its scientists and engineers, as Shepard had done with his 15-minute suborbital flight in 1961.

Focus on the Future

After leaving NASA in 1974, Shepard devoted much of his time and energy to preparing for future space programs. In the mid 1970s, Shepard was a member of the original board of the National Space Society, formed by

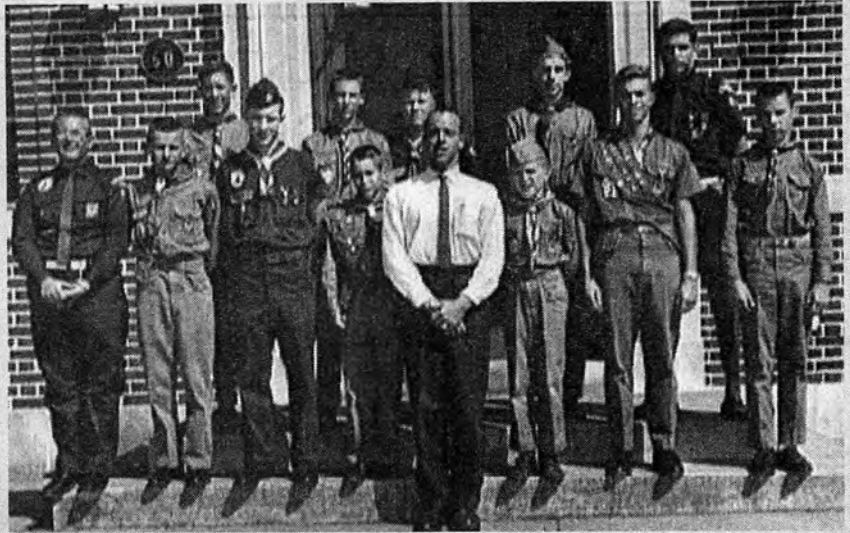
Wernher von Braun, to interest the public in space exploration.

In 1984, Shepard, the other surviving Mercury astronauts, and Gus Grissom's widow, Betty, founded the Mercury 7 Foundation in order to raise scholarship money for science and engineering students. Shepard himself raised a half-million dollars for the foundation, by playing golf with enthusiasts who hoped they could beat on the green the man who had taken two golf shots on the Moon.

Shepard also participated in the Marshall Space Flight Center's Space Camp in Huntsville, Alabama.

Alan Shepard died on July 21 of leukemia at age 74. Speaking of his death, Dan Goldin said: "Alan Shepard will be remembered, always, for his accomplishments. . . . He should also be remembered as somehow who, even in his final days, never lost sight of the future."

Sadly, Shepard's wife of more than 50 years, Louise, died a little more



NASA

Always looking toward the future, Alan Shepard met and talked with Boy Scouts from Franklin, Virginia, on June 19, 1961, at the NASA Langley Space Flight Center.

than a month later, on Aug. 25.

What Alan Shepard embodied was the spirit, dedication, sense of humor,

and integrity that characterizes the best of what the space program is, and explains how it accomplishes what it does.

New Biomedical Frontiers

(Continued from page 77)

Co-Cult experiment on Mir, where bubbles formed in the bioreactor, this did not interfere with the growth of the tissue. (See photo, back cover.)

Wolf pointed out that understanding how tissue stimulates the growth of blood vessels is important for another reason: One aim of three-dimensional tissue engineering is to grow replacement tissue for diseased or injured tissue, and ultimately, to grow entire healthy organs for transplantation. To do this, the organ tissue would have to be able to also develop its own vascular system.

Cartilage Experiments

Experiments using the bioreactor can also provide new insight into the effects of microgravity on the physiological systems of space explorers. Dr. Lisa Freed of the Massachusetts Institute of Technology, has been studying the growth of cartilage tissue, with the hope of producing engineered tissue that can be used for replacement and transplantation. In September 1996, when astronaut John Blaha boarded Mir, he brought with him bovine cartilage cells

to be grown in the bioreactor on the station. The type of cells selected for this first long-term bioreactor experiment, as noted by Dr. Neal Pellis, Program Director for Biotechnology Cell Science at the Johnson Space Center, can be found at any meat counter, because any cut of beef contains cartilage, the white fibrous tissue between the ribs.

The bovine cartilage cells stay alive up to two weeks after slaughter, Pellis said, and are very rugged, durable tissue, which is why they were chosen to go into space. Less than two months after the 10 cartilage samples arrived at Mir, and were placed in the bioreactor, researchers reported that the samples were larger than those in the ground control units. But there was a finding that proved to be as important for people in space as for people on Earth: It is well documented that astronauts suffer muscle atrophy in space, as well as adverse effects on bone and cartilage. So when Freed found that her space tissue, growing for about 140 days on Mir, proved to be mechanically weaker and less dense than mature cartilage cells grown on Earth, it was not surprising; the bioreactor cartilage tissue seemed to

be suffering from the same microgravity effects suffered by the astronauts.

Space-grown tissue will allow scientists to look at weakened cartilage for the first time, and in doing so, could lead to new solutions to the problems of the human adaptation to space. In addition, Pellis points out, immature cartilage grown in space may be found to be well suited for transplantation, because studies indicate it forms a better bond with existing cartilage.

When astronaut David Wolf reached the Mir space station in September 1997, bioreactors had been flown aboard Mir for about a year. His conclusion was that the previous experiments "verified that space is the absolutely ideal environment to unlock the secrets of the emerging field of tissue engineering. . . . This type of work takes a whole team of researchers many years in the laboratory, and what we have [on Mir] is a small area of a small space station, with one astronaut, part time. We're really in our infancy." When the ISS is operation, real breakthroughs will occur, Wolf said. "We'll have more extensive facilities and continuous time, for many years, in the laboratory."

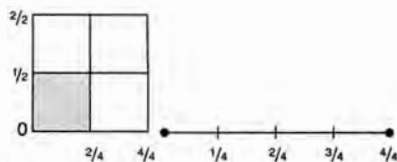
SPECIAL FOR YOUNG SCIENTISTS

Getting to the Square Root Of the Math Problem

Part 2

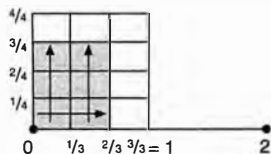
by Elijah C. Boyd

Before we jump into squares again, let me quickly remind you of what we covered in Part 1, in the Spring 1998 issue of *21st Century*, p. 84. There, we discovered that the act of constructing a square, also involved the construction of the square roots of that same square: Two sides of a square connected at a corner (also called a vertex), are the square roots. We discovered that the term the *square roots of a square* identifies a *concept*, and *not* a number, or even a series of numbers.



This geometrical identification of these two sides (as being the square roots), allows us to see that this covers *all* the number-pairs (2×2 , 3×3 , 4×4 , and so on, as well as the fractions, $1/2$ times $1/2$, and so forth). We also discovered that the line and the square may use the same numbers, but the numbers describe different geometrical objects, even if the numbers look the same.

Now, let us take a closer look at our second example from Part 1: $2/3 \times 3/4$,

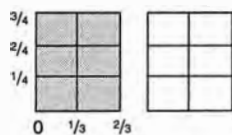


which, we discovered is $6/12$. We divide this up into two piles, 6 on one side and the 6 colored squares on the other side. So, we can say that $6/12$ is also one half.



The author (right) and friends, working on three-dimensional geometric constructions.

But *wait!* Something is a little bit fishy here.

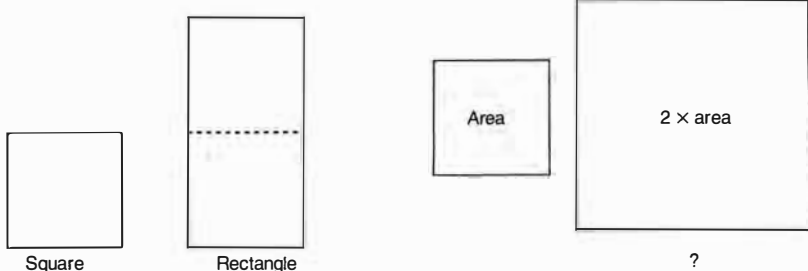


In our first example, where we multiplied $1/2 \times 1/2$, we started with a square, and we ended up with four little squares, with our answer being one little square

out of the four, or $1/4$, but, *all* the objects were *squares*.

Here, we start with a square, and end up with 12 rectangles, and our answer, $6/12$, or $1/2$, is a rectangle. Now, how, exactly do we make a square, with an area of $1/2$? Not a rectangle, as we have now, but a square with the area $1/2$? What to do?

If you find and read the story of poor Meno, and his adventure with Socrates, you will see that we have the same prob-



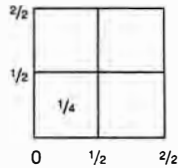
lem that Meno, and the little slave boy, had to tackle—well, almost the same problem. We actually have the inverse of the Meno problem. Meno’s problem was to start with one square and construct another one that is twice as large. In our problem, we are starting with one square, and we have to construct a new square that is half the size of the original square.

Let’s do this by attacking an even more interesting problem—the much dreaded monster, (gasp) the Pythagorean Theorem.

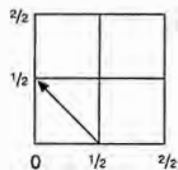
This one has been around for several thousands of years, and there are probably many books in your library which tell the story of Pythagoras, his school, and his students. Some are filled with interesting drawings and (sometimes) very complicated looking equations, and algebraic formulae. But, let’s just play with the essentials here.

First, we will go back to the problem, $1/2 \times 1/2$, and place some new squares at our zero point, as in the figure.

Now, draw a line from the bottom point marked $1/2$, up to the point marked $1/2$ on the left side. This new line is called a *diagonal*. The *diagonal* line cuts



our little square in half by making two triangles out of one little square (whose area, we already know, is $1/4$).

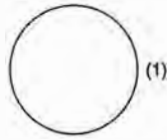


Perfect Squares from a Circle

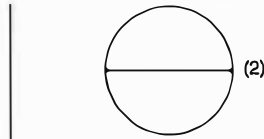
Let us pause here, and make a “perfect square”—by folding up a circle. First, we fold it in half, creating a line called a *diameter*, which makes the circular area fold over into a semi-circle. Then fold this semi-circle in half, creating a second diameter, 90 degrees from the first diameter. If we open the circle back up, we see a cross in the middle, formed from the intersection of the two diameters. So, fold the circle back up

and fold it a third time, across the arc, as shown.

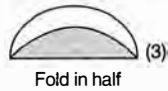
Now, when you open up the circle, you’ll see inside it a perfect square—and



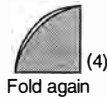
four triangles, and four little arcs of the circle as borders to the sides of the



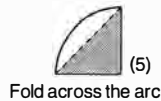
square. Are things becoming perfectly clear yet?



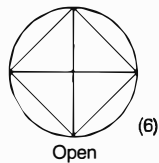
Now return back to our first square, with its two extra little squares stuck to the “zero starting point,” and with our *diagonal* line drawn across the $1/2$ point



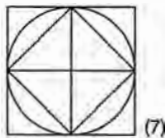
at the bottom, up to the $1/2$ point up on the left side. We now complete our work, by drawing the other three diagonals inside each of the other three



squares—and see that the *diagonals* make up a new square, inside the first



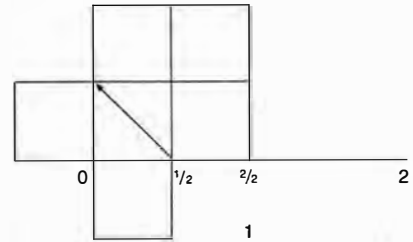
square. What is the area of the square we made out of the diagonals?



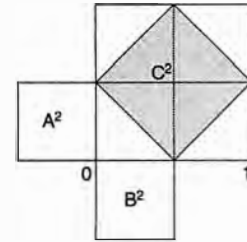
Now we can state the Pythagorean Theorem: If we arrange three squares in a triangle, with the sides of the triangle

made up by the sides of the squares—we may add the areas of two of the squares that are connected by a right (90-degree) angle, and that area will be equal to the area of the third square.

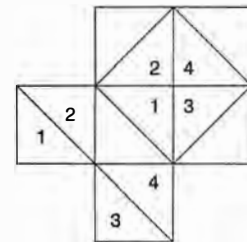
The “easier” way of saying this is “A squared plus B squared equals C squared. The “formula” is written $A^2 + B^2 = C^2$, and is just another one of the little tricks of algebra, which can be used



to allow students to convince themselves that they do not possess the brainpower to become “real scientists” or participate



in important matters of intellectual “heavy lifting.” I repeat: Parents beware: most textbooks are entirely misleading on this account.

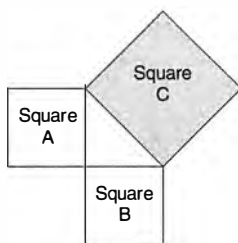


The most glaring and obvious problem is that there are no squares in the textbook examples—only algebra!

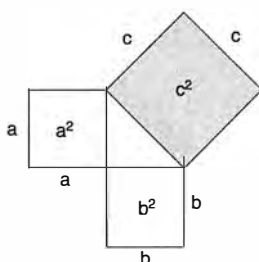
Blaaugggggggggugh!

But, if we return to the circle, in which we have inscribed a square, we can tame this little monster with geometry. Let us cut out the square, and then cut the square along its diagonals. Now we have four triangles. Place the square on a piece of paper and trace its outline. Now, take two of the triangles and arrange them into a small square, and arrange the remaining two triangles into another square.

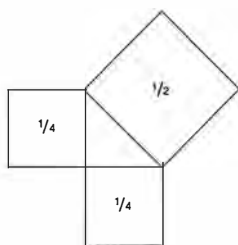
Now reconstruct the pattern, and write labels on the resulting parts of our little puzzle: Square A + Square B = Square C. If we look at the *sides* that touch, which make up the inside triangle, we can call the side of the first little square *a*, the side of the second little square *b*, and the side of the largest square *c*. Then, re-



membering that the *side* of a square is merely the border of the *area* enclosed



by the square, and that the area was constructed by dragging the side up to cover the surface needed, that operation is written a^2 . Now, we can go back and see that in our very first example, we can write $1/2 \times 1/2$ in this way: $1/2^2$, or one-half squared.



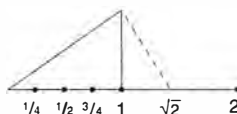
Now we see what A^2 , or a^2 (A squared) means. We also see that the whole formula $A^2 + B^2 = C^2$ means cutting up two smaller squares and fitting them together to make a big square from the little pieces.

Mathematicians, investigate whether this is always true. It is *not* true that $A^2 + B^2 = C^2$ if we try to do this on a sphere! (To see why, read the article "Have a Ball with a Lenart Sphere," by Susan Welsh in *21st Century*, Summer 1997, Vol. 10, No. 2, page 87).

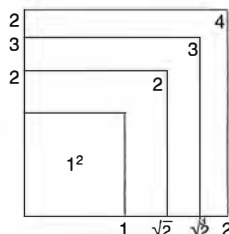
$$\frac{1}{4} + \frac{1}{4} = \frac{1}{2} \quad \text{Side} = \sqrt{1/2}$$

$$1 + 1 = 2 \quad \text{Side} = \sqrt{2}$$

So, now we have tamed our monster. Or have we? Let's see if we really have tamed this beast.



The square root of $1/2$ is not an integer; $1/4$ in area is not equal to $1/4$ of a line. We are compiling a series of para-



doxes and enhanced perspectives for viewing numbers, and our ideas about what numbers (and our mental powers) are.

To be continued

Notes

1. "Meno," translated by W.K.C. Guthrie, in *Plato, Collected Dialogues*, eds. Edith Hamilton and Huntington Cairns (Princeton: Princeton University Press, 1989).

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The Case for Mars II, Ed., C. P. McKay, 1985, Second Printing 1988, 730p, Hard Cover \$30; Soft Cover \$20

The Case for Mars I, Ed., P. J. Boston, 1984, Second Printing 1987, 348p, Hard Cover \$45

The NASA Mars Conference, Ed. D. B. Reiber, 1988, 554p, Hard Cover \$25; Soft Cover \$15.

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The Manic Sun and Its Role In Climate Change

by Brian A. Tinsley

The Manic Sun

Nigel Calder
London: Pilkington Press, 1997
Hardcover, 211 pages, \$24.95

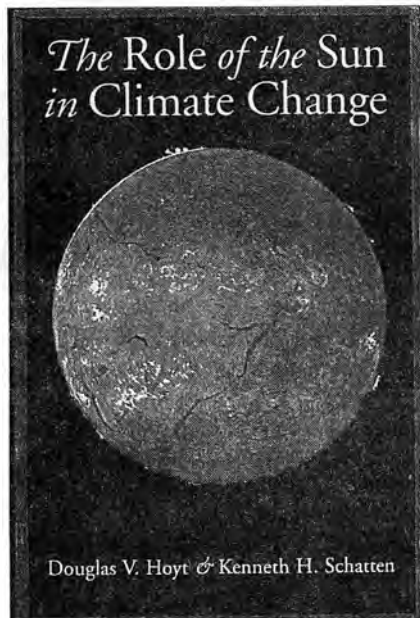
The Role of the Sun in Climate Change

Douglas V. Hoyt and Kenneth H. Schatten
New York: Oxford University Press, 1997
Paperback, 279 pages, \$29.95

These two books are reviewed together because they complement each other in a curious way. While both discuss evidence that solar activity, in the form of violent events on the surface layers of the Sun, affects climate on Earth, each book focusses on completely different mechanisms to account for the apparent Sun-Earth connection. This dichotomy brings out the uncertainties in the present understanding of solar activity influences on climate, and of the mechanisms involved in global warming in the 20th century, as part of a greater uncertainty in predicting the amount of global warming to be expected in the 21st century. The climate uncertainties include the factors influencing the radiation balance of the Earth, especially the effects of clouds.

History of Solar Activity and Climate

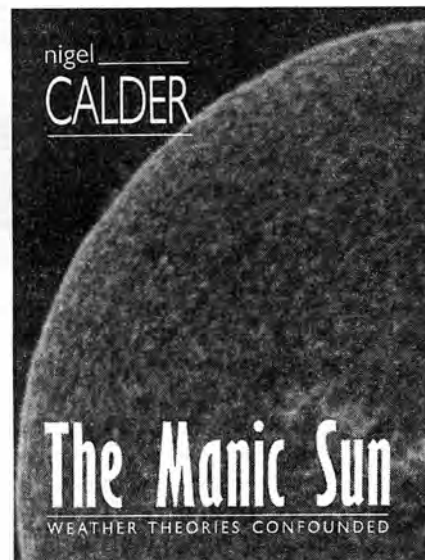
Hoyt and Schatten are solar physicists who have been immersed in the literature on solar activity and climate for many years. *The Role of the Sun in Climate Change* is their review of the field, written for non-specialists, with 119 black-and-white illustrations and several tables and appendices. They describe centuries of observations of the face of the Sun, and what this has revealed about solar activity. They then discuss the implications of more than a thousand papers, most of which have been published in the last two centuries, that report correlations between climate change on Earth and the level of solar activity.



The main theme in Hoyt and Schatten's book is the question of whether these climate changes, which include decadal changes in regional temperature and precipitation as well as long-term changes in global mean temperature, can be the result of changes in the solar brightness. More exactly, they are considering changes in the radiative component of the Sun's output, known as total solar irradiance, or the output of photons in the form of ultraviolet, visible, and infrared radiation, which is the direct heat input of the Sun to the Earth. It has been speculated for at least two centuries that the solar irradiance is variable and affects climate, but only in the last 17 years or so have there been reliable irradiance measurements that begin to define a relationship to solar activity.

Sunspots As Indicators of Solar Activity

Historical solar activity can be evaluated in two ways. The first, described in some detail by Hoyt and Schatten, is by

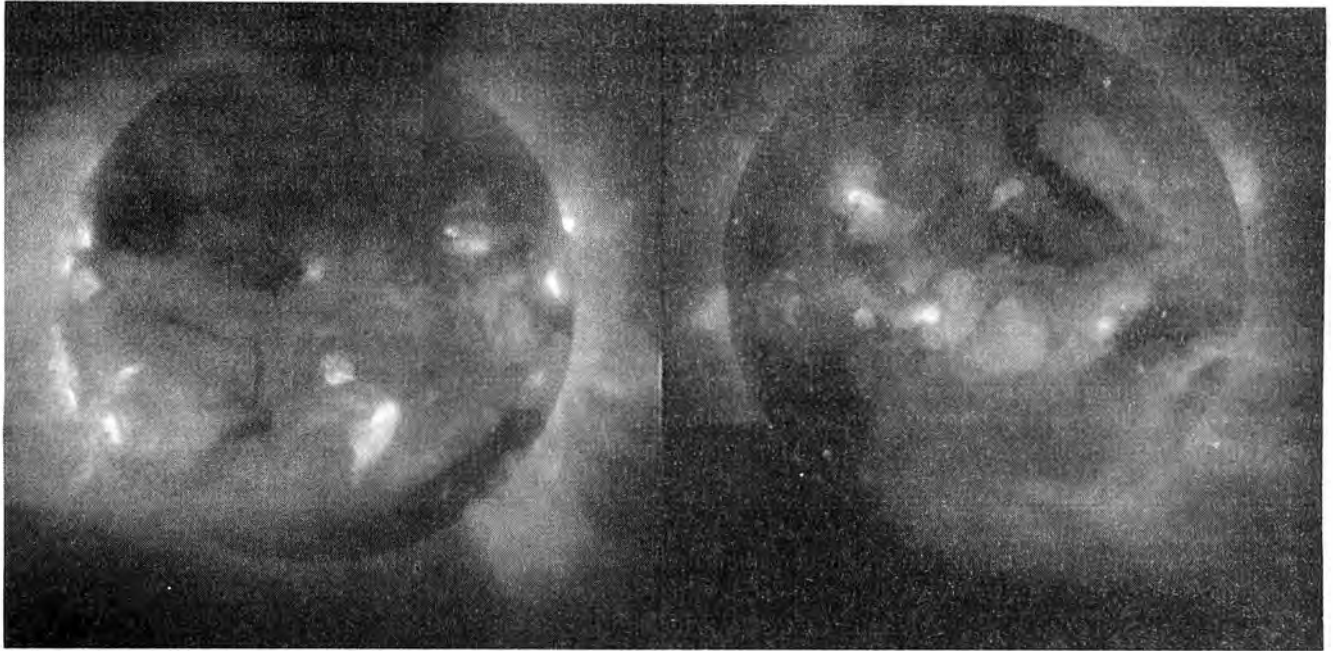


monitoring the number and appearance of the sunspots visible at any one time. Records have been made by astronomers almost daily for 400 years, and there is a well-established cycle with average period 11 years in the number present.

There are essentially zero sunspots at the minimum of the cycle, and 100 to 200 present in maxima in the latter half of the 20th century. But the number at maximum varies on a time scale of tens of decades; for about 30 years around the turn of the 20th century, there were only about 60 to 80 spots at maximum, and for about 50 years in the late 1600s, there were hardly any spots to be seen at all. This "Maunder Minimum" of solar activity coincided with the coldest part of a generally cool period in Europe known as the Little Ice Age.

Cosmic Rays As Indicators

The second way of evaluating historical solar activity involves the solar wind and cosmic rays, and is described in some detail by Nigel Calder. Calder is a science writer who writes for general au-



Images from Japan's Yohkoh spacecraft in *The Manic Sun*, p. 109

X-ray images of the Sun at maximum activity in 1991 (left) and with diminishing activity in 1994 (right). The large, dark, relatively cool areas are the source of the steady solar wind; the bright features are hot and unstable active regions. Eruptions from active regions violently perturb the solar wind magnetic fields, and reduce the cosmic ray flux to Earth.

differences on the implications for humanity of new scientific results in astronomy, biology, and the geosciences. His handsome book *The Manic Sun* is a journalistic-style narrative, lavishly illustrated with color and black-and-white photographs and diagrams. It includes remarkably up-to-date results from recent space missions and climate analyses, with a focus on cosmic rays and their effects.

Calder gives excellent descriptions of how the outer layers of the Sun generate the solar wind, which is an extremely hot (2 million°C), highly conducting gas that flows outwards from the Sun into the interstellar medium beyond the planets.

Changes in the solar wind cause magnetic storms and aurorae on Earth. The magnetic field irregularities embedded in the solar wind cause a variable amount of attenuation of the flux of cosmic rays coming into the Earth's atmosphere. The amount and strength of these irregularities of the solar wind magnetic fields increase with solar activity, so that the flux of cosmic rays varies approximately inversely with solar activity. Cosmic rays are extremely high energy nuclei of atoms that are energized by supernova explosions in the galaxy. A variety of possible cosmic ray effects on

clouds has been debated in the literature for at least 30 years, as alternative explanations for correlations of weather and climate with solar activity. Cosmic ray particles have enough energy so that nuclear reactions occur as they enter the atmosphere and collide with atomic nuclei in air molecules, producing radioactive isotopes. The trails of ionization they produce also permit the otherwise insulating air to become a weak conductor of electricity.

Calder describes the detailed and reliable records of solar wind and cosmic ray flux variations that are recorded in the annual deposits of the carbon-14 radioisotope in tree rings, and of both carbon-14 and beryllium-10 isotopes in annual layers of polar ice, which can be readily retrieved as polar ice cores. These proxy records of solar activity go back for thousands of years. They agree with the sunspot records in the region of overlap, and provide a wealth of data on the long term variations of solar activity and cosmic ray flux.

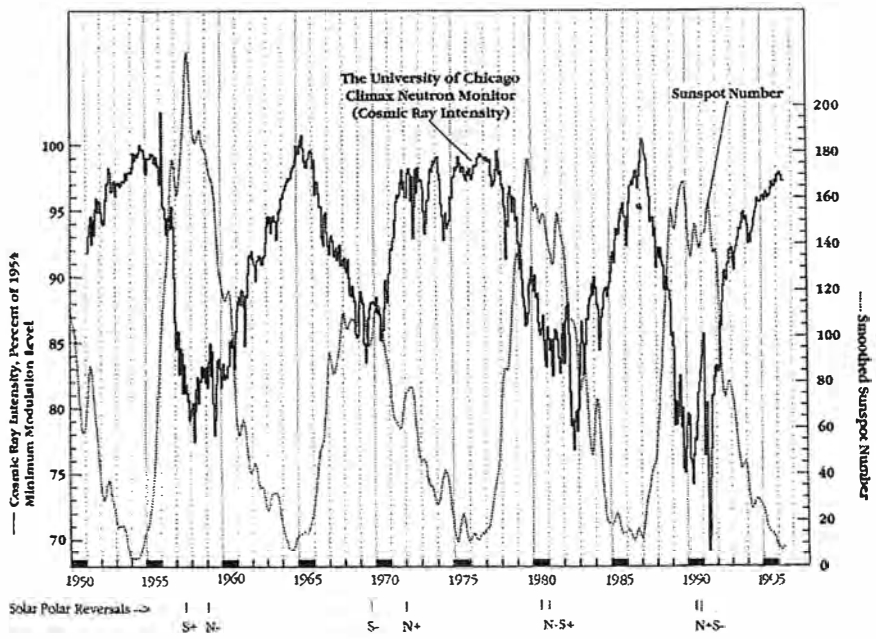
The tree rings and polar ice cores also provide direct records of regional and global climate change, which can be compared with the record of solar changes. Work by Eddy in 1976¹ showed at least five cycles of correlated variations of climate and solar activity in

the last 1,000 years, as inferred from carbon-14 and sunspot records and a variety of climate records.

Correlations with Solar Activity

In the 1970s and 1980s, much improved data bases of global climate became available in a form that could be readily analyzed by computers. Correlations with day-to-day changes in the solar wind were shown by Roberts and Wilcox and others.² Some very convincing correlations of atmospheric temperature and pressure with the decadal solar cycle were shown by Labitzke and van Loon.³ The "11-year" sunspot cycle has only an average period of 11 years, with the actual period ranging from about 9 years when the amplitude of the cycle is high, to about 13 years when the amplitude is low.

In 1991, Friis-Christensen and Lassen⁴ showed a very striking correlation between Northern Hemisphere land temperatures and solar cycle lengths, from 1860 to 1985. In 1995, Lassen and Friis-Christensen⁵ extended the cycle length and climate relationship back to 1600, using data from Chinese records, such as the earlier or later arrival of spring. (This result is discussed in detail by Calder, but is not mentioned by Hoyt and Schatten, who give few references to papers after 1993).



The Manic Sun, p. 133

Variations of cosmic ray flux at Climax, Colorado, showing the approximately inverse relationship to sunspot number, another indicator of solar activity. In addition to the solar activity cycle of average length 11 years, the cosmic ray flux shows broader peaks at alternate solar minima, for a superimposed cycle, averaging 22 years, as well as short-term decreases caused by solar eruptions.

The correlations of cycle amplitude or length with regional or global temperature prior to the 20th century—that is, before any significant rise in greenhouse gas concentrations—allow one to estimate how much of the 20th century rise in global mean temperature can be attributed to a purely solar effect (irrespective of the mechanism). A number of independent studies indicate that essentially all of the warming up to 1970 (about 0.3°C) can be attributed to the effects of solar activity, but that the warming (about 0.3°C) since 1970 could not, and is presumably caused by greenhouse gases.⁶

The 1991 study of Friis-Christensen and Lassen suggested that even the increase after 1970 was due to solar activity, but this is in conflict with the other studies. Also, a recent analysis by van Ulden and van Doorland⁷ concludes that the method used by Friis-Christensen and Lassen to estimate the solar cycle length is unreliable after 1975. Unfortunately, Calder has accepted the Friis-Christensen and Lassen results uncritically, and uses this as an argument that the human production of greenhouse gases has had small impact on global climate compared to solar activity.

By contrast, most of the atmospheric scientists that have been evaluating greenhouse gas effects and contributing to the Intergovernmental Panel on Climate Change reports on climate change have been maintaining that any effects of solar activity on global warming in the 20th century are small compared to those of human activity.

Possible Mechanisms

The major stumbling block for general acceptance of the above results pointing to significant solar activity effects on weather and climate is that it has not been possible for scientists to reach agreement on the mechanism. Hoyt and Schatten discuss solar irradiance as their only serious candidate, but point out a number of problems and inconsistencies with this interpretation, and come to no final conclusion. They are not even prepared to say whether they consider that the correlations represent a real physical response to solar activity, rather than an accidental coincidence of independent variations. One of the problems is that the solar irradiance variations, as measured during the last 17 years by satellites, and also as inferred from astronomical measurements of changes in Sun-like stars, produce ef-

fects between a factor of 2 and 10 too small, when used as inputs in global climate models.

Hoyt and Schatten choose not to discuss alternative mechanisms as a solution to these problems. They do not refer to the literature on changes in solar ultraviolet radiation affecting global ozone. This acts as a greenhouse gas and is a mechanism for climate change.⁸ Only in a brief section do they refer to “non-radiative methods by which the Sun could affect weather and climate,” describing them as “complicated mechanisms.” Although they include 30 pages of references and bibliography up to 1993, there is no discussion of work on short-term (day-to-day) responses of atmospheric temperature and dynamics to solar wind changes,^{2,9} which can be understood only in terms of non-radiative mechanisms, such as those involving clouds.¹⁰

Cloud Cover Variations

In 1997, Svensmark and Friis-Christensen¹¹ published the results of an analysis that showed a striking correlation between low latitude cloud cover changes and cosmic ray flux changes for the period 1984-1991. The cloud cover was 3 to 4 percent greater at sunspot minimum (cosmic ray maximum) than at sunspot maximum. Calder places much emphasis on this result. The change is large enough to produce important climate effects, by changing the amount of solar radiation that is reflected back to space, instead of reaching the surface. When a corresponding cloud cover decrease is related to the increase in solar activity during the 20th century, it is a large enough effect to account for all of the observed global warming.

However, a critical examination of this result again raises many uncertainties. Kuang, Jiang, and Yung¹² have analyzed the same cloud data, and although they confirmed the 3 to 4 percent variation of cloud area, they found that the cloud optical thickness (affecting the fraction of backscattered light) decreased when the cloud area increased, so that the amount of reflected sunlight, and hence effects on global temperature, remained approximately constant.

Also, the changes in cloud area correlated to some extent with the El Niño-Southern Oscillation Index. An analysis over a considerably longer period than the less than one solar cycle examined,

will be required to clearly separate cosmic ray effects from other sources of cloud cover variations.

Neither Calder nor Svensmark and Friis-Christensen address the details of any mechanism by which cosmic ray particles might affect clouds, or the various objections that have been raised in the literature concerning the possibility of a direct effect. The production of cloud droplets in a Wilson Cloud Chamber by cosmic ray particles is well known, and is described by Calder as if it were applicable to the atmosphere. However, the air in the chamber must be supersaturated by several hundred percent before droplets will form around the ions, and the supersaturation in the atmosphere is almost always less than 2 percent.

Indirect Cosmic Ray Mechanism Needed

An indirect mechanism for cosmic ray effects on clouds is called for. Such a mechanism has been developed by the author of this review, in a series of papers beginning in 1991,^{9,10} and it involves changes in clouds by a process called electrofreezing, that is, the freezing of already existing liquid droplets that are below 0°C in temperature. In this hypothesis, the rate of freezing is correlated with the accumulation of electrostatic charge on the droplets at the tops of clouds. Charge is known to flow down from the ionosphere, which, on average, is 250kV positive with respect to the surface, with the current density being determined not only by cosmic ray ionization, but by relativistic electron precipitation from the Earth's radiation belts, and also by other solar wind inputs affecting the ionospheric potential.

The current density, which is a few picoamperes per square meter, is denoted as Jz, with the z indicating the vertical direction. The Roberts effect, which is a short-term decrease in the vorticity of Northern Hemisphere winter storms, is associated with a short-term decrease in the cosmic ray flux as a solar eruption introduces magnetic irregularities into the solar wind. The reduction of cosmic ray flux and atmospheric conductivity produces a corresponding decrease in Jz.

The Wilcox effect is a very similar decrease in the vorticity of winter storms, but it is not associated with systematic

cosmic ray flux changes. It is, however, associated with decreases in Jz, apparently caused by decreases in relativistic electron flux and the associated Bremsstrahlung X-ray flux into the stratosphere.¹³ Changes in atmospheric temperature and dynamics associated with six independent variations in Jz were reviewed by this author in 1996,⁹ with two of them being independent of cosmic ray flux changes. These results are consistent with an indirect cosmic ray effect, but not a direct one.

Uncertainty in Cloud Physics

Freezing of droplets in clouds is a fundamental process leading to precipitation and cloud dissipation, but it is one of the least well understood areas in meteorology, and that of electrofreezing processes in clouds has even more uncertainties. There are a number of candidates for specific electrofreezing processes that have been discussed in the literature,^{9,10} but so far, a definitive account of one applicable to the atmosphere is not available. Current work on some promising processes seems likely to provide such an account in the next few years—if support for the research can be found. It could have important consequences for meteorology generally, as well as for the question of solar influences on global warming.

Another important uncertainty in predicting future global warming is the effect of sulfate aerosols from human industrial activity on clouds. The aerosols act as condensation nuclei, and increase the number of cloud droplets while reducing their size, which increases the reflectivity of the clouds. The uncertainties in evaluating this cooling effect have been found to be larger than previously thought,¹⁴ so that aerosol cooling could be cancelling out much of the greenhouse gas warming from the same industrial activity.

Conclusions

Calder claims that solar effects on global warming are clear, caused by changes in the flux of cosmic rays, and large enough to invalidate the work of others, who attribute most of the warming to human effects. Hoyt and Schatten discuss much evidence for solar brightness changes and for apparent effects on climate, but come to no firm conclusion as to whether they are real. This review has argued for the role of both solar variability and human effects on global

warming, but has pointed to the many remaining uncertainties, especially concerning clouds, that need to be resolved before reliable predictions can be made of the amount of global warming to be expected in the 21st century.

Brian A. Tinsley is a professor of physics at the University of Texas at Dallas. His research in upper atmosphere and space science since 1957 has led to his current work on exploring the links between "space weather" and terrestrial weather and climate. He has been active in a number of international scientific organizations, and has published more than 100 scientific papers and reports.

Notes

1. J.A. Eddy, 1976. *Science*, Vol. 192, p. 1189. Recent ice core results for correlated cosmic ray flux and climate changes are given by M. Stuiver et al., *Quaternary Research*, Vol. 44, p. 341, (1995).
2. Short-term effects of solar wind changes on tropospheric vorticity have been described by W.O. Roberts and R.H. Olson, *J. Atmos. Sci.*, Vol. 30, p. 135 (1973); J.A. Wilcox et al., *Science*, Vol. 180, p. 185 (1973); M.F. Larsen and M.C. Kelley, *Geophys. Res. Lett.*, Vol. 4, p. 337 (1977); B.A. Tinsley and G.W. Deen, *J. Geophys. Res.*, Vol. 96, p. 22283 (1991); B.A. Tinsley et al., *J. Geophys. Res.*, Vol. 99, p. 16805 (1994).
3. Joint papers by Karin Labitzke and Harry van Loon on decadal climate responses include: *J. Atmos. Terr. Phys.*, Vol. 50, p. 197 (1988); *J. Climate*, Vol. 1, p. 905 (1988); *J. Climate* Vol. 2, p. 554 (1989); *Meteorol. Zeitschrift*, Vol. 3, p. 259 (1994).
4. E. Friis-Christensen and K. Lassen, 1991. *Science*, Vol. 254, p. 698.
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A New Look at Post-Polio Syndrome

by Katherine Ransohoff Notley

The Post-Polio Syndrome: Advances in the Pathogenesis and Treatment
Marinos C. Dalakas, Harry Bartfeld, and Leonard T. Kurland, Eds.
New York: The New York Academy of Sciences, 1995
412 pages, hardback, \$100

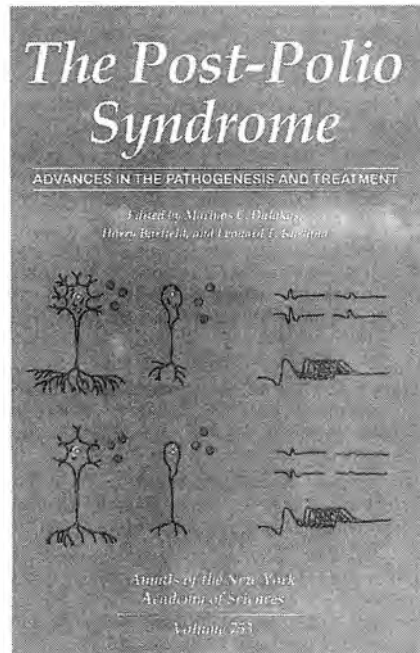
Post-polio syndrome occurs in some individuals who were stricken with paralytic poliomyelitis, and who, after an average of 30 years of stability and sometimes complete apparent recovery, undergo new symptoms of fatigue, joint and muscle pain, further weakening in affected muscles, and new weakness even in unaffected or recovered muscles (referred to as post-polio muscular atrophy). Some have new problems with breathing and swallowing (dysphagia).

This book is comprised of papers submitted to a conference on the subject in April 1994, and is clearly not meant for the layman. Nonetheless it offers much insight to those who suffer from, or are at risk, of this syndrome. I recommend it to laymen who have had polio, because, in general the authors are optimists, who avoid some of the "psycho-babble" pitfalls of earlier material. It is not "light reading," but it is "enlightening." In the decade or so that I have followed the literature, I was gratified that this book answered many of the questions I had had.

When post-polio syndrome, specifically the new muscle weakness, first became a topic of concern, frightening hypotheses included whether it was some accelerated form of an aging process, whether the disease itself was returning to strike its once-triumphant victims, or whether it was a slowly progressive, non-fatal form of amyotrophic lateral sclerosis (Lou Gehrig's disease). All were mercifully disproven.

What Is Known

In the recovery phase of acute paralytic polio, motor neurons that are undamaged, or slightly damaged, sprout to reinnervate nearby muscles whose motor neurons have been killed or severely damaged. Researchers, led by Marinos Dalakas at the National Institutes of



Health, discovered that new weakness tended to occur roughly 30 years after polio (regardless of age during the acute illness), when overextended motor neurons, innervating ever-larger muscle groups, "gave out." It was initially not clear why these neurons would themselves succumb, and comparative studies on aging controls (normally, individuals begin to lose motor neurons about age 60) only made the question more perplexing: Despite the loss of motor neurons, individuals over 60 show no progressive muscle weakness.

Several papers in this volume document that, in fact, the affected muscles of post-polio victims are being reinnervated and denervated constantly, which implies that, in time, remaining motor neurons become overextended, especially if they were subclinically damaged in the acute disease. Such a process would also account for the fact that muscular atrophy can strike limbs that, to all appearances, had been unaffected, as well as those that, to all appearances, completely recovered full strength. That still does not explain *why* these motor neurons are dying in the first place.

This book is the first I have read, that addresses the question of *subclinical* effects of the acute illness: Simply put, during epidemics striking up to 50,000 individuals, medical concern centered on restoring atrophied limbs, providing ventilation (the infamous "iron lungs"), and the long road to rehabilitation. In part, because patients who survived the acute illness, progressed in their therapy and stabilized, sometimes to full recovery, there was no urgency to investigate whether there might also be problems with what couldn't be seen. Now, because of advances in diagnostics, the subclinical damage can be tagged, even decades after the disease has left. It is absolutely to the credit of these researchers that they were never satisfied with cataloging the mechanics of the phenomenon, but continued to doggedly seek *why* it was occurring. There is a sense of optimism—patient impatience—in the contributions to this book, that I have not seen in other papers, over the years.

Individualizing Rehab and Exercise

Another element to the post-polio syndrome, less devastating than the muscle atrophy, but almost universally common and still quite debilitating, is the wear-and-tear on soft tissues, joints, other muscles, which must compensate for areas of paralysis. There are many papers that address various types of rehabilitation therapy, in order to minimize further damage, and in some cases, reverse it.

One of the best papers I have ever read that covers both elements of what is now called post-polio syndrome, appears in this book, "National Rehabilitation Hospital Limb Classification for Exercise, Research, and Clinical Trials in Post-Polio Patients," by Lauro S. Halstead, Anne Carrington Gawne, and Bao T. Pham. As the authors point out, when faced with weakening muscles, the initial reaction was to avoid overstress, meaning "either no exercise or, at the most, very limited exercise."

What Halstead (who, himself, suffers from post-polio muscular atrophy), et al. point to, however, is that carefully tailored exercise regimens are effective in

treating and even reversing some components of the syndrome as a whole. "It is now becoming clear that new muscle weakness in many persons may have a reversible or 'treatable' component that responds well to certain types of exercise. However," they stress, "it is also clear that the same exercise program cannot be prescribed to each individual because the extent of involvement and possibly the cause of new weakness may vary from individual to individual as well as from limb to limb within the same person."

In order to expand such necessary "customizing" in rehabilitation and exercise, the team developed "a limb-specific exercise classification to make exercise prescriptions . . . more rational and systematic. In addition, it is anticipated that such a classification would be very useful in clinical research trials testing the impact of various medications or new exercise protocols. It is our hope that use of this classification will give us a common language and make it possible to compare more accurately the results of different types of interventions applied to the same class of limbs—in other words to compare like with like."

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BOOKS RECEIVED

Phantoms in the Brain—Probing the Mysteries of the Human Mind, by V.S. Ramachandran. New York: William Morrow, 1998. Hardcover, 328 pages, \$27.00.

Star Ware—The Amateur Astronomer's Ultimate Guide to Choosing, Buying, and Using Telescopes and Accessories, by Philip S. Harrington. Second edition. New York: John Wiley, 1998. Paperback, 376 pages, \$19.95.

Earth Story: The Shaping of Our World, by Simon Lamb and David Sington. Princeton, N.J.: Princeton University Press, 1998. Hardcover, 240 pages, \$29.95

The Eighth Day of Creation: Makers of the Revolution in Biology, by Horace Freeland Judson. Expanded edition. Cold Spring Harbor Laboratory Press, 1996. Paperback, 714 pages.

Fracture—A Topical Encyclopedia of Current Knowledge, edited by Genady P. Cherepanov. Materials science. Malabar, Fla.: Krieger Publishing Company, 1998. Hardcover, 870 pages, \$179.50.

Waves and Grains: Reflections on Light and Learning, by Mark P. Silverman. Princeton, N.J.: Princeton University Press, 1998. Paperback, 411 pages, \$22.50.

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Laser—Light of a Million Uses, by Jeff Hecht and Dick Teresi. Mineola, N.Y.: Dover Publications, 1998. Reprint of *Laser: Supertool of the 1980s*. Paperback, 261 pages, \$8.95.

I Wish I'd Made You Angry Earlier—Essays on Science, Scientists, and Humanity, by Max Perutz. Cold Spring Harbor Laboratory Press, 1998. Hardcover, 354 pages.

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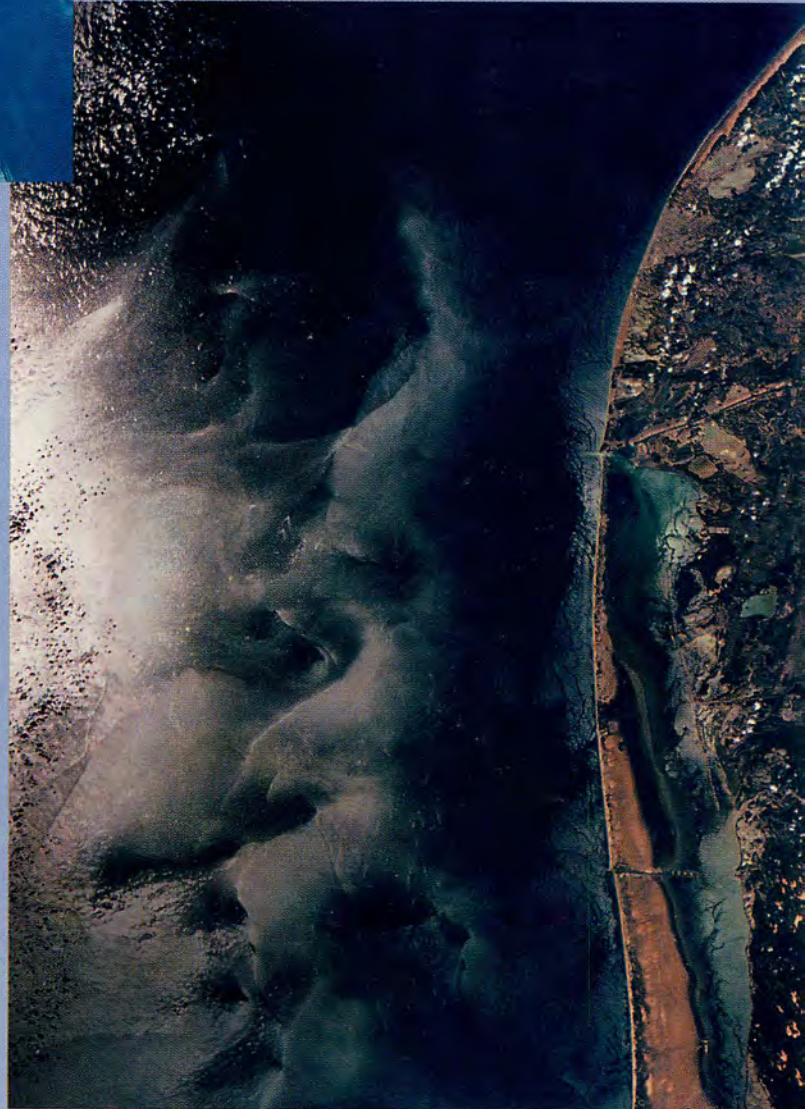
Southeast coast, near the tip of the Kamchatka Peninsula, Russia. Warming coastal waters have broken up the pack-ice, where it is caught up in upwelling plumes and formed into mushroom-shaped eddies. Vertical photo by Dr. Kathryn D. Sullivan, Payload Commander on the crew of the Atlantis, taken March 28, 1992, with a modified Hasselblad 70-mm film format with a 250 mm lens, from altitude of 160 nautical miles.



The Strait of Gibraltar is in the foreground, with the Sun's reflection covering the eddy-field in the Alboran Sea, between Spain and Morocco. The white puffs over land are clouds. Taken May 21, 1996, by Curtis H. Brown, Jr., Pilot of the Endeavour, with a modified Hasselblad 70-mm format camera with 100-mm lens, from an altitude of 153 nautical miles.

SPIRAL EDDIES: THE DISCOVERY THAT CHANGED THE FACE OF THE OCEANS

Twenty-five years ago, in November 1973, the vast field of spiral eddies spotted off the coast of Argentina by the crew of Skylab-4, piqued the interest of two Navy oceanographers who were studying acoustic signals. They hypothesized that eddies were formed along the shearing boundaries of every significant ocean current around the world, and a project was set in motion to determine this. Robert E. Stevenson, America's pioneer space oceanographer, tells the fascinating story of how the Skylab and Shuttle observations of spiral eddies, caught in the Sun glitter, revolutionized our knowledge of the oceans. As Stevenson points out, the fact that the ocean's surface is a vast, nonlinear array of spiral eddies, makes it impossible to model using the conventional averaging techniques.



Western Gulf of Mexico off Padre Island near the mouth of the Rio Grande River, Texas. Taken by Col. Robert Stewart, in October 1985, using a 70-mm film format, modified Hasselblad camera with a 250-mm lens, at an altitude of 278 nautical miles.

In This Issue:

SPACE LABORATORIES WILL ADVANCE SCIENCE AND HEALTH

The unique microgravity environment of space is a vital capability in the quest for understanding human biology and improving human health, and the coming International Space Station will make it possible for scientists to develop this capability to the fullest. Marsha Freeman reports on the exciting possibilities already unleashed by work on the Space Shuttle and the Russian Mir. As she shows, crystals grown in space are providing new clarity and detail in the structure of proteins, such that space-grown crystals of insulin provide a detailed view of its structure that is equivalent to being able to see a grain of powdered sugar from 180 miles away. Another advance is the growing of three-dimensional tissue cultures to help scientists study, treat, and cure disease.



NASA

The crystal shown here is forming from the evaporated mercury iodide in the Vapor Crystal Growth System Furnace, which was flown on an International Microgravity Laboratory Space Shuttle mission in 1992.

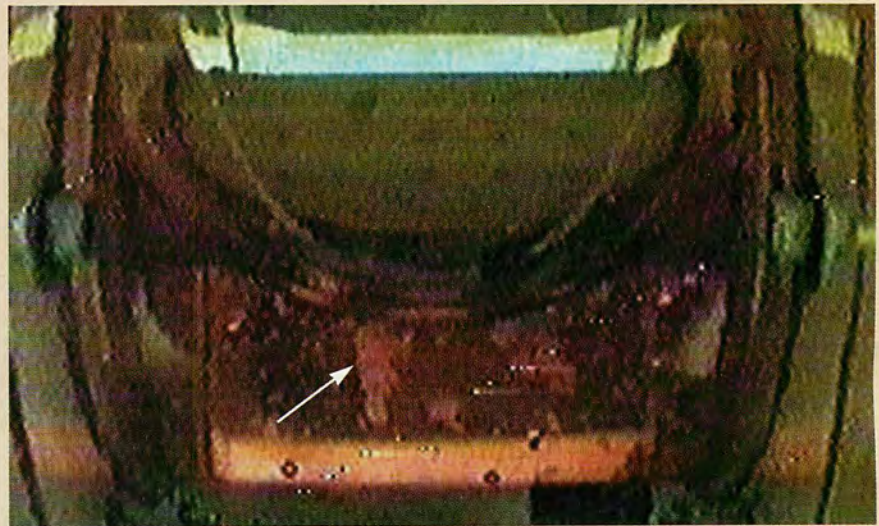


Science Museum of Virginia

Allais's experiments began with an examination of never-before studied irregularities in the Foucault pendulum. Here, a Foucault pendulum at the Science Museum of Virginia in Richmond. The pendulum rotates 360° in 29 hours, 27 minutes. The map beneath the 95.8-foot pendulum shows one half of the Earth's surface, and reminds viewers that the purpose of the pendulum experiment is to show that the Earth turns.

RECONSIDERING THE LAWS OF GRAVITATION

From 1953 to 1958, Prof. Maurice Allais carried out experiments, which revealed anomalous motions of a paraconical pendulum. As Allais demonstrates in our lead feature, the current theory of gravitation provides no explanation for this. The pendulum anomalies, observed continuously for months, suggest the existence of a previously unknown field. Allais also proposes that the same source is responsible for the anomalies he observed, and for those found in the Michelson-Morley-Miller experiments.



NASA

This photograph of human breast cancer tissue (near arrow) growing in a bioreactor was taken by astronaut Andy Thomas during his four-month stay aboard the Mir station.