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September-October 1988

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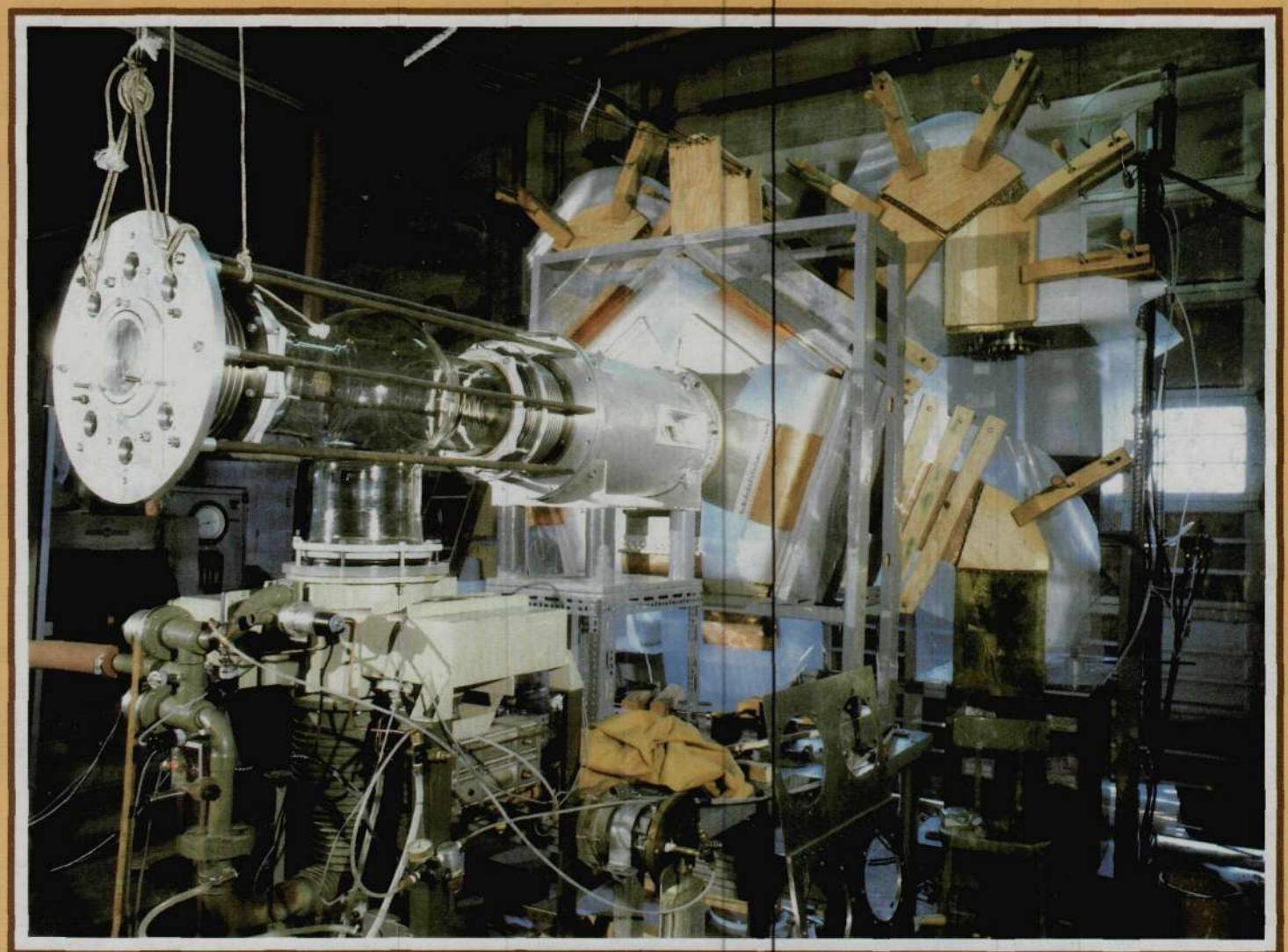
Will the U.S. Stay in Space? P. 56

The Plasma Focus

Universal Machine of the Future?



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21st CENTURY
SCIENCE & TECHNOLOGY

21st CENTURY SCIENCE & TECHNOLOGY

Vol. 1, No. 4 September-October 1988

Features

News

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21st Century Science & Technology (ISSN 0895-6820) is published six times a year, every other month, by 21st Century Science Associates, P.O. Box 65473, Washington, D.C. 20035, Tel. (703) 777-7473. Dedicated to providing accurate and comprehensive information on advanced technolgies and science policy, **21st Century** is committed to restoring American scientific and technological leadership. **21st Century** covers the *frontiers of science*, focusing on the self-developing qualities of the physical universe in such areas as plasma physics—the basis for fusion power—as well as biology and microphysics, and including ground-breaking studies of the historical development of science and technology.

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Subscriptions by mail are $20 for 6 issues or $38 for 12 issues in the USA, Canada, and Mexico. *Airmail subscriptions to other countries are* $40 for 6 issues.

Address all correspondence to **21st Century**, P.O. Box 65473, Washington, D.C. 20035.

POSTMASTER: Send address changes to **21st Century**, P.O. Box 65473, Washington, D.C. 20035.

ISSN 0895-6820

On the cover: The plasma focus device at the Stevens Institute of Technology; photograph by Louis Gardella; cover design by Virginia Baier.

The Justice Department's War On Defense—and Science

Few Americans caught up in the horror of the destruction of the Challenger have ever been told the true story behind that awful accident. They do not know that if any single agency can be blamed for the disaster, it is the U.S. Justice Department. If the Justice Department is allowed to continue to operate unchecked in its so-called investigations of alleged defense procurement frauds, then we can expect an even worse disaster to befall us: the destruction of what is invidiously called the military-industrial complex, and along with it this nation's ability to defend itself and the Western alliance.

In December 1985, James Beggs, then administrator of the National Aeronautics and Space Administration, was indicted along with other former or current management officials of the General Dynamics Corporation for conspiracy to violate Armed Services procurement regulations. Because of the indictment, Beggs was forced to resign from his position at NASA. As Beggs has stated publicly, he would never have allowed the Shuttle launch to take place under the stressful weather conditions that prevailed in Florida on the morning of Jan. 28, 1986. But the Justice Department had placed NASA in the hands of an inexperienced and politically motivated appointee, William Graham—now science adviser to President Reagan—and that launch took place.

Predictably, the case against Beggs and General Dynamics was dropped for lack of evidence in June 1987, *but by then the damage had been done*. William Weld, then head of the Justice Department's Criminal Division, held a press conference June 22, 1987 to say that he could not explain why the prosecution had "overlooked" 82 boxes of documents that proved the innocence of the defendants. However, perhaps the explanation had been made a year earlier when Weld himself bragged at Senate confirmation hearings for his Justice Department appointment that defense contractors would be his particular target.

Whether or not some corruption exists, the manner in which it is being addressed (in particular the enormous media hype putting individuals and corporations on trial that are yet to be even indicted under any judicial proceedings) will have a disastrous effect on U.S. military preparedness. *Cui Bono?* The Soviets, not the American people, are the ones most likely to benefit from the actions of the Justice Department task force.

Officers in the Pentagon will be looking over their shoulders during the most innocent transactions, wondering how their actions might be misconstrued. Worse, the paralysis of the procurement process, which will undoubtedly follow from a stretched-out investigation, will hit an industry already under enormous economic pressure because of cutbacks in the military budget, cancellations, and stretch-outs of contracts. The aerospace industry is already laying off thousands, in a situation in which civilian aviation is stagnating. The latest round of military airplane accidents has highlighted the dangerous situation in aeronautics, where planes that are no longer safe are not replaced and maintenance is inadequate.

Not a Matter of Cost Accounting

The point is that war is not a matter for cost accounting; it must be won.

War preparedness involves having under development continual advancements in weapons technology, which means the ability to scrap weapons that may be still serviceable but are obsolete. Suppliers must have great flexibility in meeting the demands of the military for upgrading weapons, even beyond the specifications that may have been negotiated in a contract.

In the long run, such a policy is of great benefit to the civilian economy because these technologies are the breeding stock for upgrading productivity in general. This happens in obvious ways, as in the case of the introduction of transistors and computers—the whole of the semiconducting industry. But it happens more subtly as well, by

upgrading the standards of machine tooling, and so on. The much studied example of this is NASA's Apollo program: For every dollar spent on development in the Apollo economy, it is conservatively estimated that the U.S. economy gained 10 dollars back from increased productivity.

President Eisenhower did this nation a grave disservice when he issued his famous warning about the dangers of the development of a "military industrial complex." This term quickly became a political buzz word, but what did it really mean? Weapons do not cause war; as history shows, war is caused by a policy of political appeasement.

The so-called military industrial complex has been and must continue to be a *science driver* for this economy, perhaps best exemplified by the Strategic Defense Initiative and its advanced technologies. At the same time, the nation must adopt and carry out higher goals, like the colonization of Mars, which can play the same role in leading the world into the 21st century.

The Antiscience Mob and Dr. Martin Welt

At a time when food shortages are on the horizon not just for the developing sector but right here in the United States, the U.S. Justice Department is conducting a witch-hunt against a pioneer of food irradiation—the technology that could vastly increase the world's food supply.

Under the banner of the antiscience mob, Dr. Martin Welt, the man who has fought for more than 20 years to commercialize food irradiation, was put under federal indictment in New Jersey in March, charged with "conspiring to obstruct justice" for alleged violations of Nuclear Regulatory Commission regulations during the time that he was president of Radiation Technology, Inc.

With much press fanfare, federal prosecutor Jacqueline Wolff announced that she wanted Welt jailed for these "crimes." Just after she handed down the indictment, she was appointed "environmental crime coordinator" for the state of New Jersey. As quoted in the *Newark Star Ledger*, Wolff said: "Environmental crime shouldn't be treated as anything less than any other type of crime. . . . I think they'll [industrial corporations] be more concerned about being incarcerated than about paying fines," she said. "It's easy for a corporation to pick up the fine. It's not so easy for them to pick up a jail term."

Welt's trial took place in late June, with prosecutor Wolff telling the jury that New Jersey had become a national disgrace as a dumping ground for dangerous chemicals. With all the histrionics of an antinuclear rabble-rouser, Wolff told the jury that the jailing of Welt was necessary to prevent the much more dangerous nuclear industry from making New Jersey its dumping ground.

The jury found Welt guilty on six counts—violations of NRC regulations—but found him innocent of the charges of conspiracy to obstruct justice. Welt will be sentenced Sept. 20.

One court observer reported that since the prosecutor had built her case on how Welt was a devil who not only had planned the NRC violations for reasons of greed, but also had conspired and lied to cover them up, it was actually a victory that the jury rejected Wolff's main argument.

A Political Witch-hunt

That this is a purely political case is clear from the simple fact that the alleged violations of NRC regulations are minor—for example, changing a safety device and not notifying the NRC until after it was done, instead of before. Usually when minor, or even major infractions of NRC safety regulations occur, there are reprimands or fines. The weekly news releases of the NRC, in fact, are full of instances of such fines.

But Welt's case was handled differently. Welt had aggressively pursued the commercialization of food irradiation and spoken out on behalf of nuclear power, publicly debating the leading antinukes. When others in the nuclear industry gave up the fight, he persisted, and it is because of his persistence that the Food and Drug Administration regulations were changed to permit the irradiation of spices, herbs, enzymes, fruits and vegetables. Because he would not cater to the environmentalists and baby their fears about the nuclear monster, he has been a prime target of the antiscience mob and its media outlets. They have made it clear that they want Welt shut down in order to shut down the technology of food irradiation.

In the past 25 years, the environmentalist movement has gained ground in America, inch by inch supplanting traditional Judeo-Christian values with pagan ideas about mother nature, replacing reason with superstition, equating technological and industrial progress with "greed." In this media-controlled environment, public "opinion" has come to take precedence over scientific fact.

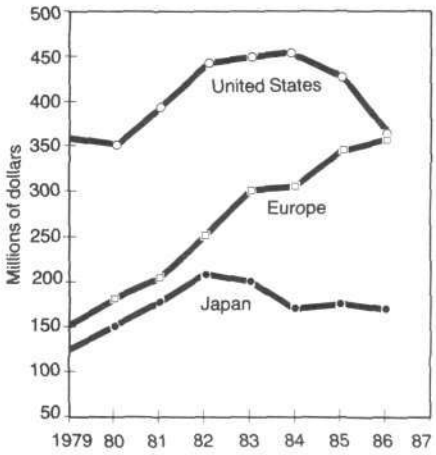
Yes, there is such a thing as environmentalist crime. And if this country wants to get serious about it, we could start convicting and jailing the environmentalists whose actions against nuclear power, against pesticides, and against industry in general have directly and indirectly lowered the standard of living in this country and caused the needless deaths of millions in the developing sector.

Letters of Support Urged

The antiscience mob wants Martin Welt jailed as a ritual sacrifice in their battle to bring us into a New Dark Age. We urge readers who know Welt or know of his work to send letters that can be used in his support to his attorney: Michael Querques, 433 Central Avenue, Orange, New Jersey 07050.

NEWS BRIEFS

Comparison of Fusion Expenditures in The U.S., Europe, and Japan



Source: Fusion Power Associates

The United States is now second to Europe in the funding of fusion research. The Japanese effort is also comparable in size, because the Japanese budgets exclude personnel costs.

WORK ON ITER, INTERNATIONAL FUSION REACTOR, MOVES FORWARD

Forty scientists from the United States, Japan, the Soviet Union, and Western Europe are working this summer at the Max Planck Institute in Garching, West Germany, on a conceptual design for a fusion energy engineering test reactor. The goal of the project, called ITER for International Thermonuclear Experimental Reactor, is to develop a design by the end of 1990. The work will also include validating research and development being conducted by the fusion programs in each of the nations. The 10-man U.S. delegation is led by Dr. John Gilliland of Lawrence Livermore National Laboratory. The U.S. Department of Energy expects to devote about $50 million to ITER over the next three years. Many fusion scientists have pointed out that it is foolhardy to believe that an international program can substitute for a dwindling U.S. program, where budget cuts have forced a halt to new experimental devices.

PROPOSAL UNDER STUDY TO MINE HELIUM-3 FROM THE MOON

The National Aeronautics and Space Administration's Lewis Research Center in Cleveland hosted a workshop in April to evaluate research ongoing at the Fusion Technology Center at the University of Wisconsin to mine the rare isotope of helium, helium-3, on the Moon and bring it back to Earth as fuel for fusion power reactors. NASA is interested in lunar industrialization proposals that would make it economically attractive to initiate an effort to go back to the Moon. Helium-3 does not exist in any abundance on Earth. The Wisconsin group has estimated that there is enough helium-3 on and near the surface of the Moon to supply all the electricity needs of the Earth for decades.

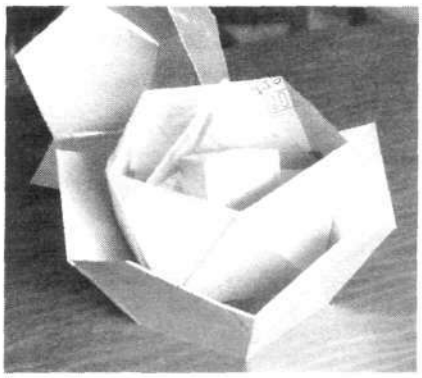
BERKELEY LAB DEVELOPS PET TECHNIQUE TO IMAGE BLOCKED ARTERIES

Lawrence Berkeley Laboratory has developed a new technique using positron emission tomography, PET, and the tracer rubidium-82 to pinpoint blocked coronary arteries, thus identifying people at risk of heart attacks before symptoms appear. The technique is noninvasive and simpler than the current procedure of coronary angiograms, which require hospitalization. The Berkeley team, which has been researching the new technique for the past 10 years, expects that the PET scan could be carried out in a doctor's office. In addition, they see the technique being used to evaluate—in real time—the effectiveness of drugs, such as those used to dissolve clots during a heart attack.

NASA ANNOUNCES COMPETITION TO NAME THE NEW SHUTTLE ORBITER

NASA invited elementary and secondary school students to suggest a name for the new Space Shuttle orbiter that will replace the Challenger. Entries must be postmarked by Dec. 31, 1988. Teachers can request entry forms by writing the NASA Orbiter-Naming Program, Council of Chief State School Officers, Suite 300, 400 North Capitol Street, N.W., Washington, D.C. 20001.

The new orbiter, under construction by Rockwell International, is scheduled for completion in April 1991. NASA's first series of orbiters was named after sea vessels used in research and exploration, and NASA will continue this tradition with Orbiter Vehicle 105.



George created this nested model of the Platonic solids and mass produced it out of discarded printing plates.

IN MEMORIAM: GEORGE FREDERICK HAMANN (1921-1988)

The *21st Century* staff mourns the loss of George Frederick Hamann who died July 2, 1988 of lung cancer at the age of 66. George collaborated closely with our writers and editors, making geometric models to illustrate articles and ongoing research. A skilled machinist and toolmaker, George completed models of all the regular and many of the semiregular geometric solids in many different materials, from plaster of paris to hardwood. Most recently, he worked with authors Robert J. Moon and Laurence Hecht to produce beautiful as well as practical teaching models for Moon's hypothesis of the atomic nucleus.

Letters

Some Comments On the Geometry Of the Nucleus

We print here a few of the responses received to the article by Laurence Hecht, "The Geometric Basis for the Periodicity of the Elements" (May-June 1988, p. 18), which develops the periodic table from the standpoint of Robert J. Moon's hypothesis on the structure of the atomic nucleus.

Pauling: Does It Match Experimental Data?

To the Editor:

. . . It seems to me that while Dr. Moon's ideas about the atomic nucleus in relation to the five Platonic solids might have some aesthetic appeal, it is highly unlikely that they have any significant validity. They seem to me to be incompatible with a great amount of experimental information that exists about the properties and structures of atomic nuclei.

. . . I shall mention one example. There are many experiments, such as the diffraction pattern of high-energy electrons from the nucleus, and the values of the rotational energy levels, that show that lead 208 has essentially a spherical structure in its normal state, and also that the nuclei of radon and protactinium are quite close to spherical. Dr. Moon's structures, shown on page 25, indicate a prolate structure with axial ratio about 2. This is a serious difference with experiment.

Linus Pauling
Linus Pauling Institute of Science and Medicine
440 Page Mill Road
Palo Alto, Calif. 94306

The Author Replies To Pauling's Criticism

Perhaps truth and beauty can, after all, be reconciled.

Dr. Moon points out that the data of high-energy electron diffraction pattern scattering must be interpreted very carefully. According to classical physics, the electron, though of slight mass, is in fact a large object when compared to the nucleus—the exact size depending on various assumptions including a spherical shape and whether the charge is distributed throughout the whole volume or the shell only. On acceleration, the additional problem presents itself that most of the charge appears, to the slower moving observer, to be flattened out into the shape of a disk.

While a "point" electron could distinguish the finer aspects of shape in the nucleus, we have no justification for assuming that that is its shape. Indeed, just what an electron looks like is among the most speculative and controversial matters in modern science. (For example, see W.H. Bostick, "The Morphology of the Electron," in the *International Journal of Fusion Energy*, Jan. 1985, p. 9.) But assuming an electron somewhat larger than the "ideal point," we see that there are two interpretations that could be given to the appearance of sphericity in the data. A large electron would be unable to distinguish the dumbbell-like shape of two dodecahedra from two spheres, especially where a large number of atoms is being examined.

In that case, the apparent sphericity of 82-lead-208, 86-radon, and 91-protactinium is just as we should expect from Moon's nuclear model: Protactinium is two complete dodecahedra, joined at a single vertex. Radon is two dodecahedra joined at a face. Lead-208 (the most abundant isotope) is one complete dodecahedron and a complete icosahedron, surrounded by a very stable dodecahedral configuration with 16 of the 20 vertices filled.

Laurence Hecht

Usefulness Questioned

To the Editor:

I do not think that the hypothesis on the structure of the elements is useful. There have been many such attempts before and complete books have been devoted to listing them. We just have to accept that the microworld in which quantum mechanics operates is different from the world of the scale of our everyday lives.

Similarly, the world on a cosmological scale is again different. Just as man made God in his own image so there is tremendous pressure to make everything else anthropocentrically and it is not necessarily so. I would recommend the textbook *Lectures on Physics* by Richard Feynman as a more reliable guide.

The deficiencies of adequate scientific education at an elementary school level cannot readily be remedied by popular magazines. Look at the state of education in the White House!

Professor Alan L. Mackay
Department of Crystallography
Birkbeck College
University of London
London WC1E 7HX

Does the Nucleus Have Crystal-like Properties?

To the Editor:

The article on the geometric structure of the nucleus is indeed very interesting. It all boils down to the question, does the nucleus (to some extent) have crystal-like properties.

In fact, very recently two other scientists, Cook and Dallacasa, have posed the same question (see "Face-centered-cubic Solid-phase Theory of the Nucleus," *Physical Review C*, Vol. 35, No. 5, May 1987, and "A Crystal

Continued on page 6

The Lightning Rod

My dear friends,

A wonderfully curious document was sent to me recently by a Latin scholar who knows of my fondness for the odd bit of knowledge. It is a document—a copy, I should say, of an ancient papyrus—which appears, from internal evidence, to have been sent to every household in the ancient city of Pompeii, sometime between 63 A.D., when the first recorded earthquakes took place on Mount Vesuvius, and the fatal date of 79 A.D. It was apparently published and circulated under the auspices of a person known as the Chief Observer, who seems to have been an Imperial official of the very highest rank. The translator informs me that he has endeavored to reproduce faithfully the curious banality of expression in the original Latin.

UNDERSTANDING THE VOLCANO

I. What the Volcano Means to You. Lately you may have heard a lot of talk about volcanos. This talk may have made you feel uncomfortable. That is understandable. Risky behavior with volcanos can be dangerous. I feel that it is important that you have the best information now available. It is up to you and your family to behave responsibly. Read this papyrus and get involved.

II. What Is a Volcano? A volcano is a natural part of things. You, for example, are living right next door to a volcano. It is not an "out there" problem, it is a "right here" problem. It doesn't matter if we're citizens or slaves—all of us have to learn to relate to the volcano. Remember, risky behavior can be dangerous.

III. Can the Volcano Hurt Me? Until very recently the volcano had never hurt anybody that we know of. Then something happened. Many people have gotten hurt by the volcano.

However, one thing we do know, is that all of them were hurt because they came too close to the hot lava. Casual contact with the volcano cannot hurt you. Only the hot lava can hurt you. Casual contact is okay. Avoid risky behavior.

IV. What Is Risky Behavior? The best way to avoid getting hurt by the volcano is not to practice risky behavior. Don't get too close to the hot lava. Don't lean over the crater to look in and see "What's cooking?" If you feel the urge to visit the mouth of the crater, talk it over with your priest or priestess first. Do a little haruspicating with your friends and family. Ask yourself, is it worth it? Chances are, you'll "just say no."

V. What Is All the Talk About Rubbers? A few years ago, nobody talked about rubbers. Everybody wore sandals, because they were much more comfortable. Now, we have to talk about rubbers a lot, for our own protection.

Letters

Continued from page 5

Clear View of the Nucleus," *New Scientist*, 31 March 1988).

However, because both the liquid drop and shell models of the nucleus are quite successful as well, these models cannot be suddenly altogether wrong. It may be, as it has been in other areas of science before, that the truth is somewhere in between. The nucleus is almost certainly superfluid, exhibiting a large energy gap, and it may perhaps be a superfluid liquid crystal.

The theory of liquid crystals was pioneered by the Soviet physicist J. Frenkel, but I could not find any reference in his work on superfluid liquid crystals. Only [Richard] Feynman did something along these lines to explain the rotons in superfluid helium predicted by [the Soviet physicist L.D.] Landau.

Dr. Friedwardt Winterberg
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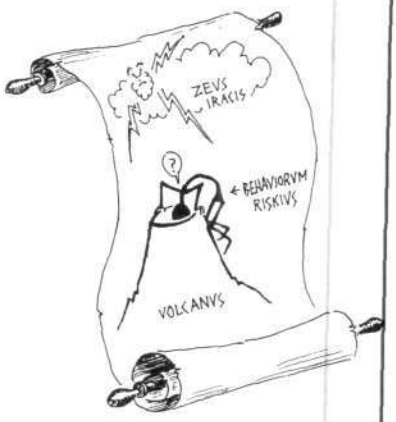


Rubbers are essential when you're visiting the mouth of the volcano. That way, if a little hot lava should happen to spill over onto your feet, you have some protection. No one should visit the mouth of the volcano without wearing rubbers. Some people just "can't say no." Those people should always wear their rubbers.

Nine out of ten doctors report rubbers are an effective lava retardant when used in conjunction with a program of avoiding risky behavior.

But not those "extra-thin" rubbers that are advertised for greater comfort—thick old-fashioned rubbers, the kind that make your feet sweat.

VI. What Do We Tell the Children? Children hear about the volcano, just as we all do. But they don't understand it, so they become frightened. They don't understand that casual contact is okay. They are worried the volcano might hurt them.

Children need to be told the volcano won't hurt them, and they don't have to worry if they wear their rubbers and "just say no." If anything happens to them, as a parent, it's your fault.

VII. Coping. There is one thing we can all do to help. We can cope. PMA—Positive Mental Attitude—is very important in survival. Every gladiator in the last ten years has credited PMA as the key to survival. So has every important actor and courtesan. With PMA, all of us can avoid panic and face the volcano comfortably.

VIII. This Is A Test.

Volcanos are:

A. Unnatural
B. Dangerous even on casual contact
C. A good reason to panic
D. Okay with PMA

If you answered (D), your opinion is as good as anybody's. Otherwise, zip it.

ADDENDUM—B.F. My friend the Latin scholar adds that in view of this treatise, lack of information about volcanos certainly cannot be blamed for the catastrophe at Pompeii in 79 A.D. He adds that it apparently was thoroughly assimilated and understood by the population, since few persons ever exhibited panicky behavior about the volcano. One fellow, L. Roscius, described by the authorities as "a real bad actor," did argue quite vehemently that "we ought to move heaven and earth to find out what's going on up there, and in the meantime, do everything we can to get the hell out of this deathtrap." He proposed a massive construction program to rebuild the entire city in a safer location, but was consistently voted down on grounds that it was unnecessary and "not cost-effective."

The strength of PMA in Pompeii has frequently been remarked on by scholars who have studied the position of the bodies. When the end came, most people were eating, sleeping, fornicating, or otherwise going about their daily business, with a calm worthy of the oriental philosophers. Only a few anguished souls look out at us from death masks that suggest that somehow, they knew what was coming.

Your obt. svt.

War Against Disease: The Forgotten Art of Pasteur

Garance Upham Phau

This year, the 100th anniversary of the Pasteur Institute is being celebrated in France and in all the African countries that have a Pasteur Institute. Unfortunately, amid the celebrations of the discovery of a vaccine against rabies, Pasteur's method has been lost, and the war he fought against disease in Africa is forgotten and even mocked by the dramatic deterioration in the health conditions of underdeveloped nations.

It is fruitful to recall some basics about the Pasteurian war on epidemics to address today's challenges—in particular the question of *screening for the AIDS virus.*

Universal and mandatory screening for the AIDS virus, HIV, is strenuously opposed by the World Health Organization (WHO) and by health authorities in the United States and in Europe. Yet, WHO itself admits that the lack of screening for all *other* diseases in Africa and Latin America over the past 10 years is the major reason for the surge in sleeping sickness, chagas, leprosy, tuberculosis, and arbovirus diseases in general. It seems that the real reason for the opposition to screening for AIDS is that screening for any disease costs money—money that these organizations and the associated governments are not willing to spend.

In this situation, even the most well intentioned physicians have forgotten why and how the disciples of Pasteur implemented screening beginning in the 1890s in Africa and Asia.

Pasteur's Philosophy

It was not the notion of "one microbe, one disease" that made Pasteur so unique, but his epistemological approach toward understanding life. For Pasteur there was an absolute specificity of the living that distinguished it from the inorganic. The universe was organized as an evolving whole, and could not be understood in a mechanistic way. In particular, Pasteur attacked the idea that disease can be reduced to a fixed chemical entity and that an epidemic is merely statistical and not a living creature.

In practice, Pasteur's concept of life meant that from the 1870s until his death in 1895, Pasteur recruited and trained hundreds of young scientists for missions into Africa, Asia, and Latin America. "Come, we shall transform the world," he wrote to one of his friends.

One of Pasteur's students, Charles Nicolle, who founded the Pasteur Institute in Tunis, recalled Pasteur's principles in a series of lectures given in Paris in 1937 that polemicized against the "mechanist thinking that will ever be incapable of understanding biological processes. "The infectious disease is endowed with the character of life," Nicolle said, "properties which come from its live origin and from the reaction of our cells that are also live. A disease is born, it lives, and it dies. It can be of individual character or assume a different collective form."

Nicolle then discussed the nature of an epidemic, a creature whose existence results from the microorganism, whose characteristic is its capacity for virulence, for "it uses the least [action] possibilities to perpetuate itself." In this regard, Nicolle recalled Leonard da Vinci's experiments with liquids proving the tendency toward maximal efficiency with the least work, a principle later refined by Leibniz.

War on Disease

What does this mean in terms of fighting disease? Since an epidemic is a live enemy invasion, it demands the same principle of warfare as applied to defense in general. First, the underlying capacity to repel an enemy invasion lies in the capacity to mobilize the economy in depth to achieve technological and cultural superiority. Therefore, one who says that economics is unrelated to the fight against epidemics, as WHO does, has already lost the war against disease. In fact, Nicolle had warned specifically that the policies of "looting" the poorer nations by "violating natural law would bring back plagues on the conquered and the conquerors."

For this reason, Pasteur's students dealt with agricultural development as well as scientific approaches against diesease; they were scientist-farmer-physician warriors.

The Colonial Health Corps

The "Alexander the Great" of epidemiology among Pasteur's students was Eugene Jamot. After the creation of the French Colonial Health Corps in 1890, it was Jamot who organized the army, devised the war strategy, and successfully fought and defeated sleeping sickness, a disease that threatened the survival of West Africa at the turn of the century. Jamot knew that to win, he needed good intelligence on the enemy, mobility of troops, and a war map established by systematic screening of the population. Jamot's roving squads screened a population of 50 million.

Jamot's principles are to this day what guides the French military health cadre. The army must be mobile, made up of roving squads combining screening and treatment capabilities who deploy out of central lab stations and smaller rural outposts.

Screening of all individuals must be carried out, for this allows the evaluation of the degree of contagiousness. One then knows where are the sick,

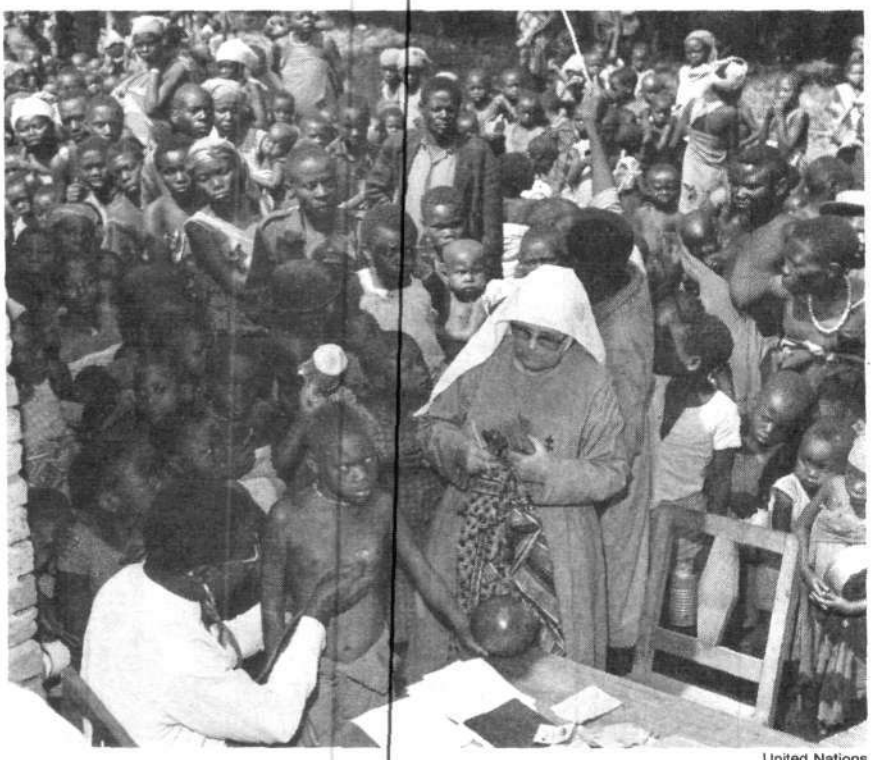
Garance Upham Phau is a member of Executive Intelligence Review's *Biological Holocaust Task Force and is based in Paris.*

where are the carriers (the most dangerous, because they spread the disease unknowingly), and where are the tse tse flies).

Jamot used the intelligence provided by the screening measures to map flanking maneuvers to prevent the enemy from moving into new regions. Carriers of the disease were removed from their villages and sent to a special agricultural village for the sick, which included research and treatment facilities to provide the best available medical care to the sick. A full-scale campaign was mounted to eradicate the breeding areas of the tse tse fly, and to set up fly traps.

Finally, Jamot instituted health passports to prevent the infestation of new areas. At the time (the 1920s), it should be noted, cities of 100,000 people or more had disappeared from the map in Cameroon, for example, wiped out by sleeping sickness.

Jamot won the war against sleeping sickness by the mid-1930s. There were still pockets of the disease, but it no longer threatened to depopulate the entire continent.



United Nations

A mobile team of doctors and nutrition experts treating an epidemic of kwashiorkor in the Congo—today Zaire—in the early 1960s.

And Today?

In the past 10 years, sleeping sickness has returned as a major killer in Africa, as universal surveillance and screening have fallen apart. In Chad and Uganda, for example, there are at least 20,000 reported cases, which means that countless more are infected. The government of Chad sent out a call for help to the international community about a month ago, and WHO has warned about the potential comeback of this and other "depopulating diseases." Leprosy, for example, has increased from a few hundred thousand cases in 1980, to 11 million in five years.

D. Henriod/WHO

A doctor in a mobile unit of WHO taking blood samples during an epidemiological survey in the 1960s.

The abandonment of screening has had other serious consequences:

- Diseases are increasingly virulent on an individual level, rendering treatment difficult, more costly, and leaving the person with more damage.
- On the collective level, diseases are more virulent, as documented graphically with the spread of AIDS.
- There is increased transmission of all diseases, and collective and individual virulence are feeding each other. There is not just one pandemic with the AIDS virus; the human population has now become a *laboratory for pandemics*.

Under these conditions, it is criminal not to reinstitute screening capabilities for all diseases, including the

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Oil Exploration in India Develops New Resources, New Technologies

by Ramtanu Maitra

When the British colonialists left India in 1947, India had only one oil field, in Digboi, Assam, in the northeastern part of the country. British experts not only claimed that they could not find more than one oil field, but also adamantly stated that India did not have any oil deposits. Whatever the motivation, this lie became clear when India set about on its own to explore its oil reserves.

India's Oil and Natural Gas Commission and Oil India Ltd., the two state sector enterprises charged with the nation's oil production effort, have already succeeded in meeting a significant part of the challenge, long since proving the lie the British had so assiduously propagated. Since 1973, India's production of crude oil has jumped up to meet almost 50 percent of India's present level of demand. Onshore production, which at the time of independence in 1947 was a meager 4 million tons per year, is now about 10 million tons per year, and hopes are high that a lot more can be found.

However, it is the vast offshore areas, where 75 percent of India's oil lies, that will be the backbone of India's future oil production.

In the difficult offshore exploration the commission has fared remarkably well. Concentrating its efforts off the Bombay coast in the west, the commission has increased India's offshore production from zero to almost 21 million tons a year. Recently, the commission has begun to explore such distant offshore areas as the Andamans in the Bay of Bengal, the Krishna-Godavari basin off the southern coast, the Cauvery basin farther south, and the Tapti basin in the west.

In spite of these efforts, financial constraints have limited exploration to only a fraction of the country, especially given the extent of promising offshore basins. For comparison, the United States, which is statistically the best-explored area in the world, has an exploration drilling facility consisting of one well for every 15 square kilometers of prospective oil-rich area—while India's ratio is about one exploratory well for every 750 to 1,000 square kilometers.

However, India benefits from the fact that the oil exploration program is among the most efficient in the world, with a "success ratio" of one strike in every seven drilled, compared to a ratio of one in every forty-two in the United States. Whether India will ever be able to completely meet its rising crude oil demand from domestic production will depend upon finding new fields that will yield copious amounts of oil and gas for an extended number of years, and this entails a sophisticated prospecting, exploring, and drilling capability.

PIB/India

Although India has a very low density of oil wells drilled, its success ratio is high: one "strike" in every seven wells drilled. For comparison, the U.S. success rate is one out of every forty-two wells drilled.

Success also requires the establishment of institutions that will act as braintrusts as well as problem-solvers. In this respect, the commission's performance is highly commendable. In Dehra Dun, Uttar Pradesh, nestled under the great Siwalik mountain range, the commission has set up a research institute, the K.D. Malaviya Institute of Petroleum Exploration, to develop innovative thinking in basin modeling.

Stratigraphy and geometry studies carried out at the institute have already helped in locating exploration targets. Discarding the conventional methods of processing samples for the recovery of plant microfossils, which involve high expenditure and are time consuming, the institute's geology division has developed two innovative methods for processing samples.

Maximizing Extraction

The commission also carries out what is known as reservoir simulation, simulating existing oilfields in order to maximize extraction. In 1978, a special institute was set up to do the work, which has already helped increase oil extraction in several offshore fields where initial capital investment for exploratory work is significantly higher than that for onshore oil fields. As a result of work during 1985 and 1986, production potential increased on the order of 2.7 million tons from the old fields, and another 6.7 million tons from new fields has been added.

Enhanced oil recovery techniques have been designed to achieve additional recovery of oil that would otherwise remain in the reservoirs even after primary and secondary production methods had been applied. Since these techniques in general are highly guarded secrets among the multinational oil companies, the lesser developed nations with oil reserves are now seeking India's expertise.

Since India's oil independence program relies heavily upon the exploitation of offshore oil fields, the commission is also mastering deep-sea drilling techniques. The backup consultancy on advanced drilling techniques is home-grown: The commission set up the Institute of Drilling and Technology, also located at Dehra Dun, Uttar Pradesh.

Drilling for oil itself is a complex process. Controlled directional drilling is the planned and intentional drilling of a well bored along a course to a target located at a given distance from the true vertical line running below the rig. Controlled directional drilling can be highly chancy when, for example, the driller is trying to reach otherwise inaccessible formations that lie below locations like towns, rivers, and lakes; when the formation is located in the overhanging cap of a salt dome; when formations are located below harbors and ocean floors; or when several oil sands intersect.

With offshore drilling, however, some of these problems cease to exist and the drilling becomes significantly more economical when several directional wells are drilled from a single platform. Although controlled directional drilling in the case of offshore drilling may be less cumbersome, in many cases the technology of building platforms in high sea and maintaining logistics smoothly while the platforms are lashed by high winds, waves, and tidal currents, is a difficult proposition.

To the commission's credit, its record so far has been highly commendable. In the last five years, the number of rigs deployed has increased more than twofold. At the same time, downtime has declined significantly. The reason for such success has been a thorough and efficient training program for the crew. More than 60 R&D projects in cement work, drilling fluid engineering, and operational research training conducted by the Institute for Drilling and Technology have laid the foundation.

In the past five years, this institute has trained more than 2,000 drillers in India, replacing expensive training programs abroad. In addition, trainees from abroad, especially from Asian and African nations, have come to the institute for training.

In Situ Coal Gasification

Now the commission is branching out into other areas to benefit the nation, for example, in situ coal gasification. Over the years, India has become increasingly dependent on coal for power generation. Today, coal provides 40 percent of India's total energy needs. At least one fertilizer plant is now operating where coal gas is used

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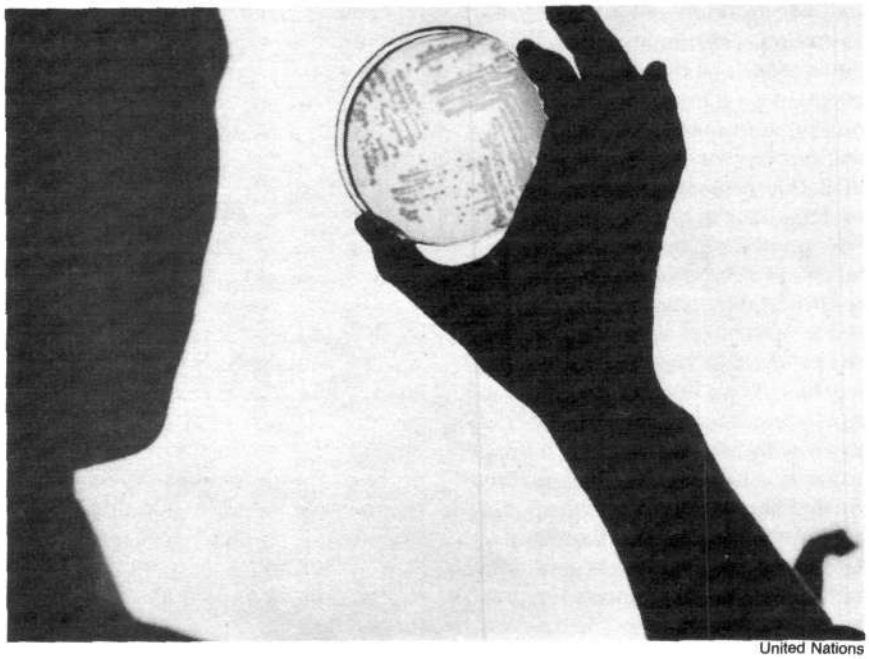

United Nations

Did the AIDS Virus Originate in a Soviet Laboratory Accident?

by John Grauerholz, MD

The most controversial scientific question about AIDS is also the most basic: Where did the virus come from? Certain scientists have speculated that the virus made a mysterious "species jump" two to three decades ago from an animal to man, but they have been unable to find the original animal reservoir. Others have hypothesized that the AIDS virus has been around for hundreds or thousands of years and underwent a mysterious mutation to a new lethal form 20 to 30 years ago. A third hypothesis is that the virus was generated spontaneously in diseased human tissue under extraordinary conditions.

Then, there is the sensational "biological warfare" theory cooked up by the Soviets, who have repeatedly charged that the AIDS virus was deliberately made in the U.S. biological warfare program at Fort Detrick, Maryland.

Here I propose an alternative hypothesis on the origin of the human immunodeficiency virus or HIV: that it originated in a laboratory accident, perhaps by a Soviet molecular biologist. This hypothesis is consistent with the known biology of these viruses and with the published scientific literature. It accounts for the apparent lack of an animal reservoir by demonstrating that such a reservoir in fact existed, and still does exist, and that its interaction with human beings most likely occurred, and still is occurring, in the laboratory.

AIDS is a clinical complex or syndrome that results from the activation of a previously latent infection by a specific kind of virus known as a *retrovirus*—the human immunodeficiency virus or HIV. HIV is a member of the lentivirus subfamily of retroviruses, a group of viruses that have been linked to the induction of arthritis, encephalitis, progressive pneumonia, and slow neurological diseases in certain species, primarily sheep, cattle, and goats.

"The more accurate a hypothesis as to the origin of AIDS, the more clues science would have in combating its spread."

Recombination Among Retroviruses

Different viruses infecting the same cell can interact and their genetic messages can be recombined, incorporating critical features of the two genetic blueprints. Recombination can occur naturally, as in an individual simultaneously infected by two viruses, or in the laboratory. Over the past two to three decades, scientists have learned how to recombine genetic messages in the laboratory. In the 1960s, molecular biologists mastered the rudiments of genetic recombination capabilities. In genetic engineering, critical features of one message can be transported into another cell or species artificially.

Retroviruses are RNA viruses in their extracellular form as free virus particles. Within an infected cell they exist as RNA in the cytoplasm or as the DNA intermediate in the nucleus, which is known as a *provirus*. As RNA viruses they are capable of the rapid evolutionary change characteristic of RNA genomes (Reanney 1982; Holland et al. 1982). This rapid evolution occurs because of a lack of the error-correcting enzymes that assure the fidelity of DNA replication. Combined with a high rate of replication, this results in rates of RNA genome mutation more than a millionfold greater than the mutation rate of host cell DNA.

In addition to the high rate of mutation characteristic of RNA viruses, retroviruses have an extraordinarily high rate of recombination (Coffin 1979). Their genomes are the result of recombination between molecules of different retrovirus genomes, and possibly other RNA virus genomes, with very little physical linkage of genetic sequences. The probability of recombi-

nation between neighboring nucleotides in the genome has been estimated to be on the order of 10^3, or 100 times higher than bacteriophages considered to have an extremely high frequency of recombination. Crossing over occurs throughout the genome with little restriction.

Because of the high mutability, and hence instability, of retroviral genomes, many deletions occur that result in production of defective viruses. Reacquisition of lost genetic information by simple recombination occurs in the presence of virus containing the deleted segments, resulting in production of complete virus (Stavnezer et al. 1986).

Recombination between retrovirus genomes and host DNA also occurs in situations involving viruses specific for one species grown in cells of another species and results in alteration of host range in such viruses (Aaronson 1971; Kotler et al. 1984).

Transmission of retroviruses originating in one species to another species, with subsequent propagation in the germ line of the second species has been documented (Todaro 1980). In such cases, DNA homology (similarity in the sequence of nucleotides) between the acquired virus and the species of origin can be detected and can serve to measure evolutionary divergence and to estimate when the crossover occurred. Such sequence homology appears to indicate that the AIDS virus HIV-2, or HTLV-IV, is related to the simian virus STLV-III, which infects African green monkeys. In such a case, it should be possible to infect these animals with this virus.

In the case of HIV-1, it is contended, no comparable, naturally occurring progenitor has so far been identified, and the origin of the virus, in the words of the Pasteur Institute's Dr. Luc Montagnier, is "a mystery."

Laboratory Origin?

Since HIV-1 is not an endogenous human virus (Howard Temin 1987) and no naturally occurring ancestor or animal reservoir has been identified, and no animal other than the chimpanzee can even be infected, where did HIV-1 come from? One possibility that must be seriously considered is that the virus could have arisen by recombination with other viruses and human cells in laboratory culture.

In contrast to natural conditions, evolution is markedly speeded up in laboratory conditions and by the time such a virus was even recognized, it could well have evolved to the point that its origins would be obscure. For this to happen, though, would require extensive co-cultivation of human cells with an animal virus that already possessed the characteristics of the AIDS virus.

One such virus is the Maedi-Visna virus of sheep, which is closely related to HIV-1 and does cause progressive neurological disease, similar to AIDS dementia, and a progressive pneumonia, similar to the chronic lymphocytic interstitial pneumonitis (CLIP) seen in some HIV-infected individuals. It has been contended by some (Seale 1986; Strecker 1986; Siegal 1986) that HIV was deliberately created as a recombinant between bovine leukemia virus (BLV) and Visna virus grown in human cells.

One problem with such an hypothesis is that it would require a good deal more to be known about lentiviruses than was reflected in the scientific literature of the period in which HIV-1 first arose, which was probably in the early 1960s. My alternative hypothesis of laboratory origin requires no premeditation and is consistent with the biology of retroviruses and the prevalence of certain laboratory conditions.

Soviet Retrovirus Research

Soviet research on the ability of Rous sarcoma virus, a tumor-causing retrovirus of chickens, to cause tumors in other animals dates from at least the late 1950s (Zilber et al. 1957, 1958). By the mid-1960s, Soviet scientists had demonstrated that Rous sarcoma virus could cause tumors in a number of primate species (Zilber, Lapin, et al. 1965, 1966). In 1967, Lapin et al. reported causing leukemia in monkeys by injecting blood from human leukemia patients, and subsequently passing the disease from animal to animal by a filtered preparation. The filtered agents (viruses) reacted with sera taken from human leukemia patients. In 1968, Adzhigitov, Lapin et al., published a report on the possibility of culturing a virus causing leukemia in monkeys.

Work on human cells was obviously under way during this period, and in 1970 Lapin and Iakovleva published an article on the viral nature of human leukemia. In 1972, Zhdanov et al. published a paper on the isolation of a leukovirus (a leukemia-causing virus) from a continuous human cell line. The virus was a C-type retrovirus (like the AIDS virus) that did not react to mouse or avian leukovirus antisera and showed some annealing of its reverse-transcribed DNA to RNA from the spleen of a leukemic patient. However, the last sentence of the Zhdanov paper contains the comment, "Another possibility is that a virus derived from cattle had been introduced into the culture with the bovine serum used in many culture passages." A subsequent paper (Zhdanov et al. 1973) on isolation of oncornaviruses (tumor viruses) from continuous human cell cultures again notes, "Besides a human origin, they may be contaminants arising from the calf serum."

Zhdanov's concern about contamination of his serum was well founded, since cattle viruses, including leukemia viruses (Khoklova and Rakhmanin 1970), are widespread in the Soviet Union. It is quite obvious that the Soviets had, in their usual ham-handed manner, unwittingly anticipated the 1978 demonstration by Georgiades that human leukemia cells could be infected with bovine Visna virus (BVV), now known as bovine immunodeficiency virus (BIV), and had been doing so for years.

It appears that viruses were not the only contaminants in Soviet cultures. In May 1972, Nixon negotiated an agreement for biomedical cooperation with the Soviet Union. In November, a group of American cancer researchers presented their Soviet colleagues with a set of animal tumor viruses. In return the Soviets presented the Americans with six cultures of cancer cells, all of which contained viruses that the Soviets suspected were the cause of the malignancies.

It turned out that all six cultures, from six different Russian cancer patients, were all descendant cells from an American black female who died in 1951, Henrietta Lacks of Baltimore. These cells, known as HeLa cells, were from the first successfully cultured human tumor cell line and are used all over the world. It is probable that HeLa contamination is widespread in the

Tass from Sovfoto

Conditions for laboratory contaminations during the 1950s and 1960s were more prevalent in parts of Europe and the Soviet Union than in the United States. Here, scientists involved in genetic engineering research at Moscow's Molecular Biology Institute in 1974.

Soviet Union, where facilities and technique in many areas of biological research are very crude. One consequence of this sloppiness was an outbreak of leukemia in the baboon population of the Sukhumi Monkey Colony, which started in 1967 and continued for several years (Lapin 1976).

Since 1971, a virus that looks exactly like a tumor-causing retrovirus has been observed in some HeLa cells. This so-called HeLa virus is widespread in human cell cultures in Europe (Gelderblom 1976), but uncommon in cultures from the United States. Since the Soviet Union acquires its reagents in Europe, it is not unreasonable to suspect that this virus is contaminating the HeLa cells, which are in turn contaminating its cell cultures.

Given the crude state of Soviet virology in terms of facilities, and the documented clumsy contamination of cultures by both viruses and cells, it would appear that Soviet virus research facilities function as a culture medium for recombination and generation of altered virus species—regardless of any intent on the part of the researchers involved. The Soviets obviously grew human cells in cultures contaminated by known, and unknown, retroviruses, including the most likely candidate for a precursor of HIV-1, and then presented the products of their sloppy technique as valid scientific discoveries. Likewise, contamination of vaccines would be a major problem in such a situation.

Contamination of Vaccines

Contamination of vaccines would account for the widespread prevalence of HIV-1 in Africa among the general population. Since most of the vaccines used in Africa originate in Europe, this would explain why HIV infection in the United States was initially confined to certain groups. It would also indicate that the conditions for such contamination were more prevalent in parts of Europe and the Soviet Union than in the United States. Thanks to the recent emphasis on budget cutting in the United States, similar conditions can be expected to develop in more and more laboratories here.

However, the point is that during the period in which the AIDS virus can be presumed to have arisen—that is, the 1950s to 1960s—conditions in U.S. and Western European laboratories were much better than in Soviet and Eastern European laboratories. The probabilities were therefore greater that an accidental recombinant could arise, and go undetected, in Soviet laboratories and the evidence would indicate that this indeed occurred.

Fetal calf serum, or fetal bovine serum (FBS), is a major component of almost all cell culture and tissue culture media. The serum is obtained by bleeding fetal calves, allowing the blood to clot, and then centrifuging it to remove the red cells and clot. The resulting serum is pooled and may or may not undergo additional purification. Virus contamination of such sera has been a recognized problem since the late 1960s at least (Molander et al. 1968). In one study (Kniazeff et al. 1975), 25 percent of 20 lots of FBS, pretested by suppliers and considered to be virus free, were found to contain endogenous bovine viruses. The techniques of detection were relatively crude and would not have detected latent or slow-acting viruses.

A number of investigators have reported spontaneous induction or production of retrovirus-like particles in human cell lines. These viruses resemble bovine Visna-like virus (BVV), now designated bovine immunodeficiency-like virus (BIV) and grow in human diploid cell lines (Demidova et al. 1975).

In view of the documented ability of retroviruses to alter their host range in tissue and cell culture, specifically the ability of BIV to infect human cells, it is entirely possible, and indeed probable, that a form of BIV with human cell tropism could have arisen in human cells grown in BIV-infected culture media. The recently isolated immunosuppressive virus of cats, FTLV (feline T-lymphotropic lentivirus, Pedersen et al. 1987) is morphologically similar to HIV and BIV and could well have arisen in feline cells grown in BIV contaminated serum.

In conclusion, I would like to emphasize that the more accurate a hypothesis as to the origin of AIDS, the more clues science will have in combating its spread. I welcome responses from readers who may have some clues to this question. In exchange, correspondents will be sent the list of 39 references to this article, which could not be printed for space reasons.

John Grauerholz, a pathologist, is an associate editor of 21st Century.

New Delhi Report

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as the feedstock.

The reason that Indian planners have continued to rely heavily on coal for power generation is because the nuclear power authorities have so far failed to deliver electricity in bulk quantity and also because of the seasonal nature of hydroelectric power. In addition, India has large reserves of coal, and coal-based power generation technology is old and time tested.

In spite of the fact that India has coal reserves of 158 billion tons, some of these reserves exist below 700 meters, making coal mining hazardous and cost-ineffective. Also, hauling large amounts of coal—the estimated mining of coal by the year 2000 is 400 million tons—puts a severe strain on the ancient railroad system of India and poses a serious problem for the environment.

In situ coal gasification resolves some of these problems. It is advantageous to burn coal where it is: The product coal gas may be cheaper because of lower capital investment; enviromental damage may be less; the hazards to miners are avoided; and, it may be possible to utilize coal resources found at depths too great to be economically attractive for conventional deep-mining operations.

Despite such apparent advantages, development of in situ coal gasification technology has remained haphazard and largely incomplete. Both in the Soviet Union and the United States, some sporadic efforts have been made since the 1930s to develop the technology, but research efforts were not sustained, principally because both nations are endowed with ample coal and deep-mining has not yet become a necessity.

Moreover, while the Soviets are relying more and more on nuclear power to meet their electricity demands, the United States is dismantling its industrial base and becoming a nonproducing nation.

In India, however, coal gas would be a much needed feedstock for a growing fertilizer industry—a key factor in increasing India's poor agricultural productivity. The commission has been entrusted with $19.1 million in the Seventh Five-Year Plan (1985-1990), which includes setting up a pilot plant at Mehsana in Gujarat for establishing the feasibility of commercial-scale operations. The coal reserves in north Gujarat are around 63 billion tonnes, with an estimated potential to produce an energy equivalent of 15,000 billion cubic meters of natural gas. These coal seams exist at 700-1,700 meters depth and are not minable by conventional mining techniques.

Diversification and New Technologies

Oil exploration in India has also opened up areas that otherwise would not have been developed. The Institute of Biotechnology and Geotechnics Studies at Jorhat, Assam, in the eastern part of India where the first oil field was located in the late 19th century, has been established to do research and development for exploring the possibilities of hydrocarbons using microbes. This is the first such institute set up in South Asia and is expected to strengthen the institutional infrastructure of the parent commission.

India's oil exploration program is now further diversifying into education. The Institute of Petroleum Safety and Environment Management, recently set up by the commission, is designed to educate personnel in safety and concern for the environment. Future plans envisage training programs to meet the requirements of offshore survival, including oil fire fighting, navigation, rescue work from burning platforms, communication, survival after helicopter crash, and escape from well fires and smoke-filled structures.

In order to enhance the quality of R&D and productivity in oil exploration, the commission is now involved in a plan to begin a dialogue with the academic institutions and fund basic research programs at universities. This is expected to help both the students who plan careers in oil exploration and also the commission, which will be able to draw on a vast pool of scientists and technologists associated with academic institutions.

Ramtanu Maitra, a nuclear engineer, is editor-in-chief of Fusion Asia *magazine.*

Jim Duree

INTERVIEW WITH CHAOVANEE AROONSAKUL

New Developments in Treating Alzheimer's

Dr. Chaovanee Aroonsakul, a neurogerontologist based in Chicago, has pioneered the use of growth hormones to treat senile dementia and Alzheimer's disease. As John Grauerholz, MD, discussed in an article on her work ("New Approach Offers Hope for Alzheimer's Disease," 21st Century, March-April 1988, p. 22), Alzheimer's is estimated to afflict 1.5 to 2.5 million Americans over the age of 60, and patients are generally unresponsive to treatment.

Now, with the collaboration of Dr. Robert J. Moon, professor emeritus at the University of Chicago, Aroonsakul is seeking to establish a rigorous research program in the use of these growth hormones to halt diseases of aging. Moon became interested in Aroonsakul's work a year ago, when asked to look into it by a colleague at the University of Chicago. Moon, a nuclear physicist and a veteran of the Manhattan Project, had studied neurology extensively in the past in order to understand more about Parkinson's disease, which afflicted his wife. Moon is particularly interested in energy relationships on the cellular level, and how increased energy can promote growth.

Here, John Grauerholz, an associate editor of 21st Century *talks with Aroonsakul about new developments in her research.*

Question: What is new in your research? You mentioned that the growth factors you use in your treatment raise the body temperature and that seems to correlate with patients' improvement.

We have found more and more evidence that the first concept of the hormonal growth factor as an intracellular mediator of cyclic adenosine monophosphate [cAMP, a metabolic messenger involved in energy transfer] seems to be correct. Research confirms this, including that done at the University of Texas School of Health Sciences. In one animal study, and in the case of the bacterium *E. coli*, it has been discovered that, when the unidentified hormone got into the cell, leading to the breakdown of ATP into ADP and AMP, and then to cyclic AMP, the physiological functioning of the cell itself changed.

With proper research funding and direction there is no reason that medical science could not reverse the effects of aging and prolong our productive years.

The hypothesis I propose, however, is that when cyclic AMP is changed, this process causes the cell temperature to increase. The cell generates heat, and this is how we can accelerate the growth process. This also reverses the death process—the dying of the cell. Dr. Robert Moon has described the use of growth factors in treating diseases of aging as the first experimental approach involving human beings to seek to increase the energy available to the cell's processes.

Question: Is lower body temperature a symptom of the presence of a disease of aging, such as Alzheimer's disease?

When the body temperature of elderly people—both healthy and those suffering from dementia—is measured, it is generally below 98.6 degrees, the level considered normal by medical science. In my patients, I have been finding a range of 94 to 97 degrees. With both senile dementia and Alzheimer's disease, the severity of brain damage and diminished mental functioning correlates closely with lower body temperature in my patients.

Question: How has treatment with growth hormones effected body temperature in your patients?

Body temperatures rise to 99.1 or 99.2. Clinical manifestations of the disease lessen; there is less mental confusion.

Question: Can you give us more details about improvements in a particular case?

One example of improvement is a 77-year-old female patient whom I shall

call Mrs. Smith. In 1983, Mrs. Smith fell and fractured her hip. During her recovery, her husband noticed that she was less alert and that her intellectual functions had diminished. In about August of 1987, she ceased to be interested in her surroundings; she was depressed, very forgetful, stopped doing any housework, and had difficulty getting up from a chair by herself. Her husband concluded that she was suffering from Alzheimer's disease and feared she would have to be put in a nursing home.

Then Moon, a friend of hers, suggested that she come to me for treatment. I administered the Aroonsakul and Allen Provocative Test. Her Nuclear Magnetic Resonance (NMR) imaging revealed moderate, stable atrophy, and her arthritis was bad. I diagnosed her as suffering from late-stage senile dementia.

Mrs. Smith's treatments with growth hormone began in September 1987, and her symptoms began to subside after 60 days of treatment. She remained stable until December, when she went on a trip with her husband and failed to refrigerate her medication. At room temperature, the polypeptide in the medication disintegrated, and it became simple distilled water. I discovered this after Mrs. Smith had returned to Chicago in a deteriorated condition.

Question: What happened then?

Unfortunately, I did not see Mrs. Smith until after she had been to the emergency roon of a local hospital, where the physicians were not aware that she had been off her medication. She was given conventional treatment but did not improve. Mr. Smith requested that the hospital bring me in to consult on her case, but this request was denied.

According to Medicare's cost-containment rules, the Diagnostic Related Groups (DRGs) system, a patient can remain in the hospital with Medicare support for only five days of treatment if no new problems develop. So Mrs. Smith was discharged.

At that point, Mr. Smith brought his wife to see me. She was in very poor condition; her pulse was weak, her heartbeat irregular, and she was extremely pale. I administered a large dose of growth hormone. Two hours later, she began to respond.

Question: Did this one dose of growth hormone turn the situation around?

She did improve almost immediately, and she began her regular regimine of growth hormone injections. After 30 days, she was able to recognize colors, although she did not correctly identify them. After 60 days, she was again able to walk without her wheelchair; she had more energy, and was joking.

On her third visit back to my office, after 100 days, her vision had improved. Clinical examination supported her own judgment that she was more interested in what was happening around her. She interacted with her surroundings and showed more initiative. For example, she wished to go out of the house on a regular basis.

Most interesting is the fact that, on a visit three or four days later, Mrs. Smith felt very weak and less improved. The outdoor temperature had dropped to 40 degrees, and her body temperature had also dropped. I administered the growth factor, and about two hours later her body temperature had risen about 1 degree to 98.3, and she was much improved.

Question: Have you made any progress in establishing a research program to test the use of growth factors on a rigorous scientific basis?

Unfortunately, many of the scientists who could help study this approach are contemptuous of it. For example, Moon brought this approach to the treatment of Alzheimer's disease to the attention of a world-renowned university neurologist. Moon told his colleague that the approach was a profound breakthrough in understanding the link between the symptoms of diseases of aging and their underlying causes, and that it could be taken much further in basic research than simply treatment of these diseases. For example, he encouraged the idea that research begin into energy relationships at the cellular level.

This neurologist responded with contempt. He said the hypothesis that growth factors can change the functioning of the cell is unfounded and invalid. To disprove the hypothesis that growth factors effect the breakdown of ATP into cyclic AMP, he rifled through a neuroendocrinology textbook for 15 minutes—and couldn't find anything.

Rita Levi-Montalcini, who won the Nobel Prize in 1986, proclaimed to the world back in the 1940s that the central nervous system could not be regenerated. Many experts still accept that as dogma, even though Levi-Montalcini herself now rejects her own earlier finding.

Question: Do you have suggestions for specific research projects that should be undertaken?

I think it would be worthwhile to set up a rigorous test of the correlation between body temperature and clinical indications of improvement, following the use of growth hormones, in patients suffering from Alzheimer's disease and senile dementia. This is something I would like to discuss with scientists and medical professionals working on similar or related problems at the first opportunity.

Viewpoint

Continued from page 9

HIV virus, in order to limit the spread of contagiousness and to treat what can be treated before permanent disabling effects occur.

The Pasteurian warriors were men of great courage, "physical courage without which life is so poor," as the French surgeon Merle d'Aubigne said. Perhaps the main enemy of the human race today is compromise, which is actually a form of prostitution, in the name of which we tolerate the intolerable. Louis Pasteur and his warriors against disease ought to remind us that if we make the political decision to adopt their method, we could stop AIDS and other diseases from depopulating Africa—and the rest of the world.

Time is short, in view of the danger we face. To fight at the level required, we must make a commitment to do so, and begin now.

Coming in the next issue:
Designing Cities on Mars
Space Medicine

Producing New Materials With Acoustic Waves

by Marsha Freeman

A factory where sound waves are tools on a production line? The technology already exists.

Experiments aboard the Space Shuttle have demonstrated that acoustic levitation will likely be a commercially viable materials-processing technology in the future.

High-intensity sound waves, like other forms of focused electromagnetic energy, can be used to create new materials and in the production of more perfectly formed products from existing materials.

By levitating or suspending material using intense sound waves or magnetic force, processing can be accomplished without using any containers: The material hangs in suspension and does not touch the sides of any container.

This is crucial for the development of new materials because there are some substances that melt at such a high temperature that no container could hold them. Other substances react chemically with the material of the container. Also, metal alloys can pick up impurities and become contaminated, which interferes with the ability to measure the properties of the metal at high temperatures.

In some cases, small particles from the container material can cause unwanted nucleation, producing crystalization in the production of glasses.

Shuttle Experiments

At the end of 1985 an acoustic generator, designed and built by Intersonics Inc. in Illinois, flew in the payload bay of the Space Shuttle Challenger on the Materials Experiment Assembly. The Single Axis Acoustic Levitator or SAAL produced sound waves that allowed liquid glass and solid materials to be levitated inside a processing furnace.

Three samples were successfully levitated at temperatures ranging from 600 to 1,550 degrees Celsius. The samples were heated, melted, cooled, and solidified while being positioned without any physical contact. Photographic records made through the optics port of the generator indicated that all three samples were successfully injected into the furnace, captured by the acoustic generator, and processed throughout heating, melting, and soaking.

According to Dr. Charles Rey, the president of Intersonics, experimenters were able to demonstrate glassification of a gallia-calcia-silica mixture of metal oxides. Until that time, the gallia was what Rey described as a "reluctant glass-former."

In addition to producing new glass materials, the experimental SAAL apparatus on the Shuttle was used to form nearly perfect, tiny, hollow glass spheres, to be filled with hydrogen and used as targets for laser fusion. On Earth, the pull of gravity makes the tiny spheres slightly out-of-round, making the laser-triggered explosion less powerful.

Producing Acoustic Waves

In space, where there is no downward pull of gravity, acoustic waves are used to hold the material suspended in position and prevent it from wandering to other parts of the furnace or other processing apparatus. At high temperatures, the acoustic forces are generally not sufficient enough to levitate a specimen on Earth, but this can be done in the microgravity of space.

The acoustic waves, or ultrasound, are generated by vibrating a ceramic compound with a high-frequency alternating current.

In the Intersonics design, a near-planar acoustic wave is generated and impinges on a small acoustic reflector, with transverse dimensions comparable to half a wavelength (Figure 2). The beam is reflected back as a spherical wave, and the difference in wave shape produces interference between the reflected and primary waves.

A beam of intense sound produces what is called radiative pressure against an object. But with the two beams, where wave interference occurs, there is mutual cancellation of the pressure effect. The regions of null pressure are called energy wells, or nodes. The function of the acoustic generator, ac-

Figure 1
CROSS SECTION OF MATERIALS-PROCESSING DEVICE USING ACOUSTIC LEVITATION

Intersonics Inc. has designed and built this device, called the Single Axis Acoustic Levitator, which has been used to perform experiments aboard the Space Shuttle. High-intensity sound waves generated from a source at the bottom travel through the materials processing furnace. The wave is reflected at the top (reflector), and the secondary waves, interfering with the first, allow samples of material to be suspended in the center of the furnace. Heating, melting, and cooling take place without any container touching the sample.

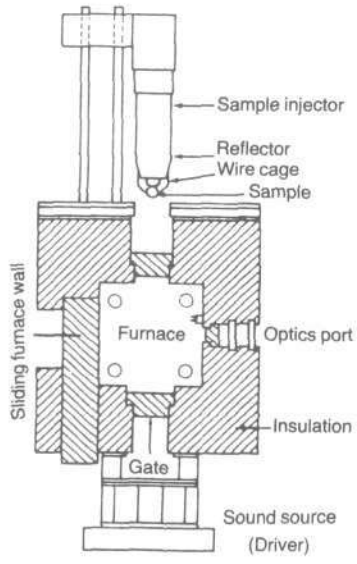
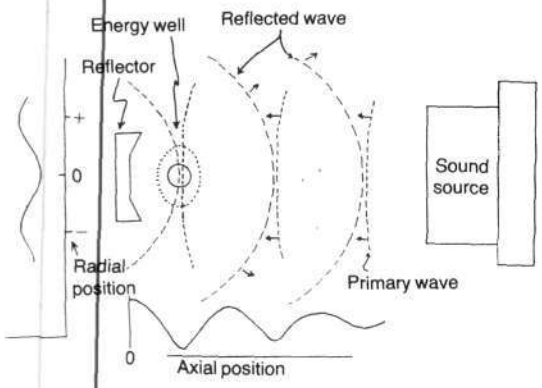


Figure 2
GENERATION OF AN ACOUSTIC ENERGY WELL

The sound source at the right for this single-axis levitator generates a near-planar primary wave, which travels from right to left. When the wave is reflected back through the levitator, it is spherical in shape and travels from left to right. An energy well is created where the two waves meet, shown here as a dotted-line oval, left of center. The spherical material sample is forced to remain within this region of null acoustic pressure.

The two graphs (left and bottom) show the intensity of acoustic pressure along the radial and axial dimensions of the device. The energy well occurs where the low points in these two dimensions coincide.



cording to Rey, is to "urge objects into that node" and hold them there so they can be processed. If the object in suspension wanders out of the energy well, the pressure of the surrounding non-interfered wave will push it back into position.

In space, the generator produces sound at a loudness of between 150 and 160 decibels. At a loud concert, the sound coming out of the speaker is usually between 130 and 135 decibels. In addition to the high intensity, the sound is at a very high frequency.

Human hearing extends to frequencies up to about 16,000 cycles per second, while the ultrasound generators go past 20,000 cycles per second.

The Next Steps

Intersonics is now building a new, improved device that it hopes the space agency will fly on a U.S. Shuttle Spacelab microgravity mission in the near future. The company envisions a generator that can extend containerless processing up to temperatures of 2,300 degrees C and beyond. This would vastly expand the range of materials that can initially be processed and created in space.

Rey sees the potential for acoustic levitation in the development of the materials for superconductivity and high-purity glass for fiber optics. Intersonics is also working on refining the generator technology to be able to use acoustic levitation for materials processing on Earth.

Compared to the 150 to 160 decibel intensity needed for space levitation, 170 decibels and more would be required for levitation on Earth. This is an increase of up to 3 orders of magnitude, since the decibel scale is logarithmic. At these very high intensities, the focus of the acoustic beam becomes harder to maintain, as harmonics of the fundamental frequency are introduced.

As in other fields of space materials processing, however, like electrophoresis technology, it is more than likely that the developments required to produce the equipment for the Shuttle experiments will also lead to new techniques for Earth-based processing.

At the end of May, Rey and his staff at Intersonics performed an exciting experiment using six separate sound sources. The interference from these six beams produced a large number of nodes, and the scientists were able to suspend 20 specimens of material at regular intervals along the beams. That result indicates the potential to carry out materials processing in a mass-production mode using acoustic levitation.

New Discoveries on The Curvature of Space

by Jonathan Tennenbaum

A journey from the microcosm to the macrocosm, following the coherent geometry of the universe—from music and the human voice to the placement of the planets in the solar system.

With their concept of the *cosmos*, the ancient Greeks already expressed their understanding that the world around us is no mere collection of objects, but is an "ordering," a lawfully composed whole. Plato's dialogue, *Timaeus*, a principal source of influence of the most advanced Greek science upon the European Renaissance, defines this universal ordering in terms of the two extremes of space—the "infinitely large," the macrocosm which is the object of astronomy, and the "infinitely small," the microcosm. To this is added a third extreme, man, who as a living being possessed of reason, constitutes the highest point of creation. Furthermore, as Plato declares, these three domains are ordered through a common principle, knowable to man through the method of *synthetic geometry*.

In the more than 2000 years since Plato, all scientific progress has ultimately been based on this concept of the cosmos. Technological progress, and with it the range of physical processes accessible to our view, and the methods of synthetic geometry have evolved. But the principle of successful advance of our knowledge concerning the ordering of creation remains the same.

This article presents some exciting new discoveries that demonstrate anew the deep coherence between classical musical composition as a characteristic expression of human reason, and the laws of the microcosm (atomic and subatomic physics) and the macrocosm (astronomy and astrophysics). These discoveries are fascinating in and of themselves. However, we also hope this presentation will give new life to Platonic scientific method in general, at a time when Aristotelianism—with its compulsive insistence on erecting artificial barriers between every possible domain of human activity—seems to reign supreme.

The discoveries reported here are primarily the work of

Lyndon H. LaRouche, Jr. and his collaborators and friends in many countries; they owe most to LaRouche's own work on scientific method and his tireless efforts to inspire others to make original contributions in a wide variety of fields.

Recently, LaRouche has drawn attention to the concept of the *nonlinear curvature of space* as the key to further progress in understanding the cosmos at its three extremal domains.[1] This idea runs as the "red thread" through the wide journey that follows, starting with the human voice and the well-tempered scale of music, proceeding to a discussion of the periodic table of elements and the construction of the atomic nucleus, and ending with the geometry of the solar system, which, as we shall see, is really "composed" along the same principles as the musical system. Rather than try to define abstractly what is meant by "the curvature of space," we present this conception in action, in the genesis of scientific discoveries. Thereby, the reader may attain a much more adequate grasp of the conception than could be gained from a mere formal definition.

The Human Voice

The first discovery is that the characteristics of the human voice, and particularly the register shifts of the perfect singing voice, constitute the essential foundation of all classical music. To a large extent this represents a rediscovery of knowledge current at the time of Mozart that has practically disappeared from musical culture over the last 100 years. In certain respects, however, the present work may go beyond classical knowledge, especially in the light of connections to geometry, biology, physics, and astronomy.

The Italian bel canto method of voice training, which originated in the work of Leonardo da Vinci and his collaborators and reached a high degree of perfection in the time of Mozart, is based on the physical *principle of least action*. This means that the maximum amount of work is done with the least expenditure of effort. The principle of least action was first enunciated by the Greeks, in the form of the *isoperimetric theorem:* The circle is uniquely defined as that closed curve that encloses the largest area for a given length.

The work done in singing—that is, what corresponds to the amount of enclosed area in the circle—is the generation of what is called acoustical turbulence in the vocal apparatus and its conversion into a propagating sound wave. The bel canto technique is simply the least action solution to this problem, the equivalent of the circular form in elementary geometry. It is no accident that the bel canto school speaks of the most perfect singing tone as "the round tone." The resulting sound wave is the acoustical equivalent of a laser beam of light, as every opera-goer easily recognizes by its extraordinary penetrating quality and by the ease with which a trained singer can "fill" a huge hall.

The essential discovery of the bel canto school is that in order to maintain this laser-like "round tone" over the entire range of the voice, the singer must change the manner of sound production at certain notes in the musical scale. These changes are called *register shifts*, and the range of the voice is thus divided into segments called *registers*. For a soprano singing in the classical tuning of Mozart's time, the principal register shifts occur between the F and F-sharp above middle C, and in the same location one octave higher (Figure 1). As children, most human beings begin with a soprano voice; therefore, the soprano voice is regarded as "primordial," and the other voices (alto, tenor, baritone, and bass) are properly considered as being lawfully derived from the soprano.

Most musicians today, even voice teachers and singers, regard the register shifts of the voice as at most a technical question of importance to singing only, not a manner of profound significance for all of music. Some schools of vocal technique even deny the existence of the registers. The main work of rediscovering the importance of voice register was to overcome the accumulated prejudices of professional musicians and scientists on this question.

First, the register shifts are well-defined physical events. Figure 2 illustrates one aspect of this. Here, a trained singer (in this case, a baritone) is asked to sing a "glissando"; that is, to begin in the low range of the voice and continuously raise the pitch, sliding from note to note. The bottom curve in the figure represents the frequency of the sung tone as a function of time. The top curve represents the volume of sound as measured at a certain distance from the singer. The middle curve is produced by a device called an *electroglottogram,* which measures the muscular tension applied to the vocal chords, using high-frequency electrodes placed on the neck of the singer.

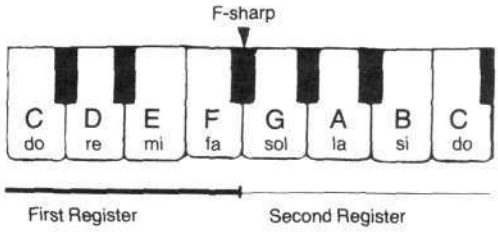
These measurements were made recently by Dr. B. Rubeau of the INSERM laboratory of the Hôpital de la Salpêtriére in Paris. The electroglottogram shows that at a certain frequency (see arrow), the tension on the vocal cords is suddenly reduced. This is the moment of the register shift. The volume is momentarily reduced, but then increases greatly, showing that in the new mode of singing, *more volume is generated with less effort of the singer.* Least-action analysis shows that at the moment of the register shift, a *discontinuous change* occurs in the entire configuration of vocal cords, muscles of the throat, flow of turbulent air inside the mouth, and vibration of resonant cavities such as the nasal sinuses. The electroglottogram shows only one aspect of these changes.

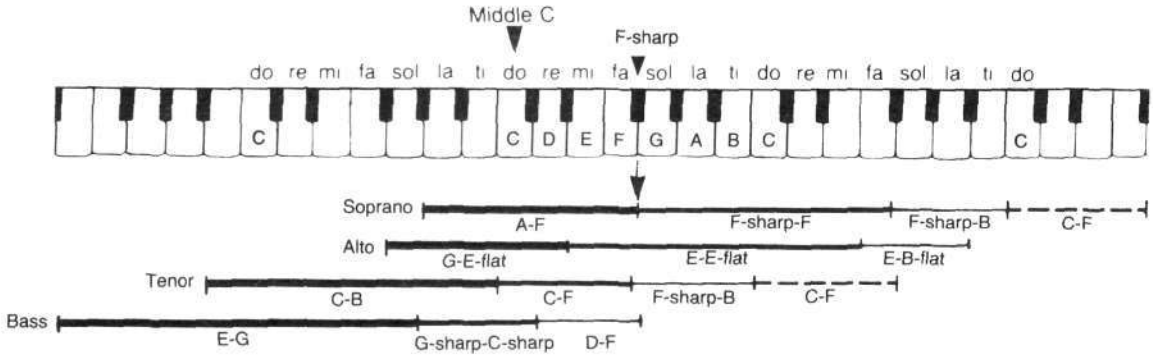
What we have here is what physicists call a "nonlinear phase change," a sudden shift in the geometrical characteristics of action in a process. Is this just an incidental feature of the voice? No! For, as the isoperimetric theorem implies, least-action production of tones by the human voice is a *unique* process, an extreme or maximum. Thus, the occurrence of the register shift at particular values of frequency is uniquely determined by least action in terms of the physiology of the human organism.

This investigation leads directly back to Leonardo da Vinci, whose investigations of wave propagation, acoustics, hydrodynamics and aerodynamics, and human anatomy, as well as his work on the human voice and on the construction of musical instruments, reveal him to be one of the originators of the bel canto school (Figure 3). Leonardo and his mathematics teacher Luca Pacioli carried out an extensive study of the morphology of the human body and other living organisms, including both internal structure and the geometrical ordering of such processes as the flow of blood in the heart. They demonstrated that the geometrical proportionings of living processes are all derived from a single

Figure 1
HUMAN VOICE REGISTERS

The Renaissance Italian bel canto school of voice training is based on the discovery that, in order to maintain a laser-like round musical tone over the entire range of the voice, a singer must change the manner of sound production at certain notes in the musical scale. These changes are called register shifts, *and the range of the voice is thus divided into segments called* registers. *As children, most human beings begin with a soprano voice; therefore, the soprano voice is regarded as "primordial," and the other voices (alto, tenor, baritone, and bass) are properly considered as being lawfully derived from the soprano. The chart shows the first, second, third, and fourth voice registers for the soprano voice, and the first, second, and third voice registers for the alto, tenor, and bass voices.*





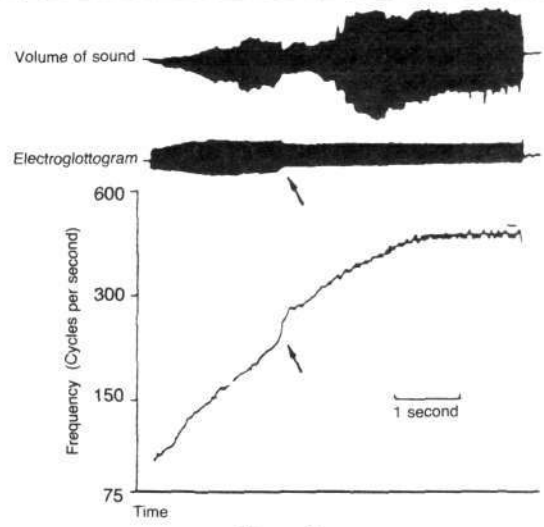


Figure 2
ELECTROGLOTTOGRAM OF A BARITONE'S REGISTER SHIFT

All three curves show the nonlinear change as the baritone shifts voice registers while singing a glissando (sliding from note to note). The arrows point to the frequency at which the shift is made. As seen in the top curve, the volume of sound increases greatly after the shift.

Source: Dr. B. Rubeau, INSERM Laboratory of the Hôpital de la Salpêtrière in Paris.

series, the so-called golden mean series, or tend to golden mean values as the "norm" about which environmentally determined variations occur (Figure 4). Leonardo and his collaborators remarked further that such golden mean derived morphologies are possessed only by living organisms and by matter shaped by activity of such organisms (like seashells). At least, this is the case for visible objects on the Earth's surface.

Today, we know that the golden mean not only dominates the macroscopic morphology of living processes, but also governs the form of the single most important microscopic biological structure, the *DNA molecule* (Figure 5).

These results concerning the relationship between the golden mean and living processes are immediately relevant to bel canto singing. For, it is the morphology of the human body that determines the proportions of the resonating chambers in the human voice. Furthermore, it is the physical characteristics of biological membranes (such as the vocal chords, the surfaces of the lungs, throat, mouth and head chambers) that determine how acoustical turbulence and sound are generated at the boundaries between air flow and membrane surfaces. These physical characteristics, modern biophysical research confirms, are also uniquely coherent with the golden mean.

In summary, the human voice, *the only musical instrument that is a living organism,* possesses characteristic discontinuous transitions called register shifts, whose existence and frequency values are determined by the geometrical ordering of the human physiology. The latter, in turn, is expressed in morphological proportionings derived

from the golden mean.

A simple vibrating string displays none of these properties; it is a dead object, having neither register shifts nor golden mean proportions. It is what the physicists call a *linear system.* Now, which of the two—the human voice or the vibrating string—should be adopted as the reference-point for musical theory and practice?

From the earliest origins of music up through the classical period of Bach, Mozart, and Beethoven, all music flowed from the human voice. All musical instruments were designed to imitate the voice, while extending its range and capabilities in various directions. Carl Philipp Emanuel Bach instructed a student in his 1787 *Versuch über die wahre Art, das Clavier zu spielen* (Essay on the True Art of Playing Keyboard Instruments):

> Above all, lose no opportunity to hear artistic singing. In so doing, the keyboardist will learn to think in terms of song. Indeed, it is a good practice to sing instrumental melodies in order to reach an understanding of their correct performance.

In the course of the last 100 years, however, musical education has come to be dominated by an opposing school of thought that denies the primacy of the human voice. This is the single most important reason for the decline of composition and performance over the same period. The classical reference in theoretical terms for the anticlassical school is Hermann Helmholtz's 1863 *Die Lehre von den Tonempfindungen als physiologische Grundlage für die*

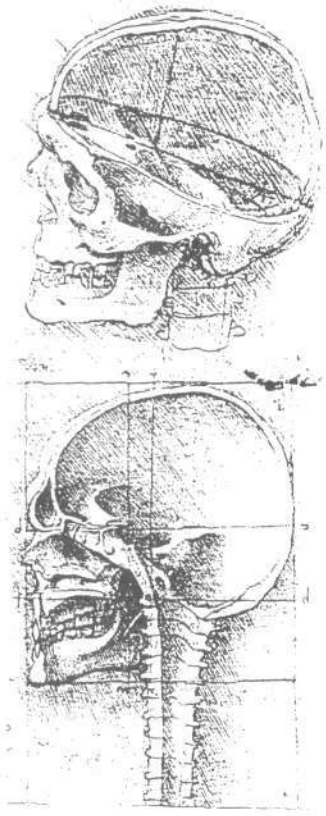
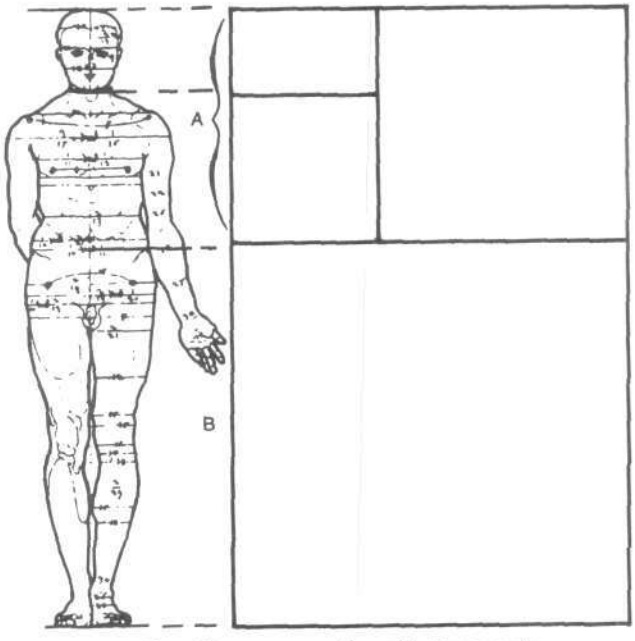


Figure 3
LEONARDO'S STUDIES ON PROPORTIONS OF THE HEAD CAVITIES

Leonardo da Vinci's investigations of wave propagation, acoustics, hydrodynamics, aerodynamics, and human anatomy, as well as his work on the human voice and the construction of musical instruments, reveal him to be one of the originators of the bel canto school of voice training.

Source: Charles D. O'Malley and J.B. de C.M. Saunders, *Leonardo da Vinci on the Human Body.* New York: Greenwich House, 1982.

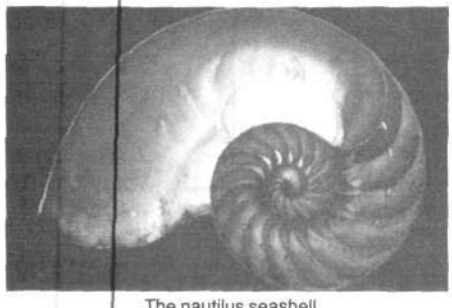


The golden mean proportions of the human body

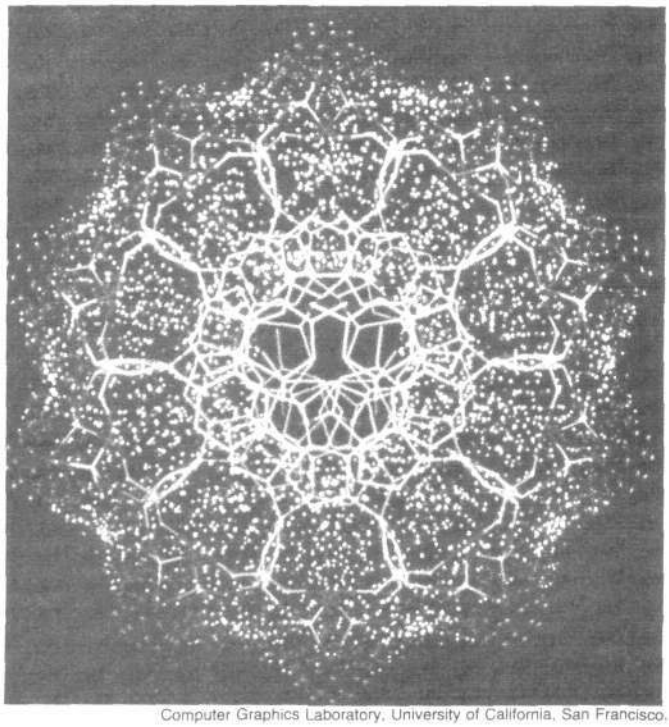
Figure 4
HOW THE GOLDEN MEAN DOMINATES LIVING MATTER

Leonardo and his mathematics teacher, Luca Pacioli, demonstrated that the geometrical proportionings of living processes grow according to the golden mean ratio. This can best be described by dividing a line into two segments, such that their ratio is equal to the ratio of the longer line length to the whole line.

For example, the divisions of the whole body by the navel (A,B) and of the part above the navel by the neck, are determined by the golden mean; in algebraic terms, A:B = B: (A + B). The chambers of the nautilus grow in the same way, where the first chamber is to the second as the second is to the sum of the first two.



The nautilus seashell



Computer Graphics Laboratory, University of California, San Francisco.

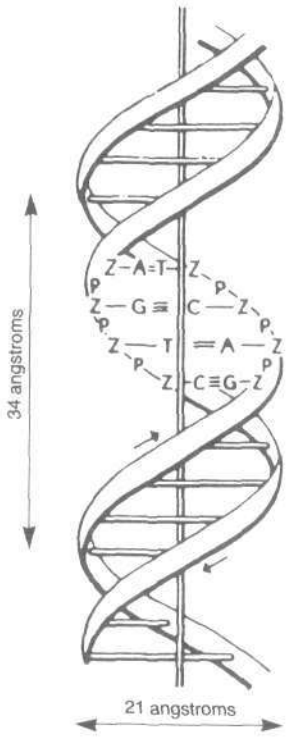


Figure 5
THE GOLDEN MEAN IN THE VERY SMALL

The golden mean dominates not only the macroscopic morphology of living processes, but also the form of the single most important microscopic biological structure, the DNA molecule. At left is a computer simulation of a DNA molecule, end-on view, showing its decagon shape. At right is one cycle of the DNA double helix, showing its golden mean proportions (1 angstrom is one 10-billionth of a meter). The ratio 34:21 is approximately the golden mean proportion $(\sqrt{5} + 1)/2$.

Theorie der Musik (The Theory of the Sensation of Tone as a Foundation for the Theory of Music). Following in the footsteps of the enemy of D'Alembert and Bach, Jean Philippe Rameau,[2] Helmholtz based his entire theory of acoustics, hearing, and musical harmony on the properties of the vibrating string. With his linear form of mathematics, Helmholtz could understand only dead things, and he denied the existence of what he could not understand.

Helmholtz belonged to a school of physiology that refused to recognize any systematic difference between living and nonliving processes, ignoring the entire weight of the earlier work of Leonardo and Pacioli on the significance of the golden mean. To Helmholtz, living processes were simply very complicated assemblies of elementary particles. Such essentially nonlinear phenomena as the vocal register shifts were inexplicable and did not exist for him as lawful events. As a matter of fact, Helmholtz was subsequently proven wrong on every essential point of his theory of human hearing and consonance and dissonance of tones. Nevertheless, his work remains the basis for teaching of music theory in most musical schools today.[3-5]

We have pledged to overturn the hegemony of Helmholtzian, Rameauian musical theory and restore the classical tradition based on the human voice. One crucial aspect of this work has been to recover the intimate connection between voice registers and the construction of the well-tempered musical scale.

The Geometry of the Musical Scale

In addition to the register shifts, there is a second essential characteristic of the human voice and ear that determines the geometry of the musical scale: the *octave*. In linear mathematics, frequency is measured by what is called a *scalar quantity*, meaning that different frequencies are ordered like points on a straight line. From this standpoint, the action of increasing frequency is like moving from right to left on a straight line. However, when we hear a singer sing a scale upward, say from middle C on the piano, we observe that there is a *rotational component* of the action, besides a mere frequency increase. For, when the singer arrives at the C one octave higher, we clearly perceive that a cycle has been completed and that the notes that follow have the significance of beginning a new cycle of action. The scale is thus organized as a *spiral*, in which one circuit around the origin defines an octave. In mathematical terms, a musical interval is a *complex number*, not a scalar.

Following the suggestion of Lyndon LaRouche, in 1981 I made the following geometrical construction [Figure 6(a)]. The musical system is represented by a cone whose axis corresponds to frequency in vibrations per second. Action

of increasing frequency is represented by a spiral on the cone, whose angle of climb is so chosen that the spiral doubles its height along the axis in every 360-degree rotation. Thus, if middle C is tuned according to the classical tuning in Mozart's time, namely, at 256 cycles per second or hertz (Hz), then the successive cycles of the spiral arrive at heights corresponding to 512, 1,024, and so on, and downward at 128, 64, 32, and so on. If we cut the cone perpendicular to its axis at these heights, then the segments of the cone thus obtained correspond to the various octave intervals of C.

Now, if we start at C 256 and proceed upward along the spiral exactly 180 degrees—that is, if we complete one half a cycle of spiral action—then we arrive at a height corresponding to a frequency of nearly exactly 362 Hz, which is the value for F-sharp! This is the first note of the middle register of the soprano, so it marks the dividing point between the lower register and the middle register. As a height on the cone, the halfway point on the spiral is the *geometric mean* of the heights of the frequencies of C and its octave; in other words, the F-sharp point must divide the ratio of C to its octave into equal proportions. Indeed, 256: 362 = 362: 512, and the interval from C to F sharp, known variously as a diminished fifth or "the devil's interval," is the same interval as that from F sharp to the C one octave higher.

It is easy to complete this construction and obtain the entire 12-tone division of the octave.[6] We have merely to divide the 360-degree cycle of rotation of the spiral into 12 equal steps of 30 degrees each. The corresponding heights on the cone give the frequencies, in equal-tempered tuning, of C-sharp, D, D-sharp/E-flat, E, F, F-sharp, and so on.

Figure 6(b) shows the equivalent construction, carried out in plane projection; in other words, we project the conical spiral onto a plane perpendicular to the axis of the cone. The result is a logarithmic spiral, the same type of spiral found in seashells. The frequencies of the equal-tempered system are proportional to the radial lengths cut off by the spiral.

This construction demonstrates, among other things, that the geometry of the musical scale coheres directly with that of the exponential *growth processes of life*, as the sea snail shows us! Second, we see that the register shift point of the soprano, F-sharp, coincides with the simplest division of the cycle of spiral action—the geometric mean. As all musicians know, the interval thereby generated—the "devil's interval," from C to F-sharp—is the crucial interval in *modulation* from the key of C to its dominant, the key of G. This same note, F-sharp, also marks the natural division of the scale of C major into its two so-called tetrachords; namely, the sequence CDEF and the sequence GABC, which have the same order of whole-step and half-step intervals.

Another beautiful proof of the conical-geometrical derivation of the most important relationships in the musical system was derived by Carol White.[7] If we cut the section of the cone from C 256 to C 512, diagonally across, then we obtain an ellipse [Figure 7(a)]. This ellipse can be considered as a geometrical *characteristic* of the octave interval. The plane projection of this ellipse is shown in Figure 7(b). One of the focal points of this ellipse is the point corresponding to the axis of the cone. Thinking of the ellipse as the orbit of a hypothetical planet, the focus-point becomes the position of the Sun, and the perihelion (shortest distance to the Sun) and aphelion (longest distance) correspond, respectively, to middle C and its octave. Then all the classical parameters of this ellipse have immediate musical meaning, as follows:

The semimajor axis corresponds to the dominant, G, and mathematically to the *arithmetic mean* of the distances for C and its octave.

The semiminor axis corresponds to F-sharp, and is the *geometric mean* of the distances for C and its octave.

The perpendicular from the focus-point to the major axis, known as the latus rectum, corresponds to F and is the *harmonic mean* of C and its octave; on the cone, this corresponds to the height at which the elliptical cut intersects the axis of the cone. (In case the reader is not familiar with them, the arithmetic, geometric, and harmonic means were defined by the Greeks and played an important role in their scientific investigations. For given lengths A and B, the corresponding scalar values are $(A+B)/2$, $\sqrt{AB}$, and $2AB/(A+B)$, respectively.)

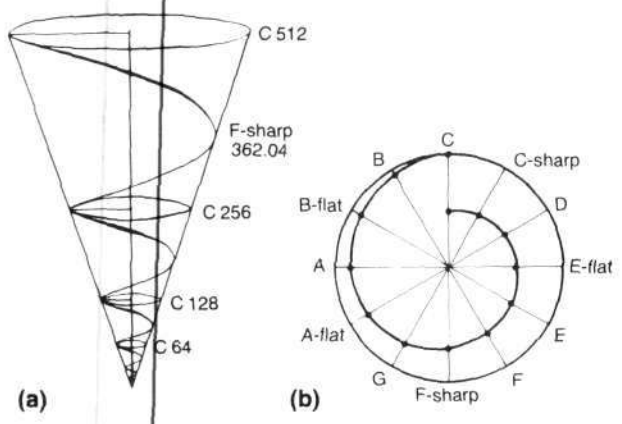


Figure 6
REPRESENTING THE MUSICAL SCALE ON A CONICAL SPIRAL

The musical system is represented by a cone (a) whose axis corresponds to frequency in vibrations per second. Action of increasing frequency is represented by a spiral on the cone; the spiral doubles its height in every 360° rotation. If middle C is tuned according to the classical tuning of Mozart's time—256 cycles per second—successive cycles of the spiral arrive at heights of 512, 1,024, and so on, and downward at 128, 64, and so on. If we start at C 256 and proceed upward along the spiral one half-cycle of action, or 180°, we arrive at a height corresponding nearly exactly to 362 cycles per second, the value of F-sharp, and the dividing point between the first and second register of the soprano voice.

The equivalent construction carried out on a plane is shown in (b). The conical spiral is projected onto a plane perpendicular to the axis of the cone, resulting in a logarithmic spiral.

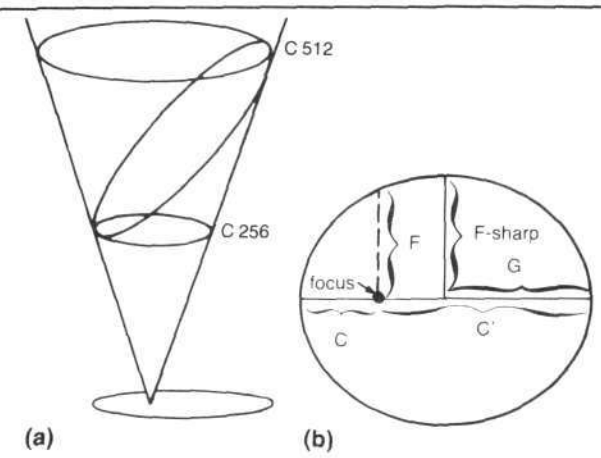


Figure 7
A CONICAL-GEOMETRICAL DERIVATION OF MUSICAL RELATIONSHIPS

A diagonal cut across the section of the cone (a), from C 256 to C 512, produces an ellipse, which can be considered as a geometrical characteristic of the octave interval. The plane projection of this ellipse is shown in (b). Thinking of this ellipse as the orbit of a hypothetical planet, the focus-point is the position of the Sun, the perihelion (shortest distance to the Sun) corresponds to middle C, and the aphelion (longest distance) corresponds to its octave. The semimajor axis corresponds to the dominant, G, and mathematically to the arithmetic mean of the distances for C and its octave; the semiminor axis corresponds to F-sharp, and is the geometric mean of the distances for C and its octave. (In this model, lengths are used to represent frequencies.)

We therefore have a beautiful characterization of the crucial complex of notes in the key of C—namely, F, F-sharp, and G—in terms of the elementary geometry of conic sections.

We know that golden mean relationships must underlie the musical scale system, since its coherence with the human voice and the logarithmic spiral characteristic of living processes has been adequately demonstrated already. However, White demonstrated the golden mean in the scale in explicit form, as follows. Mark on a linear scale designating frequency the positions corresponding to any C, the E-flat and G above this C, the octave of this C and the E, F-sharp, and G above that octave (Figure 8). The lengths of the line segments between the points thus marked, lengths proportional to the differences in frequencies of the corresponding tones, form a series in the golden mean ratio.

Composition and the Tuning of the Musical Scale

What can be said about the classical method of composition in light of these discoveries? In a systematic study of classical lieder, soprano Kathy Wolfe and others demonstrated that the points of register shift coincide, in the overwhelming majority of cases, with the principal transformations or turning-points in the content of the composition (Figure 9).[8] In other words, the shift in least-action configuration of the singing voice coincides with the *verbal action* in the composition. There are some apparent exceptions to this "rule," which, however, on closer examination actually confirm it; these are cases in which the composer aims at an ironic use of the register shift, displacing it from apparent transition points in the composition.[9]

The reason for differences in "color" between the different musical keys (like C major and E major, for example), differences that are rendered totally mysterious by the Helmholtz school of linear acoustics, becomes immediately clear once we reestablish the primacy of the human voice, as pointed out by LaRouche.[10] For, since the frequencies of the register shifts are fixed in terms of the physiology of the voice, they define an *absolute standard of musical pitch*. The principal soprano register shifts, in particular, come in the range 345 to 350 Hz and 690 to 700 Hz, in both cases between F and F-sharp (in the C 256 tuning). Depending on which key a piece is written in, the register shifts will fall in different places in the scale. So, in C major, the shift comes between the fourth and fifth steps, whereas in E major, it comes between the first and second steps. Thus, in each different key, the register shifts of the soprano and other voices occur in different geometrical contexts, defined by the positions relative to the main intervals of the key (dominant, subdominant, leading tone, and so on). Hence the different *colors*—simple!

Shifts in register do not always have to be *heard* in order to be *felt* by the listener. Each person "hears" music in terms of reference to his or her own voice, which in childhood was a soprano. For this reason, register is just as important in instrumental music as it is in vocal music—quite apart from the fact that well-designed instruments, in imitation of the human voice, also possess distinct registers of their own.

Through their extensive work on the geometry of the musical system, of which we could only touch on some highlights in this article, LaRouche and his collaborators have assembled decisive proof, that *the musical tuning based on A 440 or higher is scientifically wrong*. Figure 10 illustrates why. The increase of pitch from the classical C

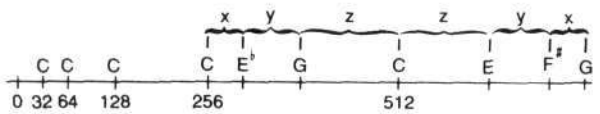


Figure 8
GOLDEN MEAN PROPORTIONS IN THE MUSICAL SCALE

Mark on a linear scale designating frequency the positions corresponding to any C, the E-flat, and G above this C, the octave of this C, and the E, F-sharp, and G above that octave. The lengths of the line segments between the points thus marked, are proportional to the differences in frequencies of the corresponding tones and form a series in the golden mean ratio: x:y = y:z.

256 (corresponding to A in the range 427 to 431) to the present norm of A 440 forced singers to change the notes at which register shifts occur. For the soprano, a tuning at A 440 pushes the frequency of F beyond the division point. As a result, today's sopranos shift between E and F, rather than between F and F-sharp as they did in the classical period. This arbitrary, politically imposed raising of pitch destroys the entire coherence sketched above, between the human voice, conical-spiral geometry, and the construction of the musical scales, and falsifies performance of all the musical classics.

We shall demonstrate below that only the classical C 256 tuning is in accord with the ordering of the macrocosmos, our solar system. First, however, we must "shift registers" and turn our attention from music to the microcosmos of atomic and subatomic physics. Here, in a domain seemingly far removed from our topic of discussion so far, we shall rediscover the same basic geometrical principles at work.

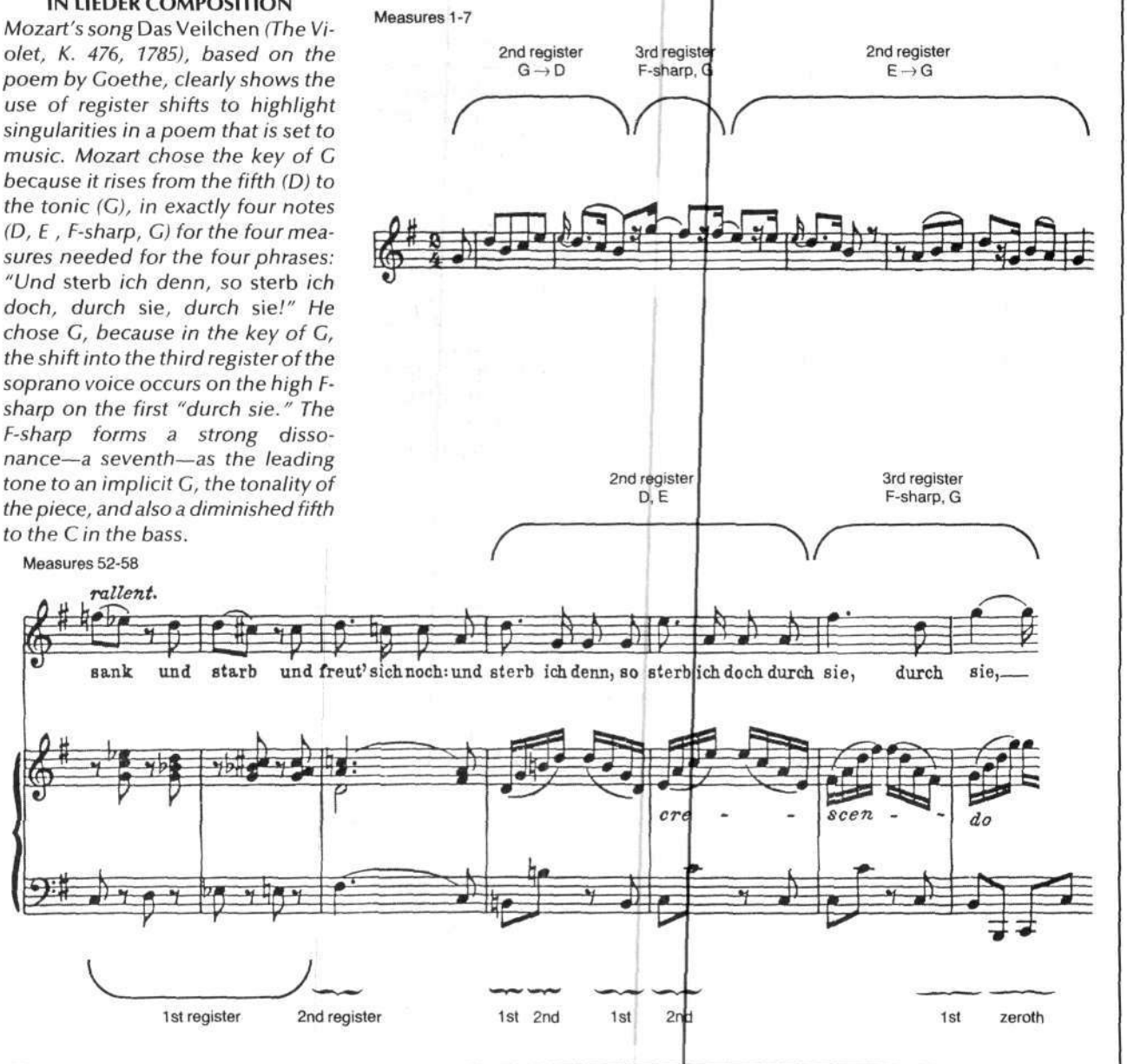
How the Periodic Table Reflects the Curvature of Space

Chemistry has its own analog of the musical scale, the periodic table of the elements. About 90 naturally occurring chemical elements form the basis upon which all matter, at least on Earth's surface, is composed.

Professor Robert J. Moon, a veteran of the Manhattan Project and an old friend of LaRouche, has spent a great

Figure 9
MOZART'S USE OF REGISTER SHIFT IN LIEDER COMPOSITION

Mozart's song Das Veilchen *(The Violet, K. 476, 1785), based on the poem by Goethe, clearly shows the use of register shifts to highlight singularities in a poem that is set to music. Mozart chose the key of G because it rises from the fifth (D) to the tonic (G), in exactly four notes (D, E , F-sharp, G) for the four measures needed for the four phrases: "Und* sterb *ich denn, so* sterb *ich doch, durch* sie, *durch* sie*!" He chose G, because in the key of G, the shift into the third register of the soprano voice occurs on the high F-sharp on the first "durch sie." The F-sharp forms a strong dissonance—a seventh—as the leading tone to an implicit G, the tonality of the piece, and also a diminished fifth to the C in the bass.*



part of his life thinking about the periodic table. About two years ago, he hit upon a new idea that promises to revolutionize our understanding of the atomic nucleus and explains many features of the system of chemical elements that until now remained a mystery.[11]

Present-day physics pictures the atomic nucleus essentially as a clump of elementary particles—protons and neutrons. Starting from a single proton, which forms the nucleus of the hydrogen atom, we keep adding protons, one by one, plus a few neutrons thrown in for stability, to go stepwise upward from element to element in the periodic table. Thus, the helium nucleus has two protons, the lithium nucleus has three, beryllium has four, boron has five, carbon has six, and so on. Finally, we get to uranium with 92 protons and 143 to 146 neutrons.

What a boring theory! With this linear conception of cumulatively adding particles, we can never understand the tremendous variety of physical properties of the elements, their different colors, different chemical affinities, and so on. We can never understand, on such a basis, why certain specific atoms, like magnesium or calcium, play specific, essential roles in living processes while others do not. One aspect of this nonlinear behavior, incomprehensible to the "accumulation theory," is shown in Figure 11. Here we see the volume or density of atoms as a function of their atomic number (number of protons in the nucleus). Naively, we should expect it to constantly increase as more particles are thrown into the nucleus. But, no! It oscillates with sharp maxima and minima at specific elements. Other physical parameters, like melting points, elasticity, and so on, change in a similar nonlinear manner.

To understand the atom we must give up the naive belief that an atom is a *thing*. Instead, we have to understand it as a *process*, or more precisely as a singularity in a process. In other words, the question, "*what* is an atom?" is incorrectly formulated. Instead, we should ask, "What is the specific geometry of action that gives a particular species of atom its apparent properties?"

Exactly this sort of approach was applied with great success by another collaborator of LaRouche, plasma physicist Winston Bostick, to the structure of the electron and other subatomic particles.[12] The real electron, he showed, hardly resembles the inert "hard ball" concept of textbook physics; it is actually a complex hydroelectrodynamic process that take a huge variety of "shapes" depending on the larger process in which it participates. Furthermore, the electron is not really "elementary." In certain processes the indivisible unit of action takes the form of a coherent configuration of what appears to be a large number of electrons "merged together." Such, for example, are the so-called electron shells in the atom, as well as the coherent *current waves* that conduct electricity in superconductors.

Moon looked at the atomic nucleus in the same way: not as an assemblage of "hard ball" particles, but as a *coherent form of action*. If we know what the possible *forms* are, then we know all possible nuclei and all possible chemical elements and their properties. So, we have a problem of geometry!

The kernel of Moon's preliminary solution was provided by Johannes Kepler in his work on the geometry of the solar system. Kepler observed, following the earlier work of Plato, Nicholas of Cusa, and Leonardo da Vinci, that *the range of lawful or intelligible forms that can exist in visual space is not unlimited, but is bounded in possibility in a certain knowable way*. The proof certains on the fact that, in visible space, only five regular solids can be constructed: the tetrahedron, cube, octahedron, dodecahedron, and icosahedron (Figure 12). *No other polyhedra exist in which all the faces are identical.* This seems to define an absolute limit on how finely space can be divided in a perfectly symmetrical way.

This discovery of the strictly bounded possibility of lawful construction in visible space is believed to have originated in the Cyrenaic Temple of Ammon in Egypt. The discovery exercised a decisive influence, via Moses, on the rational current of Judaic Law as well as on the development of

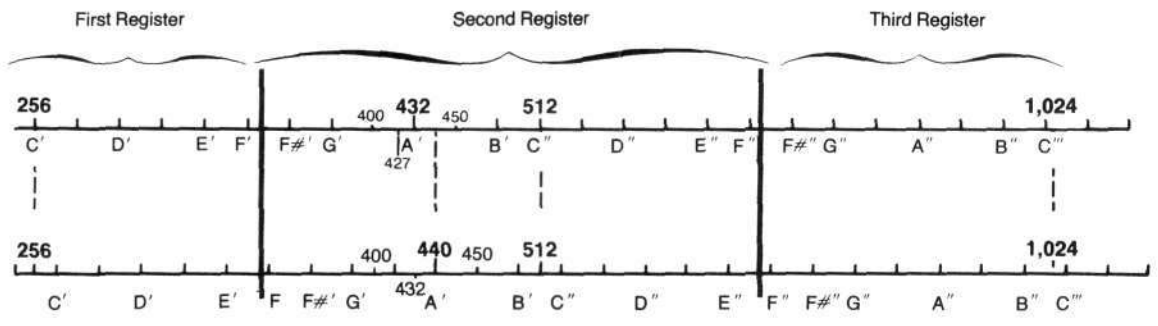


Figure 10
THE EFFECT OF RAISING PITCH FROM C 256 TO A 440

The increase of pitch from the classical C 256 to the present norm of A 440 forces singers to change the notes at which voice register shifts occur. For the soprano, a tuning at A 440 pushes the frequency of F beyond the dividing point between the first and second register. This arbitrary raising of pitch falsifies performance of all the musical classics.

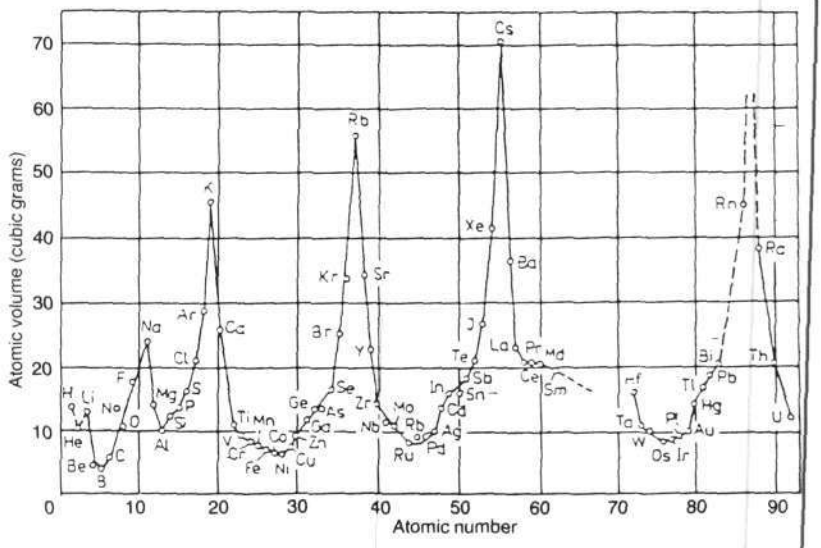


Figure 11
ATOMIC VOLUME AND ATOMIC NUMBER

If the elements were simply a linearly expanding collection of protons and neutrons, one would expect the volume of atoms to constantly increase as the number of particles in the nucleus increases. Instead, there are sharp peaks and troughs at specific elements—nonlinear behavior.

science in Greece.[13] But it raises a crucial theological question: If space is bounded, does this mean that God, too, is constrained in his work of creation? Does creation come to a halt because of the limitations of space? The answer, clearly, is no: *the characteristics of visual space do not limit physical action (creation) per se, but only the way in which action can appear to us, given our limited nature as created beings.*

We do not see reality directly, as God does, but in terms of visual and related sense images. We have to find out the lawful connection between reality, as it really is, and the images we see. Kepler saw the crucial clue to this in the isoperimetric theorem: Least action in the universe must assume an intelligible form in terms of the geometry of the circle and its three-dimensional counterpart, the sphere. This does not mean that everything must have the shape of a circle or sphere or their regular divisions (regular polygons and polyhedra), but rather, that *the limitations of visual space define the circumstances in which a change or discontinuity has to occur in the visible manifestation of a least-action process.* This, in first approximation, is the meaning of the term curvature of space.

Moon's construction of the periodic table of elements provides a beautiful illustration of the epistemological principles just discussed. Moon considers that the chemical elements are forms of least action, like the well-tempered tones of a bel canto singer. Assuming that such least action must manifest spatial characteristics coherent with the regular solids, Moon proposed that the atomic number of a given element corresponds to the number of vertices on the spatial form of its nucleus. So, for example, he conjectures that the oxygen nucleus, with atomic number 8, has the form of a perfect cube [Figure 13(a)]. The preceding element, nitrogen, with atomic number 7, he considers, only fills 7 of the 8 possible corners of the cube; perhaps it looks like a cube with one corner cut off [Figure 13(b)]. With oxygen, the possibilities of the cube are exhausted: A singularity must occur here! Moon proposes that the next elements have their vertices on the cube and on an octahedron, which can be considered either as enclosing the cube or as being formed by the midpoints of the faces of the cube [Figure 13(c)]. Since the octahedron has 8 vertices, this provides 14 possible locations in all. These are exhausted by the 14th element, *silicon*. At this point a new domain must be opened up: the icosahedron with 12 potential new locations. These are exhausted at element 14 + 12 = 26, which is *iron*.

Moon now observes with delight that oxygen, silicon, and iron are believed by geologists to be the most abundant elements making up the mass of the Earth. As can be seen in the table, these three elements together constitute an estimated more than 80 percent of the Earth's mass. The next most abundant element is *magnesium*, estimated to make up about 13 percent of the Earth's mass. This fits beautifully with Moon's basic hypothesis, since magnesium, the 12th element, would correspond directly with a completely filled icosahedron, clearly a least-action configuration!

Resuming Moon's construction of the periodic table, we stopped at iron (atomic number 26) whose vertices fill the corners of the cube, octahedron and icosahedron. The only remaining Platonic solid is the dodecahedron. (Moon excludes the tetrahedron for reasons not elaborated here.) The dodecahedron provides an additional 20 vertex locations, which are exhausted at element number 26 + 20 = 46, palladium [Figure 13(e)]. At this point the periodic system must have a "register change"; the possibilities of the regular solids, at least insofar as the vertices correspond to atomic number, are exhausted, and something new must happen. Moon proposes, in effect, that the nuclei become asymmetrical, with a second system of solids adjoined to the first [Figure 13(f)]. This would provide an additional 46 vertices, leading to none other than *uranium*, atomic number 92, the endpoint of the classical periodic table and the heaviest of the elements to be found in more than infinitesimal quantities. Moon notes, also with great pleasure, that his hinged twin-nucleus model indicates why the heaviest nuclei undergo fission, splitting into two lighter nuclei.

One of the most successful features of Moon's model is that it provides the first simple and coherent hypothesis for the nonlinear oscillations of atomic volume (Figure 11) and other physical characteristics. The minima of the curve are all located at or near the transition points in Moon's construction, that is, the points at which one of the regular solids in the nested series is completed. These are: oxygen (8), silicon (14), iron (26), and palladium (46). Further minima occur near atomic numbers 72 (46 + 26) and 92 (46 + 46), which are key stages in the filling of the second twin.

Laurence Hecht has extended Moon's considerations to the electron configurations of the atom, which are important for the spectral and chemical characteristics. Based on the models constructed by Kepler, which combine, respectively, the pairs of regular solids (cube/octahedron and icosahedron/dodecahedron), Ralph Schauerhammer has found an even simpler formulation of Moon's fundamental idea, which gives even more extensive agreement with observed abundances of elements and identifies as singularities many of the essential elements in biological systems (carbon, calcium, magnesium, phosphorus, and so on).[14]

Moon's essential accomplishment is that he demonstrates the feasibility of a purely geometrical theory of subatomic and atomic physics, one that makes no assumptions of any kind about the properties of particles or forces, but is based on the concept of least action alone. A great deal of work remains, to elaborate this beautiful discovery into the nuclear physics of the future.

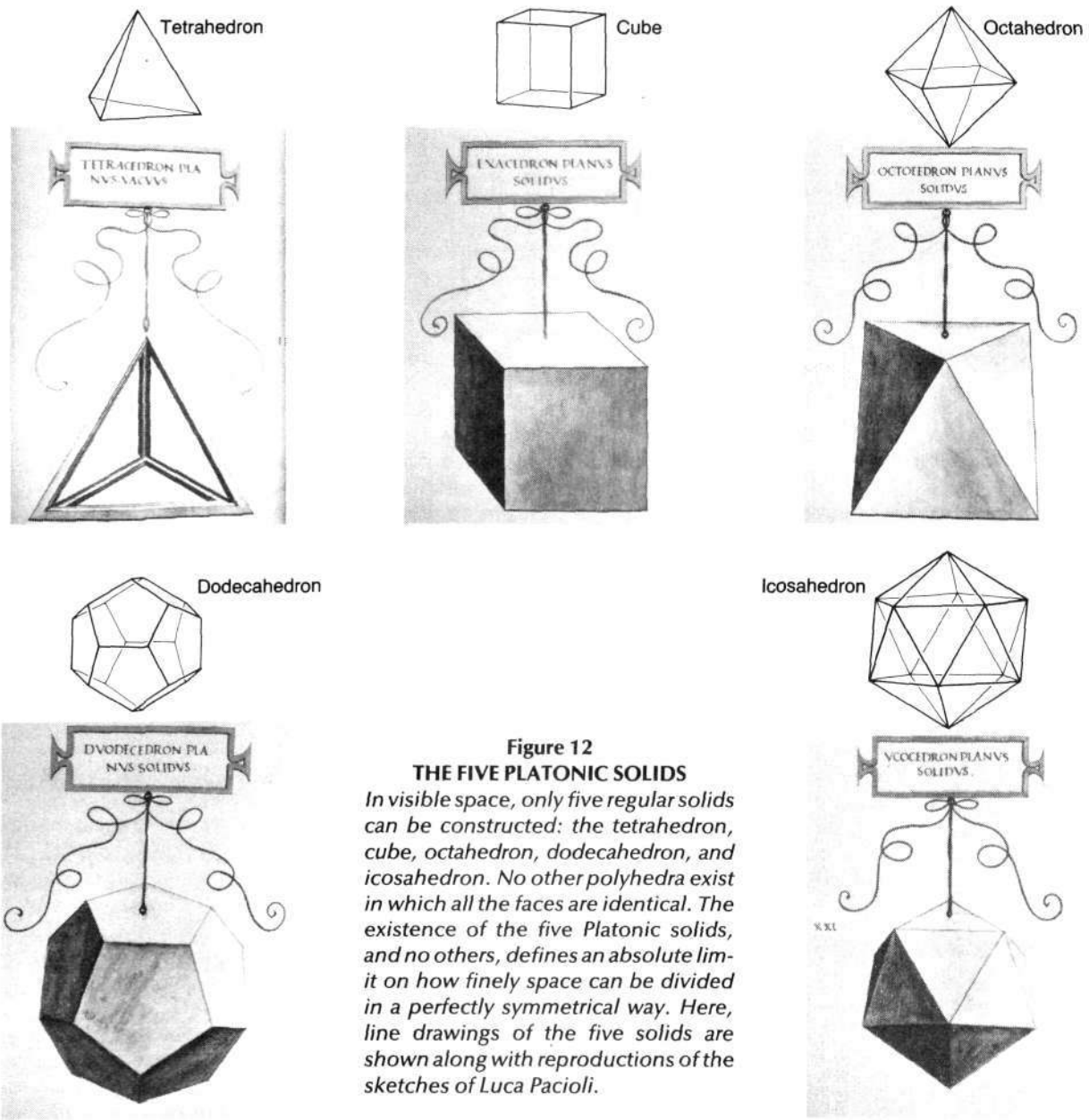


Figure 12
THE FIVE PLATONIC SOLIDS
In visible space, only five regular solids can be constructed: the tetrahedron, cube, octahedron, dodecahedron, and icosahedron. No other polyhedra exist in which all the faces are identical. The existence of the five Platonic solids, and no others, defines an absolute limit on how finely space can be divided in a perfectly symmetrical way. Here, line drawings of the five solids are shown along with reproductions of the sketches of Luca Pacioli.

We come now to the last step of our long journey: The macrocosmos of our solar system and the demonstration that here, too, the same geometrical principles apply as for the realm of music and the realm of the atom.

The Geometrical Composition of the Solar System

To this day, students of science are indoctrinated in Newtonian mechanics, which seeks to reduce reality to a system of "mass points" moving about and exerting forces upon one another within an infinite, otherwise empty void called absolute space. This indoctrination continues in spite of the fact that Newtonian mechanics has long been refuted and abandoned in microphysics (quantum physics), after it was found that the electrons in an atom do not move freely about but are constrained to a discrete set of orbits and "quantum states." A close look at our solar system refutes Newton as devastatingly as do the discrete spectra of atomic physics.

Long before Newton, Johannes Kepler had established beyond any doubt that the orbits of the planets are lawfully ordered by harmonic proportions derived from the five regular solids. According to Kepler, not all elliptical paths around the Sun are "possible," but only a discrete set of orbital regions, which we actually see "filled" by the planets. These possible orbits are determined by the geometry of space. Kepler showed that the orbital radii of the first six planets (Mercury, Venus, Earth, Mars, Jupiter, and Saturn) are proportioned according to a series of concentric spheres in which the five regular solids are alternately inscribed and circumscribed (Figure 14).

In his last great work, *The Harmonies of the World,* Kepler furthermore demonstrated that the elliptical deviations of the planetary orbits from exact circles are proportioned in such a way, that the *angular velocities* of the planets around the Sun, taken at their closest and farthest distances, form the same numerical ratios as the notes of the diatonic musical scale. He explained the coherence of these results by showing that the diatonic musical scale itself derives from the geometry of the circle and the regular solids (Figure 15). The frequency ratios of the principal consonant intervals are all provided by the divisions of the circle defined by the equilateral triangle, square, and pentagon—those figures constituting the faces of the regular solids. Kepler's construction of the scale is not entirely accurate, but it is a first approximation to the methods described above. In short, he defines what is called perfect tuning, but not the well-tempered tuning necessary for musical development centering on the process of modulation.

The most interesting astronomical problem left over by Kepler's work concerns the large gap between the orbits of Mars and Jupiter (Figure 16). This is the gap spanned by the tetrahedron in Kepler's concentric spheres construction of the orbital distances. Now, as Kepler already pointed out, and as modern planetary exploration has confirmed with much additional information, this gap divides our solar system into two qualitatively distinct sets of planets, so clearly different that we can talk about a "register shift" in the system. Leaving the outermost-known planet, Pluto, aside for the moment, the outer planets Jupiter, Saturn, Uranus, and Neptune are all very large and gaseous in composition, with many moons and with systems of rings. In contrast, the inner planets, Mercury, Venus, Earth, and Mars are all much smaller and solid in composition, with no or few moons and no rings.

Kepler conjectured that there should be an additional orbital region inside the Mars-Jupiter gap, a region which, considering the register shift and the fact that it is not admitted in the "diatonic" orbital series determined by the regular solids, must have a "singular" character. For 200 years, astronomers searched for objects in the region indi-

Author Jonathan Tennenbaum, shown here during his presentation to the Schiller Institute's international conference on musical tuning, held in Milan, Italy, April 9, 1988. The conference gathered scientists, musicians, and public figures at Milan's famous Casa Giuseppe Verdi, the Renaissance-style building that the composer had built for retired musicians. Its theme was the need to reimpose as the standard musical pitch C 256, instead of today's heightened A 440, and to reassert the classical principle of the human singing voice as the basis of all great music.

Speakers included the institute's president, Helga Zepp-LaRouche; renowned operatic soprano Renata Tebaldi, and baritone Piero Cappuccilli. Messages and greetings came from Spanish soprano Montserrat Caballé, Swiss soprano Anneliese Rothenberger, German bass Kurt Moll, Mexican tenor Placido Domingo, German soprano Edda Moser, and Italian tenors Luciano Pavarotti, Carlo Bergonzi, and Giuseppe Di Stefano.

Videotapes of the conference proceedings, including Tennenbaum's address on the science of musical tuning, are available from the Schiller Institute (see page 19).

cated by Kepler, until finally an Italian, Giuseppe Piazzi, found the asteroid Ceres on the first day of 1801. From Piazzi's scant data, the 24-year old Karl Gauss succeeded in calculating Ceres's orbit and verified that it, indeed, had the parameters prescribed by Kepler. Today, astronomers have catalogued more than 1,000 of an estimated 100,000 or more small bodies orbiting in the region between Mars and Jupiter. The vast majority of these asteroids, which may be the fragments of an exploded planet, occupy a sharply bounded band-like region between 2.2 and 3.2 astronomical units from the Sun (an astronomical unit is the distance from the Earth to the Sun—about 149 million kilometers). This region is truly "singular" in the solar system, as Kepler had thought.

Inspired by the obvious analogy between the register shift of the human voice and the "planetary register shift" occurring in the asteroid belt, I decided to look for a direct correspondence between the geometry of the solar system and the geometry of the well-tempered system in music. First I asked the question, "Where is the asteroid belt locat-

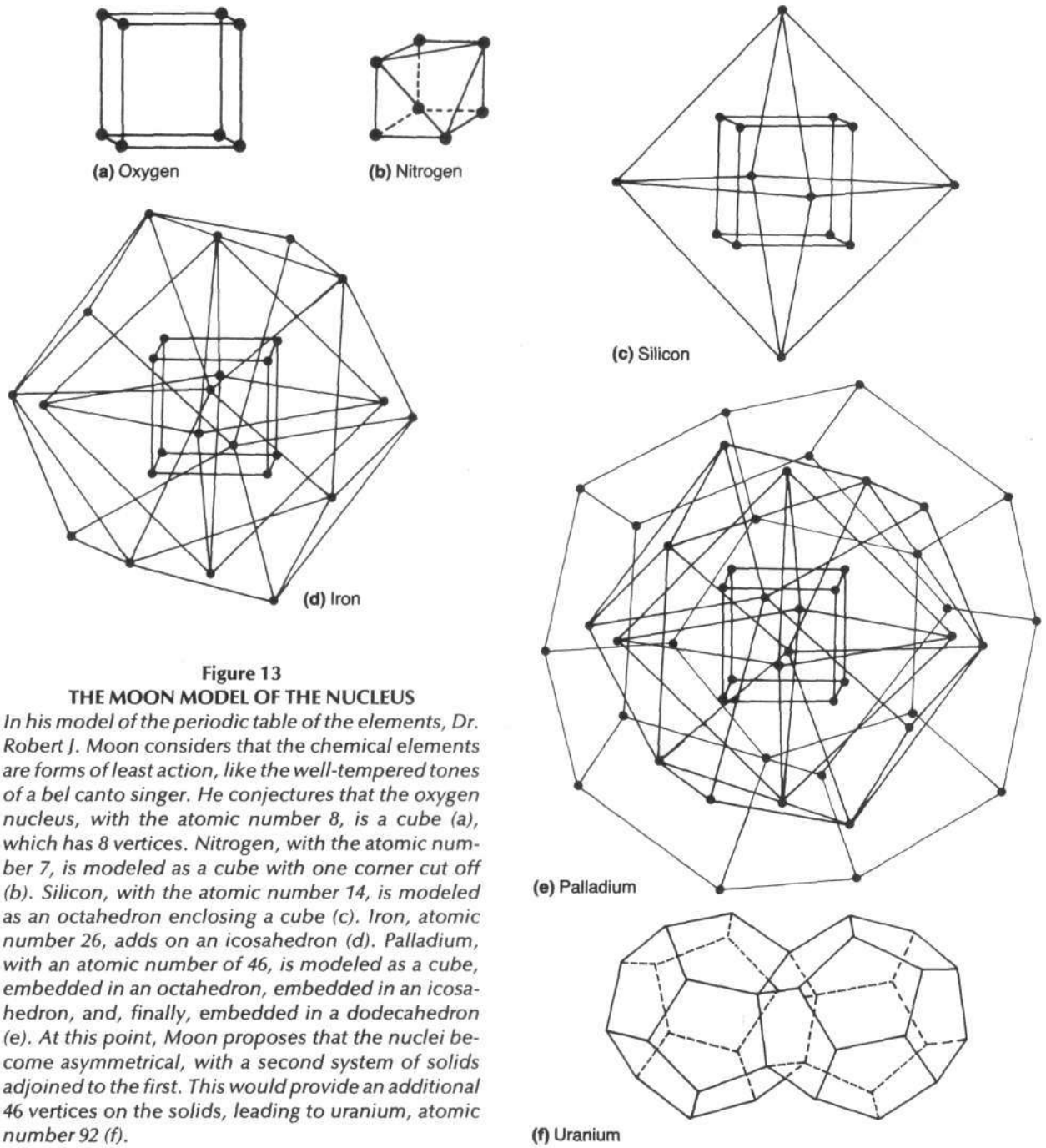


Figure 13
THE MOON MODEL OF THE NUCLEUS

In his model of the periodic table of the elements, Dr. Robert J. Moon considers that the chemical elements are forms of least action, like the well-tempered tones of a bel canto singer. He conjectures that the oxygen nucleus, with the atomic number 8, is a cube (a), which has 8 vertices. Nitrogen, with the atomic number 7, is modeled as a cube with one corner cut off (b). Silicon, with the atomic number 14, is modeled as an octahedron enclosing a cube (c). Iron, atomic number 26, adds on an icosahedron (d). Palladium, with an atomic number of 46, is modeled as a cube, embedded in an octahedron, embedded in an icosahedron, and, finally, embedded in a dodecahedron (e). At this point, Moon proposes that the nuclei become asymmetrical, with a second system of solids adjoined to the first. This would provide an additional 46 vertices on the solids, leading to uranium, atomic number 92 (f).

ed in the context of the solar system as a whole?" The answer, in first approximation, is very simple. The orbits of the planets are comprised between 0.39 astronomical units (mean orbital radius of Mercury) and 39.5 astronomical units (mean orbital radius of Pluto). The *geometrical mean* of these two distances is 3.9 astronomical units, just slightly larger than the upper boundary of the asteroid belt! Thus, if we think of the interval between Mercury and Pluto as equivalent to the musical octave from C to C, then the upper limit of the asteroid belt corresponds to F-sharp, the geometrical mean of the octave and the register-shift note of the soprano voice! Examining now the entire solar system from the standpoint of conical geometry, I confirmed the most simple and beautiful relationship to the musical system that I could ever have imagined.

The entire system of elliptical orbits in the solar system can be thought of as obtained by projection from a set of slightly inclined cuts of a single cone, whose axis can be thought of as lying on the line perpendicular to the ecliptic plane and whose summit is at the center of the Sun (Figure 17). I then constructed a self-similar spiral on the cone, making exactly one full cycle in passing from the height corresponding to the perihelion of Mercury, to the height corresponding to the (nearly circular) orbit of Neptune. (The reason for choosing Neptune rather than Pluto is that Neptune constitutes the last of the "second register" planets beginning with Jupiter. Pluto probably starts a new register, still largely unknown to astronomy.)

The ratio between starting-point height (Mercury perihelion) and ending-point height (Neptune orbit) is nearly exactly 1:100. The halfway point of the spiral, that reached in rotation through 180 degrees, corresponds very closely to the upper limit of the asteroids. In analogy with the construction of the musical scale, I then divided the full 360-degree rotation of the spiral into 12 equal steps, and found, to my delight, that the positions of the planetary orbits fit with remarkable accuracy to the steps corresponding to the musical scale!

THE MOST ABUNDANT ELEMENTS

Element	Percentage of Earth's mass
Oxygen	29.5
Iron	36.6
Silicon	15.2
Magnesium	12.7
Sulfur	1.9
Nickel	2.4
Calcium	1.1
Aluminum	1.1

In Robert J. Moon's model of the nucleus, the four most abundant elements—oxygen, iron, silicon, and magnesium—are those that correspond to the completely filled cube, dodecahedron, octahedron, and icosahedron (as shown in Figure 13).

Jan van der Heyden

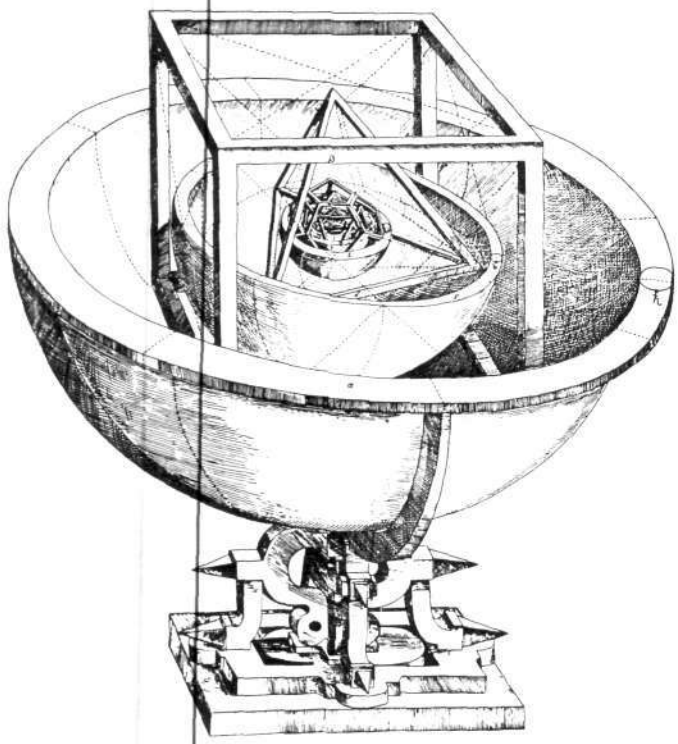


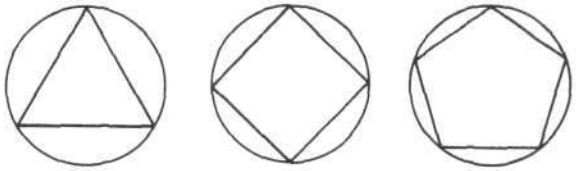
Figure 14
KEPLER'S PLANETARY GEOMETRY
In his 1596 work, The Secret of the Universe, *Kepler represented the distances from the Sun of the first six planets by nesting a series of spheres (the orbits) within the Platonic solids. The outside sphere is Saturn's orbit, inside of which nests a cube. Inside the cube is a sphere representing Jupiter's orbit, with a tetrahedron nested within it. The dodecahedron, icosahedron, and octahedron follow, in that order.*

The perihelion of Mercury corresponds to C, its aphelion to C-sharp; the Venus orbit (nearly circular) to D, the Earth to E-flat, Mars to E; the lower boundary of the asteroid belt is exactly at F, the upper boundary at F-sharp; Jupiter is at G, Saturn at A, Uranus at B, and Neptune at the octave C. Even Pluto fits very beautifully: It has a highly eccentric orbit, just barely cutting through the Neptune orbit at its perihelion (corresponding to C), and reaching just beyond the point corresponding to C-sharp! Thus, the two most eccentric orbits in the solar system, those of Mercury and Pluto, both span intervals corresponding exactly to the half-tone from C to C-sharp! The asteroids fill out the interval from F to F-sharp, which is the locus of the "register shift." Thus, the planetary system and the musical system are in most perfect imaginable agreement. The difference is, that one is geometrically proportioned according to a spiral with

Figure 15
KEPLER'S DERIVATION OF MUSICAL INTERVALS

Kepler showed that the geometry of the regular polygons produced the musical relationships of the diatonic scale. The divisions of the circle defined by inscribing an equilateral triangle, a square, and a pentagon, for example, provide the frequency ratios of the principal consonant intervals (a). The equilateral triangle yields the fifth (3:2), the square yields the fourth (4:3), and the pentagon yields the major third (5:4).

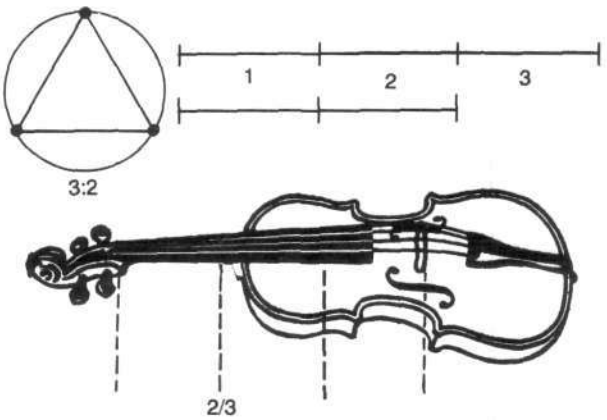
(a) Inscribing the regular polygons



If the circumference of the circumscribing circle is taken as a musical string (b), then the triangle would divide that string into three equal parts. Plucking the string at the two-thirds point produces the musical interval of the fifth. (Hence the ratio 3:2.) Similarly, when the string is divided in four parts and is plucked at the three-quarter point, it produces the fourth, 4:3. Plucking the string divided by a pentagon at the four-fifths point produces the third, 5:4.

Kepler explained that the dissonant musical intervals, such as 7:6, were dissonant because they could not be represented by a regular polygon inscribed in a circle.

(b) Plucking a musical string



(a)

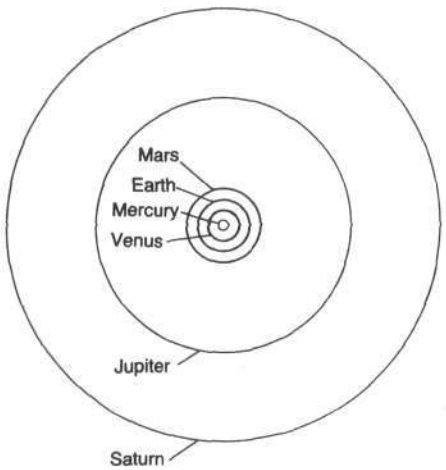
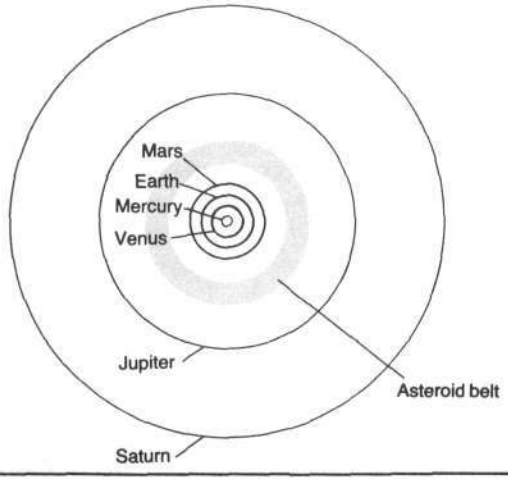


Figure 16
THE GAP BETWEEN THE INNER AND OUTER PLANETS

The gap between the inner planets (Mercury, Venus, Earth, and Mars) and the outer planets (Jupiter and Saturn) is evident (a). The orbits of Uranus, Neptune, and Pluto, not known in Kepler's time, are omitted in the diagram. As Kepler pointed out, and as modern planetary exploration has confirmed, this gap divides our solar system into two qualitatively distinct sets of planets, so clearly different that we can talk about a "register shift" in the system.

The same view of the solar system with the asteroid belt drawn in is shown in (b). The existence of an additional orbital region inside the Mars-Jupiter gap was hypothesized by Kepler.

(b)



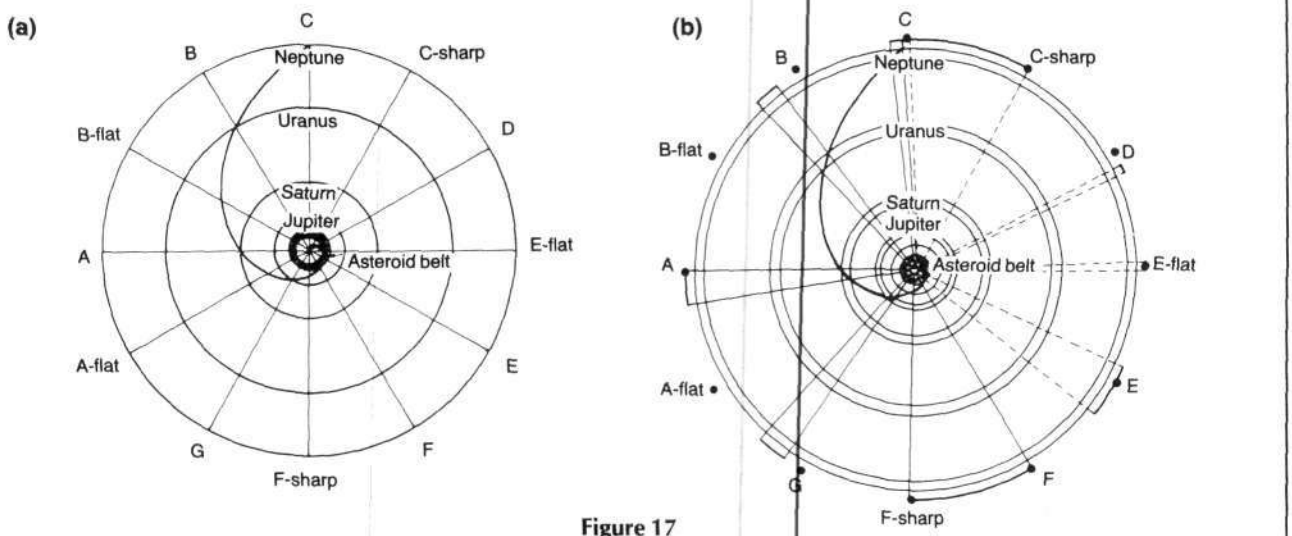


Figure 17

THE MUSICAL GEOMETRY OF THE SOLAR SYSTEM

The solar system's set of elliptical orbits can be obtained by a projection from a set of slightly inclined cuts of a single cone, whose axis lines on the plane perpendicular to the ecliptic plane and whose summit is at the center of the Sun (a). A self-similar spiral is constructed on the cone, making one full cycle in passing from the height corresponding to the perihelion of Mercury (not shown here in detail) to the height corresponding to the nearly circular orbit of Neptune; the ratio between the starting and ending point is 1:100. The halfway point of the spiral corresponds to the upper limit of the asteroid belt. If the full 360° rotation of the spiral is divided into 12 equal steps, the positions of the planets correspond to the steps in the musical scale. Next, project the construction onto the plane of the planetary orbits (b). Two circles have been drawn for each planet, corresponding to the perihelion and aphelion distances, and their intersections were projected with the logarithmic spiral out to the circle of Neptune's orbit. This construction shows that important features of the solar system appear in "octaves." The surface of the Sun corresponds to C-sharp, one octave below the aphelion of Mercury and two octaves below the aphelion of Pluto.

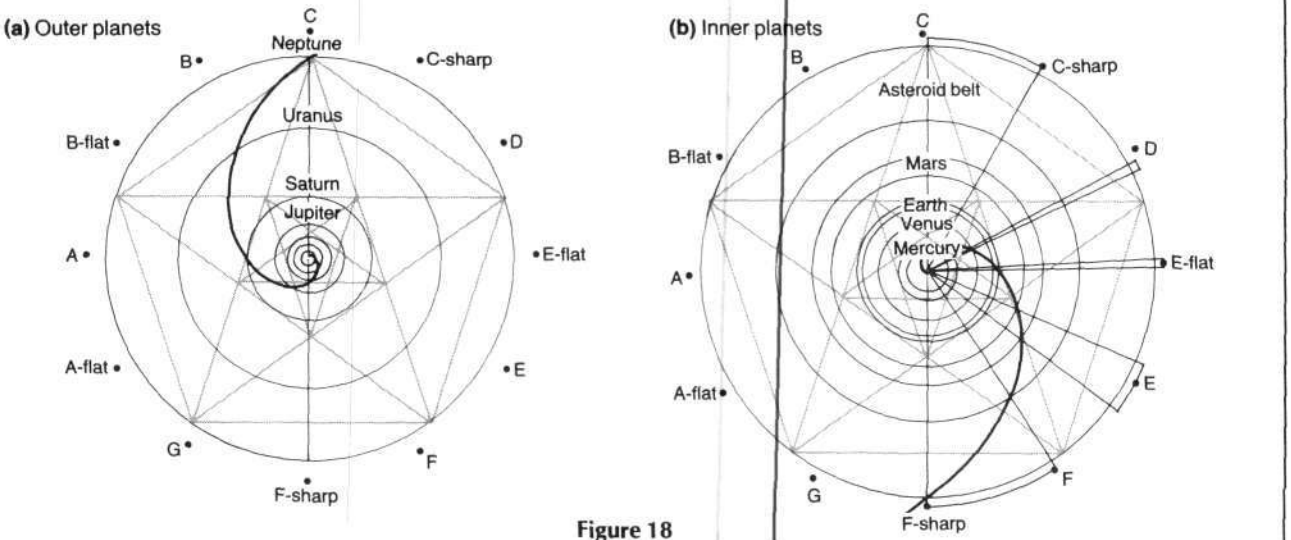


Figure 18

THE GOLDEN MEAN PROPORTIONS OF THE SOLAR SYSTEM

The golden mean proportions of the solar system are shown by the following construction (a). Inscribe a regular pentagon in the orbit of Neptune. Draw the diagonals of this pentagon, a smaller pentagon will be obtained, which exactly circumscribes the orbit of Saturn. The next smaller pentagon, generated from this one, circumscribes the circular limits of the asteroid belt. If we now inscribe a further pentagon inside the outer circular limits of the asteroid belt, then its first "daughter" pentagon exactly circumscribes the orbit of the Earth. The second "daughter" fits between the aphelion and perihelion of Mercury.

ratio 1:100, while the other derives from the ratio 1:2 (the frequency ratio of the musical octave).

Figure 17(b) shows this construction in projection onto the plane of the planetary orbits. For each planet I have drawn two circles, corresponding to the perihelion and aphelion distances, and projected their intersections with the logarithmic spiral out to the circle of Neptune's orbit.

If the solar system is really organized in the indicated way, then we should expect important features to appear in other "octaves." The continuation of the solar system beyond Pluto is unknown to us. But, if we continue our spiral inward toward the center of the Sun, then we reach, in one full rotation starting from Mercury, none other than the *surface of the Sun!* As detailed calculation or direct geometrical construction shows, the surface of the Sun corresponds exactly to C-sharp, one octave below the aphelion of Mercury, and two octaves below the aphelion of Pluto. The low "C" gives another astronomically meaningful location: It is the region inside the Sun, at about seven-tenths of the solar radius from the center, where strong hydrodynamic turbulence (convection) begins in the process of transmitting fusion energy from the Sun's core outward toward the surface. So, we have two clearly defined "octaves" of the solar system: one from the turbulent layer and surface of the Sun to Mercury, and the second from Mercury to Neptune and Pluto. Our hypothesis is confirmed with wonderful completeness.

This construction provides further, devastating proof against the modern A = 440 tuning of the musical scale, and for a return to the classical C = 256. For, only in the lower tuning does the characteristic register shift of the human voice, the soprano shift, fall between F and F-sharp of the scale—in exactly the region occupied by the asteroid belt and the register shift of our solar system. Raising the pitch to A = 440 has destroyed this most complete harmony between music and the universe, rendered music incoherent and irrational. C = 256 has an immediate astronomical meaning, too: It is derived by division by two from the *second,* which is a lawful division of the oldest astronomical cycle, the rotation of the Earth. To obtain 1 second, we divide the rotation of the Earth, first by 24, then by 60, and again by 60. These division numbers are themselves derived from the elementary regular polygons, the equilateral triangle, square, and pentagon: $24 = 2 \times 3 \times 4$, $60 = 3 \times 4 \times 5$. They are therefore coherent with the fundamental consonant intervals of the scale, according to Kepler. Therefore, C = 256 is the only scientific tuning, and A = 440 has nothing to speak for it but slavish attachment to a false convention, representing only the arbitrary fashion of the moment.

We saw earlier that the conical spiral action underlying the exponential growth of living organisms always expresses itself in visual space in the form of golden mean and derived morphological proportions. This must be the case because of the characteristic boundedness of visual space expressed in the uniqueness of the five regular solids. As Leonardo da Vinci's teacher, Luca Pacioli, demonstrated, all five solids are immediately derivable from one of them, the dodecahedron, whose characteristic proportion is the golden mean. It follows from our construction that the solar system, too, must be proportioned according to the golden mean. Kepler had already demonstrated this implicitly, but now we can prove it directly. We inscribe a regular pentagon in the orbit of Neptune. If we now draw in the diagonals of this pentagon [Figure 18(a)], we obtain a smaller pentagon whose proportion to the first one is the square of the golden mean. This pentagon exactly circumscribes the orbit of Saturn. The next smaller pentagon, generated from this one, exactly circumscribes the outer boundary of the asteroid ring. If we now inscribe a further pentagon inside the outer circular limit of the asteroids, then its first "daughter" pentagon exactly circumscribes the orbit of the Earth [Figure 18(b)]. The second "daughter" fits between the aphelion and perihelion of Mercury. There are more such relationships that we could elaborate but these suffice to show, that *our solar system, like a living organism, is proportioned according to the golden mean.*

We have come to the end of our long journey of geometrical discovery, from music and the human voice, to the atomic nucleus, and outward to the limits of our solar system. Everywhere we have found the same underlying organizing principle: a kind of "curvature" shaping the morphology of living processes as well as the microcosm and macrocosm of our universe, and rendering all three intelligible to the human mind.

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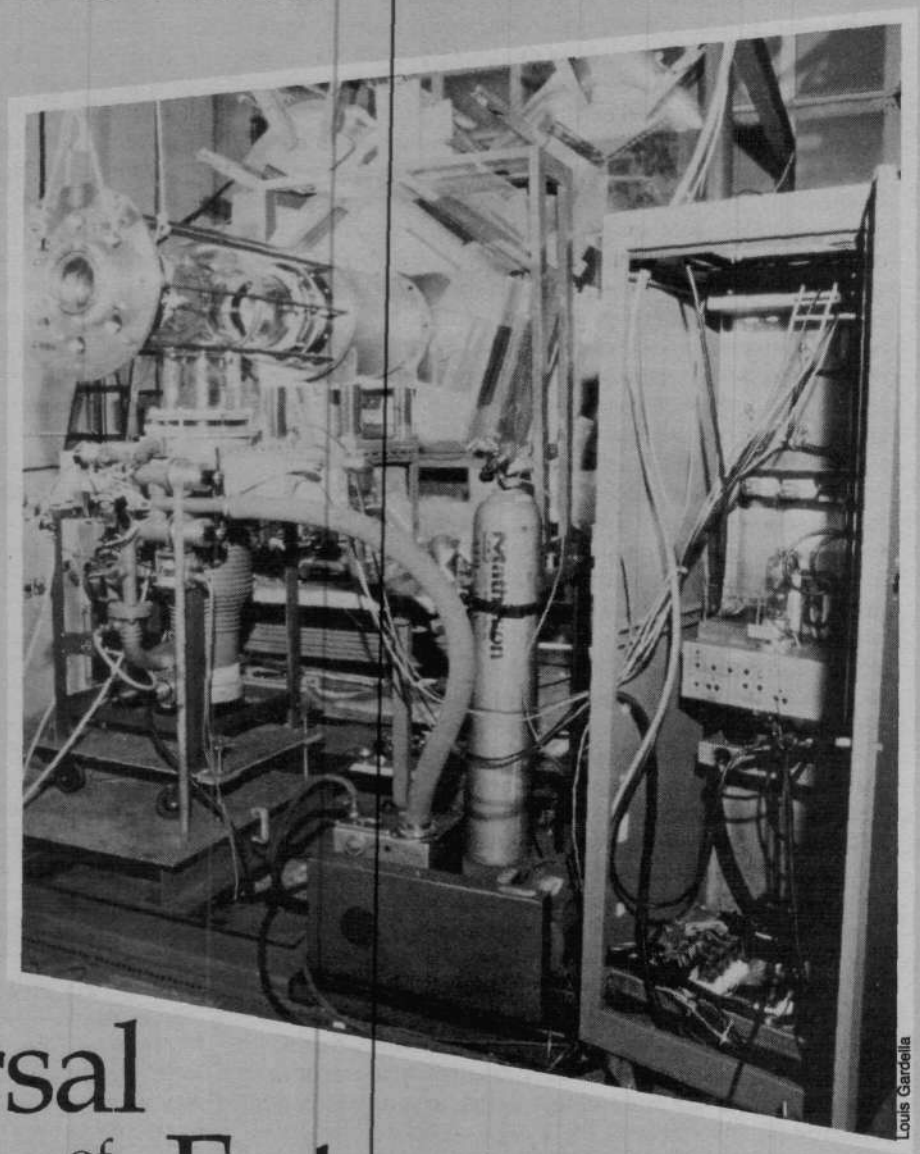
Notes

1. Lyndon H. LaRouche, "A Non-Mystical View of the Necessity of Existence of the Notion of 'Absolute Time,'" March 16, 1988, (to be published).
2. J.S. Bach's student Johann Kirnberger, in his *Kunst des reinen Satses in der Musik* (1779) quotes a letter to him from C.P.E. Bach attacking Rameau's theory of harmony and composition: "You may openly declare that my basic principles and those of my father are anti-Rameau."
3. Jonathan Tennenbaum, "Riemann and the Science of Life," *Fusion,* September-October 1984, pp. 16-23.
4. Robert L. Gallagher, "Riemann and the Göttingen School of Physiology," *Fusion,* September-October 1984, pp. 24-30.
5. Bernhard Riemann (1866), "The Mechanism of the Ear," *Fusion,* September-October 1984, pp. 31-38. First English translation.
6. The principle of division by 12 derives from the dodecahedron, which generates all the regular solids, and whose edges, projected onto a concentric sphere, divide its area into 12 identical areas. Since the regular solids define the geometry of visual space, and since hearing must be coherent with vision, it follows that the natural division of the octave is into 12 semitone steps. See also: Jonathan Tennebaum, "A Mathematics Curriculum for Creating Citizens," *Fusion,* March-April 1983, pp. 26-34, especially 'The Logarithmic Principle and Music,' p. 34.
7. Carol White, "The Universe Sings," *21st Century,* July-August 1988, p. 53.
8. Kathy Wolfe, "Mozart Lieder on the Fortepiano," *Executive Intelligence Review,* Oct. 16, 1987, pp. 36-37.
9. Liliana Celani, "Zurück zur wissenschaftlichen Stimmung," *Ibykus—Zeitschrift für Poesie, Wissenschaft und Staatskunst,* No. 21 (1987), pp. 37-44.
10. Lyndon H. LaRouche, "The Primacy of the Singing Voice in Musical Theory," *New Federalist,* Sept. 4, 1987, pp. 5-8.
11. Laurence Hecht, "Mysterium Microcosmicum: The Geometric Basis For the Periodicity of the Elements," *21st Century,* May-June 1988, pp. 18-30.
12. Winston Bostick, "The Morphology of the Electron," *International Journal of Fusion Energy,* **3**:1 (January 1985), pp. 9-52.
13. Lyndon H. LaRouche, "The Rudiments of Tuning and Registration," *New Federalist,* April 22, 1988, p. 5, and April 29, 1988, p. 5. This is the foreword to a manual on the principles of classical music, in preparation as a book to be published by the Schiller Institute.
14. Ralph Schauerhammer, "Neues zum 'Kepler Atom,'" (German-language edition) *Fusion* March 1988, pp. 39-41.

The Plasma Focus Fusion Device



The plasma focus device at Stevens Institute of Technology in Hoboken, N.J. The vacuum chamber containing the electrodes is at the upper left.

Universal Machine of the Future

by Charles B. Stevens

The plasma focus fusion device is ready for breakout in the area of energy production as well as spinoff applications in medicine and defense.

Although simple in design, modest in requirements, and prolific in output among the world's fusion research devices, the plasma focus has been relegated to the scientific basement, and the big R&D laboratories and leading plasma science authorities avoid it like the plague. This unscientific diagnosis probably derives from the propensity of the plasma focus for generating anomalous results whose most regular feature is that they contravene conventional scientific opinion and wisdom. Despite this policy of scientific apartheid, however, the plasma focus has continued to progress experimentally in small research laboratories throughout the world and has now reached the point where it has demonstrated the capacity for many near-term technological applications, to such a degree that mere prejudice can no longer hold it back.

Among these near-term applications is that of utilizing the plasma focus to generate short-lived radioisotopes for medical and biological diagnostics. In fact, the demonstrated capabilities of the plasma focus are such that it alone could reduce current costs for many medical diagnostics by as much as an order of magnitude. This would lower the cost sufficiently to permit the general proliferation of these procedures throughout all major health facilities. Today, the most advanced radioisotope diagnostic capabilities are found only in a handful of large hospitals, and then at great cost.

A second, near-term application is to use the plasma focus for generating relativistic beams for destroying ballistic missiles and their thermonuclear warheads over ranges of thousands of miles. This plasma focus defense technology is currently being pursued by Soviet scientists in a crash program which, U.S. experts have determined, began about five years ago.

The third area of near-term application of the plasma focus is to provide a test-bed for developing materials and engineering technology for thermonuclear fusion reactors.

Here I will review the general scientific background of the plasma focus and recent experimental developments. The first and third areas mentioned above will be explored in some detail.

The Plasma Focus: An Energy-Compressing Transformer

What makes the plasma focus such an experimental powerhouse is the fact that it functions like an ideal energy compression and storage-transforming device with no moving parts—except possibly the plasma that it generates. Depending on its initial set-up mode, the plasma focus can efficiently generate intense high-energy clustered-ion and electron beams, microwaves, X-rays, and neutrons. More recently, it has shown that it can produce copious heavy ion fusion—a result that directly bears on its capacity for short-lived radioisotope production.

In general, the plasma focus's versatility and compactness derive from its ability to compress and transform energy. In terms of its basic operation, the laboratory plasma focus looks like a large radio tube. It consists of two electrodes, both shaped like hollow cylinders, with one placed inside the other (Figure 1).

The motive power for the device consists of a pulse of electrical current generated by a bank of capacitors. Capacitor banks provide an initial means of compressing energy, and using a commercial power line input, they can be charged up in series. Once brought up to full capacity, the bank can be discharged in a relatively short pulse through the use of fast-acting circuit switches that reconfigure the bank from a series connection to a parallel connection. The resulting compressed current pulse is simultaneously switched into one of the plasma focus electrodes.

The plasma focus vacuum chamber, in which the two cylindrical electrodes are located, is usually filled with a small quantity of hydrogen gas, although other materials like oxygen, nitrogen, and carbon can be utilized.

Within the few billionths of a second that the current pulse takes to arrive at the electrodes, a large electric field is generated between the electrodes. This field causes the fill gas to "break down." That is, free electrons in the gas are accelerated to high velocities, and they cause gas molecules to become ionized through collisions. Within a few billionths of a second, the gas is transformed into an ionized plasma. This takes place at the end of the plasma focus where the two electrodes are mechanically connected together with an intervening layer of insulator.

The Plasma State

Plasma is sometimes referred to as a fourth state of matter—solid, liquid, and gas being the first three. All four states are, generally, macroscopically electrically neutral. Plasmas sometimes act like a solid, sometimes like an incompressible fluid, and sometimes like a compressible gas. In fact, it is better to think of solids, liquids, and gases as being three special varieties of plasma.

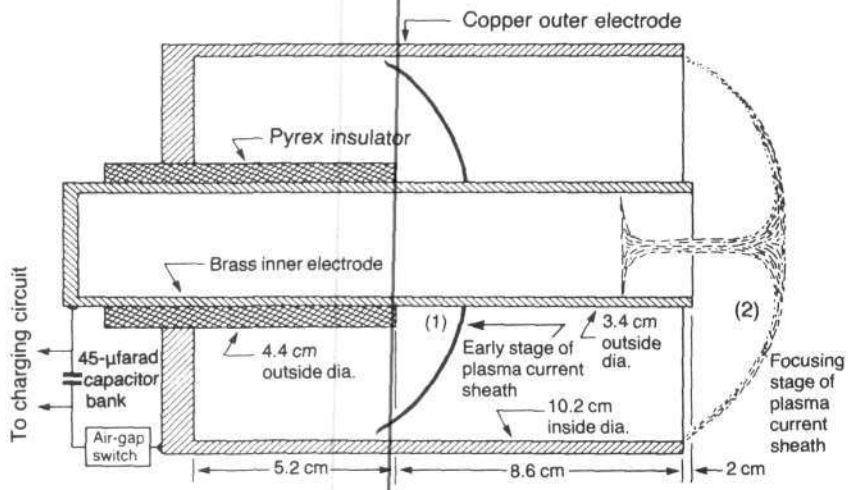
In general, the electrons and nuclei that make up atoms and molecules become separated in a plasma, that is, ionized. In other words, the atoms and molecules that constitute the relatively electromagnetically insulated elementary constituents of a solid, liquid, or gas are broken up. With plasma, long-range electrodynamic forces predominate over the short-range chemical bonds and molecular interactions that characterize solids, liquids, and gases. This long-range electrodynamic interaction is the chief manifestation of the plasma state.

The question arises, therefore: What are the elementary constituents of a plasma? The textbook answer is usually: negatively charged electrons and positively charged ions—the fragments of the atoms and molecules present before "breakdown." However, because of long-range interactions, the dynamics and motion of these individual electrons and ions cannot be accounted for locally. In place of these "elementary constituents," we find that plasmas generate nonparticle coherent structures: various types of waves, solitons, vortices, and circulation cells. In place of short-range chemical bonds and van der Waals molecular interactions, the plasma's fundamental constituents are held together by the long-range electric and magnetic fields of the plasma.

While making the plasma far more complicated theoretically and experimentally, this long-range nature of the plasma interaction also makes the plasma potentially far stronger and capable of supporting virtually infinitely great-

Figure 1
SCHEMATIC OF THE PLASMA FOCUS IN CROSS SECTION

The plasma focus consists of two cylindrical electrodes, one placed inside the other. The outer copper electrode and inner brass electrode are coaxial and separated by a Pyrex insulator. The entire assembly is placed within a vacuum chamber, not shown here. A current pulse is switched into the plasma focus from a capacitor bank. This leads to the formation of an annular (ring-shaped) plasma sheath near the Pyrex insulator end, marked (1). This sheath accelerates down the length of the space between the electrodes—left to right in the diagram—and forms a plasma pinch at the right-hand, open end of the machine, marked (2).



Source: Winston H. Bostick, "The Morphology of the Electron," *International Journal of Fusion Energy*, Vol. 3, No. 1, Jan. 1985, p. 46.

er energy densities. For example, with solids, the strength of materials is fundamentally delimited by the strength of the short-range chemical bond. Therefore, if a sufficiently intense electric or magnetic field (or mechanical stress) is applied to the material, these bonds begin to break down and the material structurally fails—falls apart.

In the plasma, however, its elementary constituents are held together by the long-range electric and magnetic fields. Therefore, not only does the plasma withstand the application of intense electric and magnetic fields, but also these applied fields can further increase the strength and rigidity of the plasma structure. Because of this, plasmas are capable of sustaining virtually unlimited energy densities compared to those ordinary solids and liquids can sustain. And, as we will see with the plasma focus, given sufficient freedom, plasmas will naturally configure themselves into such dynamically stable structures when an intense field is applied to them.

Beating the Alfvén Limit

Returning to the description of plasma focus operation: The current pulse from the capacitors generates an intense electric field between the two cylindrical electrodes, and the gas fill breaks down and forms a plasma at the insulator end of the focus. This breakdown plasma has a high electrical conductivity and therefore permits the flow of electric current between the electrodes; the current is driven by the electric field. In fact, as shown in Figure 2, an annular sheet of conducting plasma rapidly forms between the electrodes.

To comprehend how the plasma focus compresses, stores, and transforms the energy input, it is essential to examine this annular plasma sheath and the fine, microscopic plasma structures it forms. What happens is as follows: The current flowing through the plasma current sheath interacts with the ambient magnetic field and generates a force that accelerates the plasma sheath laterally away from the insulator end of the focus toward its open end. (The ambient magnetic field is generated by lateral current flows in the cylindrical electrodes.)

While the plasma sheath undergoes acceleration toward the open end, it gathers up more mass deriving from the background gas fill. It also absorbs a significant fraction of the electrical current passing through it and stores this energy input in the form of intense magnetic fields within the plasma sheath.

Once the sheath reaches the open end of the two cylindrical electrodes, a stationary plasma pinch is generated. As this compressed plasma is formed, the stored magnetic energy is transformed back into intense electric fields and kinetic energy of the plasma electrons and ions. Small nodules of dense plasma form within the pinch plasma. These dense plasma nodules sustain energy densities trillions of times greater than that of the capacitor bank. Intense, relativistic electron and ion beams are generated together with bursts of X-rays. The ambient densities and temperatures are sufficient to support copious thermonuclear reactions with resulting neutron outputs.

In other words, the plasma focus *focuses* the energy of the input current pulse in both time and space. It also transforms the energy up to much greater voltages in the process. What allows this to take place is the emergence of highly organized plasma structures that can withstand energy densities trillions of times greater than ordinary materials.

The Plasma Pinch

To comprehend how this energy densification comes about, it is necessary to examine the fine-grain geometry and dynamics of the plasma structures generated in the plasma focus. This is best pursued by looking at how the plasma overcomes several apparent barriers projected by

conventional plasma electrodynamic theory. For example, the conduction of electricity by free charges, as in a plasma, appears to be limited to the Alfvén current limit. As an electrical current is passed through a plasma column, the axially direct current generates an azimuthal magnetic field (Figure 3).

This magnetic field exerts an inward pressure causing the plasma column to contract—that is, pinch. This decrease in plasma column radius means that the current density increases, and the azimuthal magnetic field strength compressing the surface of the plasma column is proportional to the current density. Thus, the plasma column continues to be pinched to smaller and smaller radii—the plasma pinch. Eventually, however, the magnetic field becomes sufficiently great to prevent the linear current from propagating. The current is literally turned inside out by the strong magnetic field and flows backward. This circumstance has been calculated in detail and a specific, limiting current has been determined, which is called the *Alfvén limiting current*.

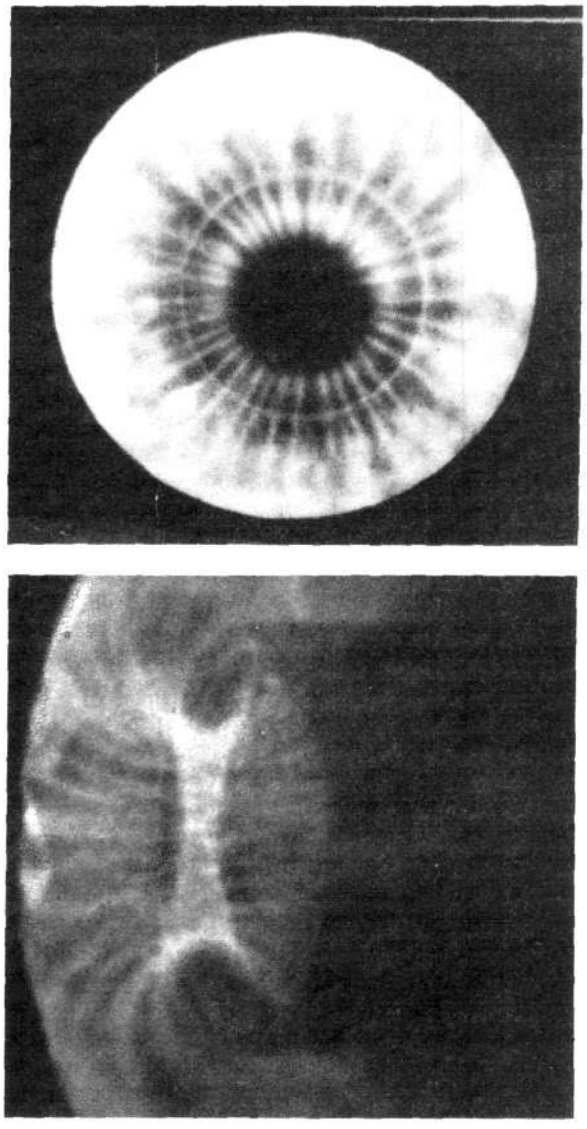


Figure 2
THE PLASMA FOCUS CURRENT SHEATH
These are photographs of the plasma inside the plasma focus device. The inner electrode is located at the circle at the center of the sheath. The outer electrode is located at the circumscribing circle. Barely visible here as pairs of radial lines are the plasma vortex filaments that carry the electric current between the plasma focus electrodes.

Source: Winston Bostick

However, the plasma focus has experimentally demonstrated that it regularly overcomes this Alfvén current limit. How? Investigations led by Professor Winston Bostick, the father of the plasma focus (see page 43), and others have shown that the current in the plasma cylinder does not follow a linear path parallel to the axis. Instead, it follows a *spiral path*. A nested series of spiral paths is set up such that the generated magnetic fields cancel out in terms of their effects on the motion of the current flow. In fact, all the force fields of the plasma—the electric field, the magnetic field, the fluid flow, and the fluid vorticity—locally follow these same paths; that is, they are collinear. Under this circumstance, the interaction of these "force" fields is zero and the configuration is termed *force free* (Figure 4).

The possibility of this type of flow pattern was first elaborated by the 19th century Italian mathematician Eugenio Beltrami. Beltrami was a close collaborator of the great German mathematician Bernhard Riemann. Winston Bostick and his student, Daniel Wells, now of the University of Miami at Coral Gables, Florida, applied Beltrami's work to the data they were obtaining in plasma experiments like those with the plasma focus. Beltrami had developed these particular hydrodynamic models for analysis of fundamental questions in electrodynamics and as a continuation and elaboration of work that Bernhard Riemann first presented in his famous paper "On the Hypotheses Which Underlie Geometry"—a paper that founded the field of Riemannian geometry, modern topology, and is generally considered today to provide the framework for 20th-century relativity theory. Recently, Wells has succeeded in applying his further developments on Beltrami's theory to provide the first coherent theoretical model for formation of the solar system from a plasma.[1]

Experimental data show that the annular current sheath consists of a number of Beltrami vortex pairs (each pair consisting of a right-handed vortex and a left-handed one) running between the inner and outer electrodes (Figure 5).

These Beltrami vortex pairs not only permit the plasma focus to beat the Alfvén current limit, but also transform a significant fraction of the input electrical energy into intense magnetic fields. When the final pinch is formed at the end of the focus, many of these Beltrami vortices explosively disintegrate; these Beltrami vortices are highly dynamic, metastable structures that require precise flow conditions to be maintained. When the current sheath is suddenly brought to a halt at the end of the focus, these required flow conditions no longer obtain. The energy stored in the

magnetic fields of these vortices is suddenly released and heats the plasma to high temperatures. A few of the vortices are apparently able to reconnect to themselves before disintegrating (Figure 6). These reconnected vortices form closed loops—little plasma tori. The turbulent plasma flow in the general pinch region generates the conditions to maintain these vortex tori as stable structures.

These tori are apparently the dense plasma nodules from which intense electron and ion beams—and neutron bursts due to thermonuclear fusion reactions—are seen to emerge. They apparently have the highest energy densities. It is these dense plasma nodules that appear to be responsible for the enhanced rates of thermonuclear fusion reactions in plasma foci, when these devices are scaled to larger sizes, and for the efficient rates of heavy ion fusion needed to generate the short-lived radioisotopes required for the medical diagnostic system known as positron emission tomography or PET (see box, page 44).

Application of the Plasma Focus to PET

In the area of medical diagnostics, the plasma focus promises high output at less cost than existing alternatives.

For example, the radioisotopes utilized for positron electron tomography, or PET, have half-lives measured in minutes—that is, half of any given quantity of the material disintegrates every few minutes. Therefore, these isotopes must be generated by nuclear reactions just before they are utilized. The existing method is to use a small, high-energy particle accelerator called the cyclotron. The cyclotron high-energy hydrogen ion beam, which reaches energies of millions of volts, is directed onto a solid target. The beam generates nuclear reactions when it strikes the target, and, given the presence of the appropriate elements, the required radioisotopes are generated.

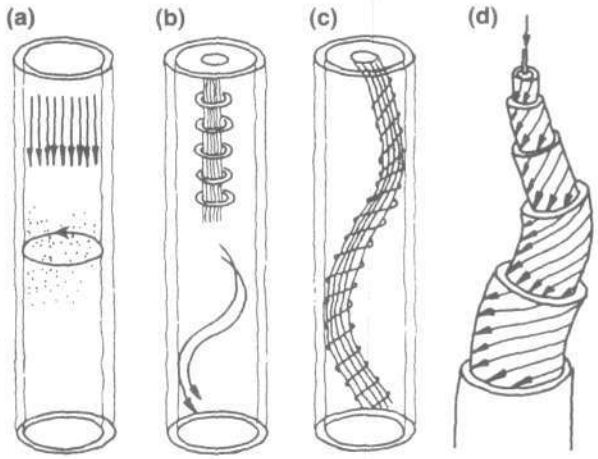
These radioisotopes are then chemically extracted from the solid target and transferred to a gaseous reaction vessel in which the desired chemical molecules are produced. The extraction process requires several hours of time, and so the initial production of the radioisotopes must be relatively large, because half of the material is disintegrating every few minutes.

The plasma focus is both much more compact and efficient than the cyclotron for the production of short-lived radioisotopes. The required size of the cyclotron accelera-

Figure 3
ELECTRIC CURRENT PASSING THROUGH A COLUMN OF PLASMA

The initial conditions are shown in (a). The arrows represent electric current and the dots represent the plasma gas. The azimuthal magnetic field generated by the passage of the electric current is shown as a circle and these circles (magnetic field lines) extend along the full length of the column.

The pinch effect is shown in (b), where the azimuthal magnetic field has compressed the plasma column. As shown, this initial configuration is unstable and the plasma column will undergo magnetohydrodynamic motions (c) to reconfigure itself into a Beltrami configuration (d), in which magnetic field lines range from axial to azimuthal throughout the column, as explained in Figure 4.



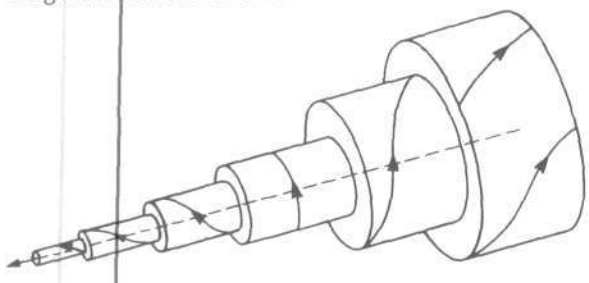
Source: Winston Bostick

Figure 4
BELTRAMI VORTEX CONFIGURATION

This cutout view of a plasma column shows the flow configurations on the column's interior cylindrical surfaces. Each arrow shows the pitch of the flow at the given cylindrical radius.

The cylindrical surface with zero radius is shown as having a straight, axial flow path to the left. The next larger cylindrical surface shows a spiral flow path of low pitch. On each successive surface these spiral flow paths increase in pitch until a surface is reached in which the flow is purely circular (azimuthal). Cylindrical surfaces of yet greater radius have spiral flow paths of decreasing pitch, oppositely directed to those within the surface of azimuthal flow.

The fluid velocity, current density, electric field, magnetic field, and vorticity all follow these same flow lines. Because of this particular Beltrami geometry of parallel flow, the configuration is said to be force-free. Two basic types of vortices are possible: ones in which the fluid flow, electric field, and magnetic field are all going in the same direction or ones in which the fluid flow is oppositely directed to that of the electric and magnetic field directions.



Source: *International Journal of Fusion Energy*, Vol. 3, No. 1, January 1985, p. 38.

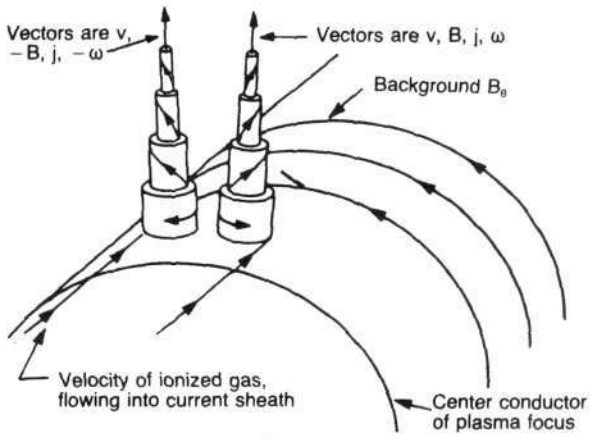


Figure 5
A PLASMA VORTEX PAIR IN A PLASMA FOCUS CURRENT SHEATH

A pair of plasma Beltrami flow vortex filaments are shown here within the current sheath of a plasma focus. Actually, the annular current sheath is made up of about a score of such vortex pairs. In each pair, one vortex has a right-handed helical flow (shown by the arrows on the cylindrical cutouts of the plasma columns making up the vortex) and the other has a left-handed helical flow. These vortex pairs literally roll along each other's surface down the plasma focus electrodes.

The vectors are v, *velocity;* B, *magnetic field;* j, *current density; and* ω, *vorticity.*

Source: *International Journal of Fusion Energy*, Vol. 3, No. 1, January 1985, p. 45.

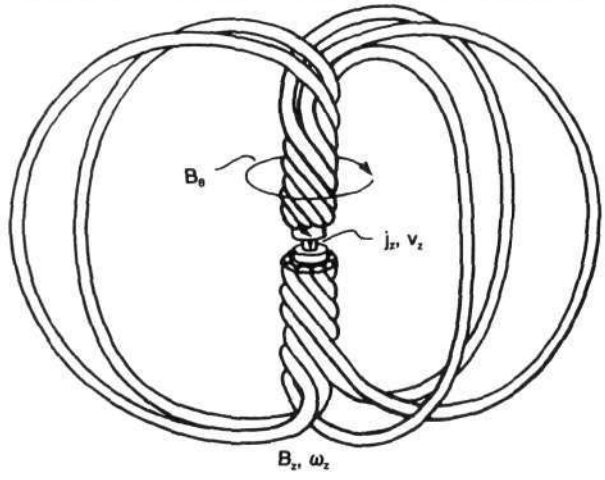


Figure 6
BOSTICK'S HYPOTHESIZED PLASMA NODULE CONFIGURATION

This is the configuration that Winston Bostick believes best fits his data for the dense plasma nodules seen in the final pinch plasma of the plasma focus (at the right-hand end of the device as shown in Figure 1). This closed configuration is formed when a linear vortex within the current sheath breaks away from the electrodes and reconnects to itself to form a complex toroidal structure.

The labeled vectors are B_θ, *azimuthal magnetic field;* j, *axial current density;* v, *axial velocity;* B, *axial magnetic field; and* ω, *axial vorticity.*

Source: *International Journal of Fusion Energy*, Vol. 3, No. 1, January 1985, p. 47.

tor now costs on the order of $1 million, and the required scale for the plasma focus would be about one order of magnitude less than this. This is because the plasma focus generates these radioisotopes much more efficiently and in a gaseous form that is directly ready for chemical processing into the required molecules—no solid target extraction is necessary.

Experiments at the Stevens Institute of Technology in New Jersey have shown that significant rates of the desired reactions can be obtained in the plasma focus. Mixtures of deuterium (the heavy isotope of hydrogen that contains one proton and one neutron) and carbon, and mixtures of deuterium and nitrogen have been tested as gas fills in the plasma focus.

With deuterium and carbon, the reaction is: deuterium + carbon-12 = neutron + nitrogen-13. The generated nitrogen-13 is a positron-emitting radioisotope of nitrogen with about a 10-minute half-life.

With a mixture of deuterium and nitrogen, the reaction is deuterium + nitrogen-14 = neutron + oxygen-15. Oxygen-15 is a positron-emitting radioisotope of oxygen with about a 2-minute half-life.

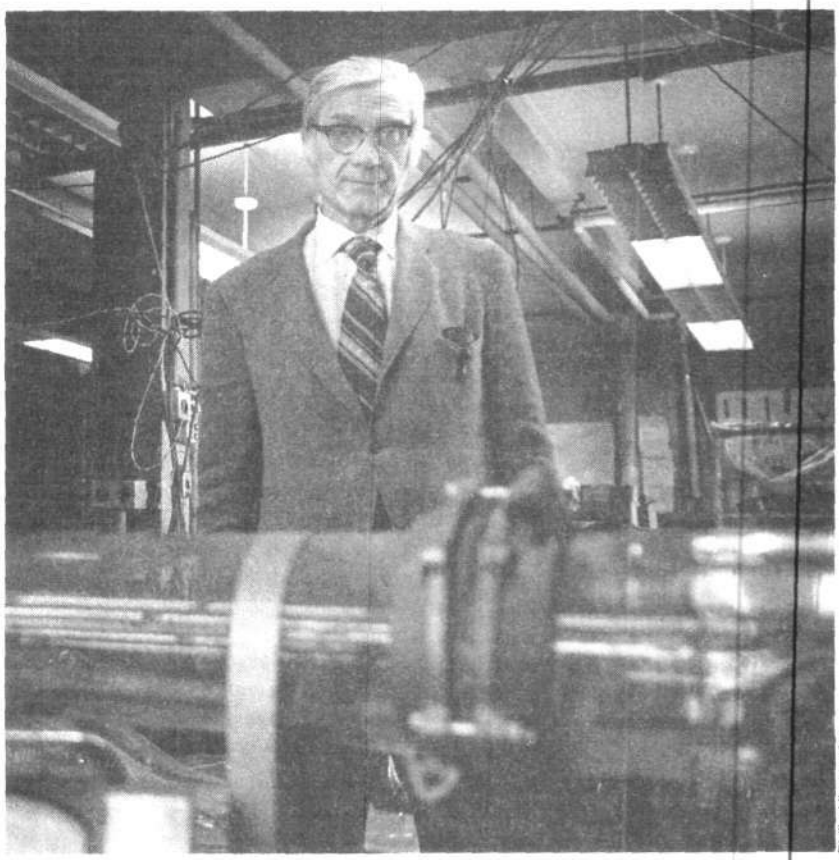
Fewer than 10 percent of the generated radioisotopes escape from the plasma focus pinch. This means that most of the generated material remains in the plasma focus in gaseous form once the plasma cools down. In this way the output is ready for chemical processing within seconds, instead of hours, as is the case with the cyclotron.

Apparently, it is the closed plasma nodules in the final plasma pinch that are responsible for both efficient generation of the required nuclear reactions and the trapping of the product radioisotopes in the plasma pinch region. These nodules contain very intense electric fields, which make them act like micro-accelerators to produce high-energy particle beams that then produce the required nuclear reactions. Furthermore, these nodules are held together with very intense magnetic fields—in some cases reaching intensities 100 million times that of the Earth's magnetic field. These strong magnetic fields entrap the radioisotope products and keep them within the plasma pinch so that they will be present in the plasma focus gas fill once the machine cools down after a shot.

Building Fusion Reactors

It has long been recognized that realization of thermonuclear fusion power reactors based on the neutron generating deuterium-tritium fusion reactions will require development of entire new arrays of materials. These materials range from structural components, insulators, and magnets to heat transfer mediums and energy conversion systems.

The deuterium-tritium fusion environment represents a



Philip Ulanowsky

The father of the plasma focus is Winston Bostick, now professor emeritus at Stevens Institute of Technology in Hoboken, New Jersey. Bostick has helped to set up plasma focus research groups throughout the world, and his home-base group at Stevens has been a leader in exploring the experimental frontiers. Although fundamentally an experimentalist, Bostick has significantly contributed to the recent development of a coherent unified field theory based on insights garnered from the plasma hydroelectrodynamics of the plasma focus.

Bostick is shown here in 1979 with an earlier version of the plasma focus device.

major challenge from the materials standpoint. The fusion plasma will operate at temperatures of hundreds of millions of degrees. This plasma will irradiate reactor components with fluxes of high-energy neutrons—several million watts per square meter—which will deeply penetrate into reactor components and the "first wall" of the fusion reactor chamber, in particular. These fusion-generated neutrons actually contain 80 percent of the fusion energy generated, so that once the neutrons are deposited within the first wall of the reactor, the heat energy generated must be efficiently transferred out of the reactor to electric generators.

Although hot plasma and electromagnetic radiation will interact with the surfaces of various reactor components and thus cause significant wear and tear, it is the effects of the deeply penetrating neutrons that determine the most difficult problems for designing efficient and economical fusion reactors. These deep-penetrating neutrons generate a wide variety of effects that degrade reactor components. For example, the fast neutrons undergo many collisions with the atoms of the material making up the first wall. These collisions cause these atoms to be displaced from their normal positions in the crystalline lattice structure of the first wall material and eventually lead to the material losing its mechanical strength.

Neutrons also generate nuclear reactions within the first wall. These reactions can produce a number of deleterious effects. First, they generate radioactive materials that make the first wall too radioactive to handle and repair. This induced radioactivity can also be a serious safety problem. Some of the reaction products are in the form of gas, which causes the first-wall materials to swell in volume and undergo various other forms of degradation.

These unique nuclear effects are combined with more conventional materials problems, such as holding up to the thermal and mechanical stresses, especially since most fusion reactors are based on designs whose parameters will change over time. Although many of these effects can be theoretically extrapolated from existing experience gained with nuclear fission reactors, the only certain way to test the full and combined effects is to recreate the same environment that will be found in a fusion power reactor itself.

Recent advances in the experimental performance of the plasma focus indicate that this device could be capable of generating these required conditions at a cost 10 times less than that of other alternatives.

The Stevens Institute plasma focus group submitted a design to the March 1988 San Diego International Energy Agency Workshop on Requirements for an International Fusion Materials Irradiation Facility. They proposed a system called CAPT, for Compact Accelerator Plasma Target, that would meet the requirements for fusion reactor materials development and testing.

The experimental results from plasma focus experiments over the past several decades demonstrate that this compact device has some of the best scale-ups for producing fusion, making it possible to reach levels required for re-

actor materials R&D with a relatively small system. Recent advances have significantly improved these already good scaling laws.

For example, Stevens Institute researchers have developed a technique involving the introduction of an electric field distortion during the breakdown and initiation phase of the plasma focus. This field distortion is caused by the introduction of a knife edge near the insulator end of the focus. The field distortion leads to the generation of a much more tightly packed moving plasma current sheath which, in turn, leads to a 10-fold increase in fusion reactions produced when the plasma pinch forms. The field distortion has also eliminated plasma focus misfirings and creates conditions in which the lifetime of the insulator at the breach of the coaxial electrodes is increased by a factor of 100 to 1,000.

Repetitive modes of operation have been also demonstrated ranging from up to 1 million shots per second down to 2 to 10 large-scale shots per second, which combine trains of many plasma sheaths to form one final pinch plasma.

Professor Vittorio Nardi of Stevens Institute presented to

How the PET Scanner Works

The PET scanner upgrades the quality of diagnostic information by providing a dynamic view of internal processes. PET stands for positron emission tomography. The information obtained from conventional X-ray imaging techniques gives only a static picture of body structures, usually according to their density differentials. However, processes involving time-dependent chemical reactions and tissue compositions can provide far more information about how the body is functioning and can lead to early detection of disease. For example, most diseases involve distinct chemical changes in body metabolism and biochemistry that occur long before macroscopic changes in body organs and their densities.

PET utilizes radioactively labeled compounds that are injected into the body in trace amounts to follow what is happening along various chosen biochemical pathways. The general use of such radioisotope tracers in the medical and biological sciences has a long history. But applying the techniques of computerized tomography permits the active mapping of the distribution of these radionuclides, producing a spatial and temporal image of these biochemical processes in the body.

Radioisotope Requirements

The radioisotopes used for PET must meet three requirements. First, they must behave like the chemical elements found in metabolic processes. Second, their radioactive emanations must be able to escape the body and follow paths that can be predicted. Third, the radioisotopes must be short-lived—that is, they must have a short half-life. This will mean that the intensity of the radioactive emission will be large enough to detect with very dilute levels of radioisotopes present, and the actual body exposures will be very low—hundreds of times less than with the more familiar X-ray CAT scan.

Radioisotopes that emit positrons—antimatter positive electrons—meet these requirements. When the positron is emitted, it travels only a microscopic distance before it is annihilated in an antimatter reaction with a normal electron. This antimatter-matter annihilation reaction generates two gamma-rays, each of which has a precise energy of 511 kiloelectron volts and each of which is oppositely directed. Because of their short wavelength, gamma-rays can pass undisturbed through large quantities of matter—much more so than other, shorter-wavelength electromagnetic waves, like X-rays.

In general, the best radioisotopes for PET are carbon-11, nitrogen-13, oxygen-15 and fluorine-18.

From the outside, the PET system looks much the same as the CAT scanner. Gamma-ray scintillators are arranged in rings; typically, there are about 100 detectors per ring, with up to five rings in the gantry. The coincidence detection between two detectors across from each other on the donut ring defines a line through the object being imaged, along which positron annihilation must have occurred.

Collecting millions of such coincidence counts along thousands of possible projection rays permits the reconstruction of the positron distribution—and therefore, the radioisotope distribution—through the use of back-projection techniques.

The resolution of the image can be improved by placing the detectors closer together. Alternatively, determining where along the coincidence line positron annihilation took place can also improve resolution. Fast scintillator counters and "time-of-flight" measurements for the gamma-ray are being utilized along these lines. Very small amounts of radioisotope tracer are required for PET. Carbon-11-labeled carbon monoxide is used to trace blood flow to detect motion abnormalities of the heart walls by measuring heart contractions. Fewer than 200 billion carbon monoxide molecules are required for this imaging—less than one-third of a picomole.

PET differs from other radiologic imaging techniques in that it gives a dynamic picture. And while this can be generally applied to all organs, the application of PET to dynamic brain imaging has made the greatest contributions to medical diagnostics. For example, a fluorinated analogue of glucose, 2-fluor-2-deoxyglucose (FDG), tagged with fluorine-18 positron emitter, can be injected into the bloodstream and pass through the blood-brain barrier. But since this compound cannot be metabolized by brain cells in the same manner as regular glucose, it therefore tends to accumulate within the brain cells in direct proportion to brain activity at a given time. If the visual cortex is active, the FDG accumulates in the visual

the San Diego workshop the latest experimental results, which demonstrate that a compact 10-million-watt neutron output plasma focus could be constructed at costs many times lower than other proposed devices. Nardi reviewed a two-stage proposed program. A $20 million demonstration facility could be constructed and tested within 3 years. It would consist of a 1-megawatt, 0.5-megajoule plasma focus. The final facility would cost about $100 million and be completed within 4 years. This would be a 5-megajoule plasma focus with a 10-megawatt neutron output for testing fusion reactor materials.

At this point, the promise of the plasma focus is near realization. What is necessary, as with the other pathways to fusion energy and its many spinoffs, is the research funds to get the job done.

Charles B. Stevens is an associate editor of 21st Century *magazine.*

Notes

1. Wells's article on the solar system appeared in the July-August issue of *21st Century*, p. 18.

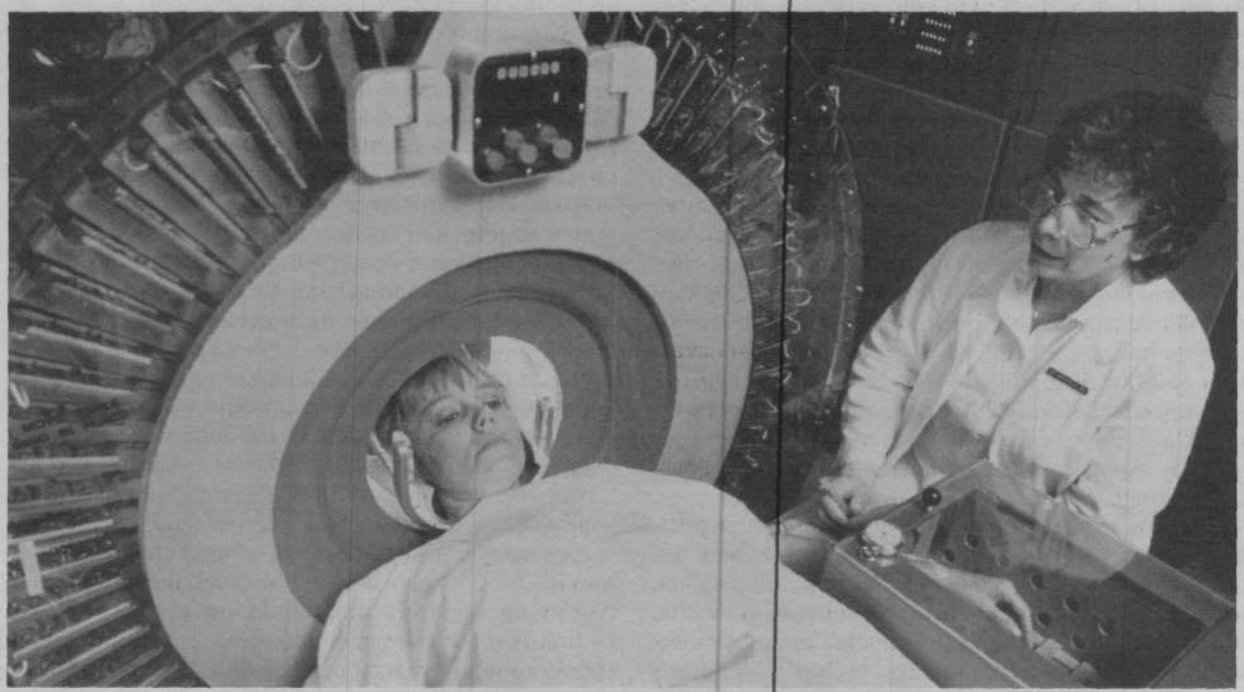
areas.

After detecting and recording the PET scan, the computer converts this data into a colored biochemical motion picture of brain activity. And, while active PET scans are increasingly providing physicians with the means for early detection of brain tumors and with crucial measurements on disorders such as Alzheimer's disease and senile dementia, it is the application of PET to the normal brain that holds the greatest promise. It is possible to observe patterns of glucose use while the subject is listening to a symphony or engaged in a variety of activities.

Insight into Brain Activity

These measurements of "normal" brains with PET hold particular promise when combined with the rapidly developing technology of brain electrical activity mapping. Combining these two widely differing diagnostics has been likened by researchers to transforming a black and white snapshot into a color motion picture. The use of different radioisotope tracers for PET is like changing the filters on a camera—new and different pictures are obtained of the same process. At the present time, such diagnostic combinations are difficult to carry out in practice. One of the major technical roadblocks has been the computing time required for analyzing PET data. But with the recent development of cheap, real-time, large-scale computing capabilities by the Strategic Defense Initiative, this roadblock is ready to disappear.

PET is by no means limited to providing insights to biological and medical processes. In fact, many aspects of the living process have been shown to be anomalous when compared to similar, non-living chemical and physical processes. Some leading researchers believe that a combination of PET with other diagnostics on electrical and chemical brain activities—when applied to workings of nerve action in a human brain consciously engaged in creative activity—could provide crucial insights into fundamental questions of electrodynamics, the curvature of space-time, and the real basis for living processes.



Hank Morgan/Science Source

A PET scan in progress at Brookhaven Hospital.

How to Survive When Everyone's Scared

by Thomas H. Jukes, Ph.D.

A leading biochemist offers some advice to those who fear the supposedly unnatural toxins in everyday life.

Most of us are surviving very well. The length of life expectancy is increasing steadily and probably will soon reach a plateau. Life expectancy in the United States in 1900 was 49 years, and in 1983, 75 years (Table 1).

The reason why people are scared is that terrifying statements about chemicals, pollution, and cancer are constantly issued by certain scientists, by governmental agencies, and by professional environmentalists and consumerists. The media pick up and amplify these statements. The scare stories are perceived as doing a public service by alerting the public, and there is no limit to exaggeration. Anyone who downplays scare stories is apt to be held up to criticism as being a polluter, and may be called an enemy of the public interest. For example, critics of the Delaney Clause of the federal Food and Drug Administration's food additive act (which says that no additive is "deemed to be safe if it is found to induce cancer when ingested by man or animal") are accused of being in favor of cancer.

It is regarded as noble to join the battle against the establishment, but today the alarmists *are* the establishment. Representatives of the chemical industry are particularly vulnerable. Usually the industry decides, "If you can't lick 'em, join 'em." The costs of joining them by carrying out unnecessarily elaborate clean-up procedures are passed on to the consuming public. Sometimes, however, faint cries of protest are heard, such as one by the president of the California Chamber of Commerce against California's Proposition 65.[1]

More scare stories are on the way. There are about 60,000 entries in the Registry of Toxic Effects of Chemical Substances, and many of them have shown, or are being studied for, carcinogenicity. Methods of detection are continually being refined. Today's part per billion is tomorrow's part per trillion. In the meantime, the only form of cancer increasing significantly in the United States is lung cancer, and cigarette ads continue to be seen on billboards and in the print media.

My intent is to make the following points. First, the rate of cancer has not increased rapidly as was predicted in the early 1900s, when it was prophesied that the expansion of the chemical industry would lead to a great increase in cancer.[2] Second, I identify a vested interest in these scare stories, and I expose the fallacy of the one-molecule theory of carcinogenesis. Third, natural carcinogens in our daily diet far exceed in quantity and potency the carcinogens to which we are exposed as a result of chemical technology. Fourth, I make recommendations on how to survive when everyone is scared (Table 2).

Of course, many people like to be scared. Horror stories sell newspapers and attract television viewers. In contrast, most scientific facts are as dull as dishwater and the very language of science is unattractive to many readers.

The media are firmly committed to the principle of equal time, or more than equal time, for nonsense. They regard this as being part of the doctrine of fair play. It is also in the well-established American tradition of anti-intellectualism. For example, in the *Los Angeles Times* Aug. 17, 1986 (page 3), Ms. Djuanna Anderson, who says that scientists don't

"know what the hell they are doing," gets her picture displayed prominently with her comments on the dangers of laboratory-produced bacteria that reduce frost damage, while Dr. Steven Lindow of the University of California, who has spent years of research on frost resistance, gets a few lines, and the back of Ms. Anderson's hand.

The Cancer Scare

For obvious reasons, everyone is afraid of cancer, and this fear has been exploited until the public is becoming numbed. An extreme example of scare tactics is in this quotation from the *Washington Post*:

> Five physicians: Roy Hertz, Umberto Saffiotti of the National Cancer Institute, Morton Lipsett, . . . Arthur Herbst and Peter Greenwald . . . all . . . emphasized that no one knows how tiny an amount of a carcinogen, taken for how short a time, can induce cancer. Perhaps one molecule [of DES] in the 340 trillion in a 5-ounce serving of beef liver can do it.

The facts are that DES is a synthetic estrogenic hormone. The endogenous production of estrogenic hormones is about 600×10^{15} molecules per person daily. A molecule of another estrogen, added to this total, is obviously lost against the background.

The one-molecule theory was reaffirmed by Dr. Arthur Upton, former director of the National Cancer Institute, as follows:

> Many scientists believe there is no "safe" level of carcinogen. Transformation of a normal cell into a cancer cell could conceivably occur with one molecule of a carcinogen acting on a single cell.

Upton has recently been quoted as repeating this statement, which evidently is a policy statement by the National Cancer Institute. How true is it? Is there any connection between his allegation and the fact that the budget of the National Cancer Institute is more than $2 million *per day*?

The presence of molecules in cells was examined by G.E. Hutchinson in an address at the 100th anniversary meeting of the National Academy of Sciences.[3] His results are shown in Table 3. Arsenic, cadmium, and chromium are officially rated as carcinogenic by the Occupational Safety and Health Administration (OSHA). Yet these substances are present in our bodies because we are a part of the solar system. The amounts of these elements normally present in the body of a healthy human being supply respectively 100,000, 2,000,000, and 700,000 molecules per cell.

In addition, there are male and female sex steroid hormones present in each cell and needed for normal bodily functions. These substances are officially classified as carcinogens because of their effect at high levels on increasing the cancer rate in experimental animals. Obviously, there must be a threshold for this effect. An estimate has been made by B. D. Dinman that "a threshold for biological activity exists within a cell at 10,000 atoms."

In the case of arsenic, if we say that each molecule has a 1-in-1-million chance of transforming a normal cell into a cell that will produce cancer, and even if we say that only one cell in a billion has the potential of being transformed into a dangerous cancer cell, there are still odds of 1 million to 1 in favor of getting cancer from our normal content of arsenic. This does not include the corresponding calculations for chromium, cadmium, and uranium. So at this rate all of us must now be dead from cancer caused by arsenic! In short, the one-molecule theory of cancer is nonsense. Yet scientists have done practically nothing to explain this to the media.

Natural Carcinogens

Currently, we are terrified by announcements by scientists and government agencies about the contamination of our drinking water with chemicals.

These stories have been challenged by Professor Bruce Ames, chairman of the Department of Biochemistry at the University of California at Berkeley. He estimates that more than 99.99 percent of the carcinogens ingested by Californians are natural (such as natural toxic chemicals in plants and mold carcinogens) or traditional (cooking food, smoking cigarettes, drinking alcohol). The most polluted well in Silicon Valley, with 2,800 parts per billion of trichloroethylene, he estimates as 1,000 times less hazardous than an equal volume of cola, beer, wine, or coffee, which contain carcinogens like alcohol, formaldehyde, hydrogen peroxide, and methyl glyoxal.[4]

Natural carcinogens occur in raw foods in massive amounts by comparison with traces of residues, including pesticide residues, from the chemical industry. These naturally occurring amounts are augmented by carcinogens that are produced by pyrolysis of foods during ordinary cooking. Some of these carcinogens have been identified

Table 1
CHANGES IN LIFE EXPECTANCY IN THE UNITED STATES

Year*	Life Expectancy at birth	Decade gain (%)	Life expectancy at age 45	Decade gain (%)
1900	49.2	—	24.8	—
1910	51.5	4.7	24.5	−1.2
1920	56.4	9.5	26.3	7.3
1930	59.2	5.0	25.8	−1.9
1940	63.6	7.4	26.9	4.3
1950	68.1	7.1	28.5	5.9
1960	69.9	2.6	29.5	3.5
1970	70.8	1.3	30.1	2.0
1980**	73.6	4.0	32.1	6.6

In 1983, life expectancy at birth reached a new high of 74.6 years.

Source: J.M. McGinnis, "Recent Health Gains for Adults," *New England Journal of Medicine* 306:671 (1982); National Center for Health Statistics.

*Except for 1910 and 1980, the numbers given are three-year composites. For example, the 1970 data reflect changes occurring from 1969 to 1971.

** Provisional data.

Table 2
DIETARY EXCLUSIONS BY MARC KRANZ
(born 1957, died 1986)

1. No red meat "for health reasons."
2. No poultry, "because chickens and turkeys were being pumped full of chemicals."
3. No canned goods, "because of additives and preservatives."
4. No dairy products because of processing.
5. No fish because water pollution caused cancerous lesions in them.
6. No fruits and vegetables because of insecticide spraying.
7. No tap water "because it contains chemicals like ammonia and chlorine."

Marc Kranz was a physical education instructor in Leipzig, East Germany, who gradually stopped eating for fear of harming his health. He started by eliminating red meat in 1976, and gradually eliminated everything.

Source: *Weekly World News*, Sept. 2, 1986.

and synthesized by T. Sugimura and his colleagues.[5] Tests with animals, some still in progress, show that all nine such compounds tested in mice and all five tested in rats are carcinogenic. The theory that cancer is a man-made by-product of rampant industrialism, and that nature is beneficial and pure, is false—and most scientists have known it to be false for years. Yet despite abundant scientific evidence of natural carcinogens, governmental agencies fail to report on most of them, and instead issue warnings only about industrial carcinogens.

DDT is still a favorite for scare stories. DDT was thoroughly lynched by environmental scientists and the Environmental Protection Agency in the 1960s and early 1970s. As a direct result of the campaign, the Olin Corporation, a former manufacturer of DDT, settled in 1982 for $24 million against claims by residents of Triana, Alabama. The claims were largely based on the residents' complaints that they were being harmed by DDT present in a creek bed, causing residues in locally caught fish.

The investigation by the U.S. Centers for Disease Control showed that the main measurable effect on the people was an increase in the level of an enzyme, blood gamma-glutamyl transpeptidase, and the U.S. Public Health Service said "the effect is small and probably does not affect well being." The fish were being caught alive and apparently well, with DDT contents ranging up to 627 parts per million. Fish are generally supposed, erroneously, to be easily killed by DDT. The Olin Corporation stated: "We live in a time when the popular perceptions regarding a chemical are inconsistent with the scientific facts." Olin concluded that to have pursued the matter in courts would have involved years of protracted trials and appeals.

The main effect of DDT on human beings has been accelerating population growth by preventing malaria and other deadly tropical diseases. This was thoroughly documented by the U.S. Public Health Service and the World Health Organization in the 1950s and 1960s. No cases of cancer in human beings are attributable to DDT, even when exposure was several hundred times the average level for prolonged periods.

The Costly Natural Foods Fantasy

Astonishing as it may seem, most of the public believes that synthetic compounds are different from their identical natural counterparts. This expensive misunderstanding is fostered by the health food industry. In a recent press conference, when I said that the synthetic and natural vitamins were identical, the food editor of the *Washington Post* told me that most of my colleagues did not agree with me. There is now a flourishing market for natural flavors, such as natural amyl acetate, the banana flavor, identical with the synthetic compound, but costing far more. The Feingold Association, (an organization of parents who think that hyperactivity in their children is caused by synthetic food additives), claims that the children of "Feingold households" are allergic to vanillin, but can tolerate vanilla extract—which contains vanillin and also resins not present in synthetic vanillin.

The science of organic synthesis of natural products is founded on the discovery by Friedrich Wöhler in 1828 (Table 4). Synthesis of the vitamins has had tremendously beneficial effects; synthetic thiamine has saved tens of thousands of lives from nutritional deficiency, especially in Asia, and synthetic vitamin A is being used to protect thousands of developing sector children from blindness. These achievements are seldom mentioned. Instead, premium prices are charged in every American drugstore for so-called natural vitamins.

Many common foods are labeled as "natural" so as to place a stigma on synthetic chemistry. For example, sodium propionate has been removed from many brands of bread, so that they can be labeled "Contains No Additives." Propionates, a normal metabolite present naturally in Swiss cheese, were credited a few years ago with saving 10 percent of bread production from going moldy.

Let the eccentrics pay extra money for fertilized eggs and enjoy salmonella in their raw milk, but don't impose this superstitious nonsense on the general public. Also, let us remember that the local opponents of fluoridation are still depriving the children of Los Angeles of fluoride in the water supply that would protect their teeth.

New, beneficial biotechnologies are also under attack with a new set of horror stories.

The *New York Times*, which is a consistent opponent of scientific agriculture, allied itself with professional environmentalist Jeremy Rifkin in attacking biotechnology on April 6, 1986. The *Times* said it was outraged because Advanced Genetic Sciences, a California company, tested an ice-minus strain of *Pseudomonas* "outside greenhouse walls" in "deceit and recklessness" and "failed to report damage to trees noticed in the illicit tests."[6]

What the *New York Times* neglected to mention is the

Table 3
APPROXIMATE NUMBERS OF ATOMS OF SELECTED ELEMENTS PER HUMAN CELL

more than 10^{14}	hydrogen, oxygen
10^{12}—10^{14}	carbon, nitrogen
10^{10}—10^{12}	silicon, phosphorous, sodium, potassium, magnesium, chlorine, calcium, silicon
10^{8}—10^{10}	zinc, lithium, rubidium, copper, manganese, aluminum, iron, bromine
10^{6}—10^{8}	tin, titanium, molybdenum, cobalt, iodine, lead, silver, boron, strontium, nickel, vanadium, scandium, cadmium, chromium, selenium
10^{4}—10^{6}	uranium, mercury, beryllium
10^{2}—10^{4}	40 additional elements probably in these rows
10^{0}—10^{2}	radium

Many compounds listed as carcinogens are present in the healthy human cell.

fact that such ice-minus strains occur spontaneously in nature; nor did it tell its readers that, as a simple fact of microbiology, it is impossible to confine bacteria within "greenhouse walls." No "damage to trees" was noted by any competent scientist, and the U.S. Environmental Protection Agency "now accepts this 'evidence' was inaccurate."

The same *New York Times* also attacked "a second offender, even more arrogant and irresponsible." This was the U.S. Department of Agriculture, which had released a genetically altered virus as a vaccine to treat an epidemic of pseudo-rabies in pigs. The virus had a gene removed by genetic engineering, which made the virus a "novel organism" that *might* run riot and become a pest, said the *New York Times,* without mentioning the fact that it was actually the *unaltered* virus that had "run riot and become a pest."

The *Times* said also that "genetically engineered organisms are novel to all environments"—using the term genetically engineered in this context as a scary buzz-word, like dioxin, PCBs, or DDT. Of course, the statement that a genetically altered organism is "novel" is incorrect because genetic manipulation, with consequent genetic alterations, has been the basis of plant and animal breeding for more than a century. The scaremongering would seem to indicate that we are witnessing a destruction of the United States' leading position in biotechnology, which should be a real cause for alarm.

These are only a few examples of attacks and distortions aimed against science and technology. What we need is more courageous scientists to combat these falsifications. Remember the 1564 dictum of Paracelsus, in which toxicology is founded: "All things are poisonous, yet nothing is poisonous. The dose alone determines poisoning."

The future rests in science. We cannot go back to the good old days that never existed. In conclusion, as an experienced survivor, I give you my recommendations for how to survive when everyone's scared:

> (1) Don't believe unscientific scare stories. (2) Eat what you like, but not too much. (3) Avoid "health foods" and blackened foods. (4) Take exercise, such as backpacking. (5) Don't smoke. Drink only in moderation. (6) Think scientifically—and critically.

Thomas H. Jukes is a professor of biophysics at the University of California at Berkeley.

Table 4
SCIENTIFIC PROGRESS, 1828-1985

"I have prepared urea without a kidney, a bladder, or a dog."

—Friedrich Wöhler 1828

"A [living cell] fed synthetically [with vitamins] will go into convulsions and die before your very eyes, whereas when you feed [vitamins by means of] natural substances . . . it has a kind of a radiant glow."

—Forrest Shaklee, Jr., quoted by Victor F. Zenana, *Los Angeles Times,* Jan. 26, 1986.

Notes

1. Kirk West, 1986. "Toxics: A Plea for Common Sense," *Alert,* California Chamber of Commerce **12 (29)**:18 (Aug.). West notes in this commentary that "Proposition 65 throws out the rule book. Current laws, regulations and safety standards governing toxic substances will be replaced by a 'black list' of chemicals to be drawn up from potentially thousands of common substances used by California businesses ranging from dry cleaners to house painters. Household and garden chemicals would not be immune. This simplistic approach, according to the initiative's proponents, can be enforced effectively in court by lawsuits brought by attorneys for environmental activist groups who will be rewarded by the 25 percent bounty provided for in the initiative. This just sets up a bounty hunter system encouraging a never-ending stream of litigation."
2. I.J. Selikoff, 1975. "Perspectives in the Investigation of Health Hazards in the Chemical Industry," Meeting of the Scientific Committee on Occupational Medicine, Milan, Dec. 12, 1975 (Sezione: Medicine del Lavoro, Igiene Ambientale; Comitato Scientifico, Fondazione Carlo Erba), p. 79.
3. Incidentally, Hutchinson proposes that "the length of life of the biosphere as an inhabitable region for organisms is to be measured in decades rather than in hundreds of millions of years." In short, he is not trying to lull us into complacency.
4. Testimony of Bruce N. Ames to California Senate Committee on Toxics and Public Safety Management, State Senator Art Torres, Chairman, (Nov. 11, 1985).
5. T. Sugimura, 1986. "Studies in Environmental Carcinogenesis in Japan," *Science* **233**:312-318.
6. "A Novel Strain of Recklessness," *New York Times* April 16, 1986, reprinted in *Science* **233**:704-705 (1986).
7. J. Bedbrook *et al.*, 1986. *Nature* **322**:494.

For additional reading

B. Ames, 1983. *Science* **221**:1256.
E. Efron, 1984. *The Apocalyptics,* (New York: Simon and Schuster).
T. Sugimura. See Note 5.
E. Whelan, 1985. *The Truth About Toxic Terror* (Ottawa, Ill.: Jameson Books).
M.A. Ottoboni, 1984. *The Dose Makes the Poison* (Berkeley, Calif.: Vincente Books).

1-2-3 High-Temperature Superconductor Made With Lanthanum

by David Cherry

Editor's Note

This new feature is devoted to the scientific work of young people and will report on science fair projects and other work, including that of groups. Readers' ideas for articles are welcome and should be addressed to David Cherry at 21st Century.

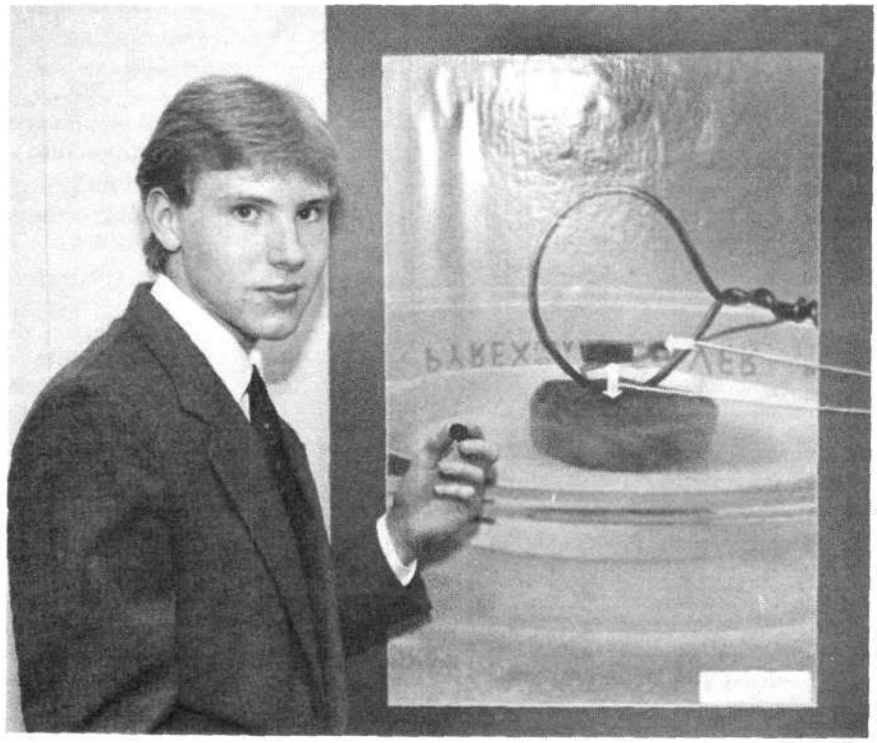
The possible applications of superconductors have fired the imaginations of professional scientists and amateur experimentalists alike, especially since the discovery in early 1987 of ceramics that continue to act as superconductors above 77 Kelvin, the boiling point of nitrogen.*

Imagine the practical advantages of electrical circuits with no resistance: Very large electrical currents could flow without generating heat in the equipment—a crucial problem for computers and magnetic fusion, and currents could be sent over long distances with negligible losses along the way.

As recently as 1980, the warmest known superconductor stopped performing when it reached 23 K. Now we are at a limit just above 120 K, but someday room temperature superconductors may be possible.

It is not necessary to have a perfect understanding of how these high-temperature superconductors work in order to experiment with making them. In fact, no one has a good understanding of how they work. It is even possible that our understanding of the electron and the interactions of electrons with crystalline structures is not good enough to allow us to explain high-temperature superconductivity.

Erik Robins, whose work is reported here, is a sophomore at Broad Run High School in Ashburn, Va. Although he has not had a chemistry course, he is one of numerous students who developed science fair projects this past year on the new high-temperature superconductors. Robins achieved state-of-the-art results in fabricating superconductors that perform up to about 92-93 K.



Stuart Lewis

"I didn't have anybody that knew about superconductivity," Erik Robins said, "until my father checked around at the National Bureau of Standards where he works." The Bureau supplied Robins with the standard formula for the so-called 1-2-3 superconductor that had just been developed.

Robins also wanted to try some variation on the basic formula. "I found that the barium carbonate and the copper oxide were always used in ceramic superconductors, but that a substitution could be made for yttrium. When I looked under yttrium on the Periodic Table, the only element in the same family that I could actually obtain was lanthanum." His results are reported here.

One irony of Robins's project is that he got test results indicating superconductivity in the range 175-195 K, and believed he had achieved a new upper limit. The results were erroneous, but Robins's experience was no different from some professionals in the past two years who have been fooled by initial results that couldn't be reproduced!

Formulae and Phase Diagrams

The compounds Robins used were barium carbonate ($BaCO_3$), copper oxide (CuO), yttrium oxide (Y_2O_3), and lanthanum hydroxide [$La(OH)_3$].

His formulae are shown in Table 1. The first line in each case looks like a chemical formula, but is just an expression of the proportions of the

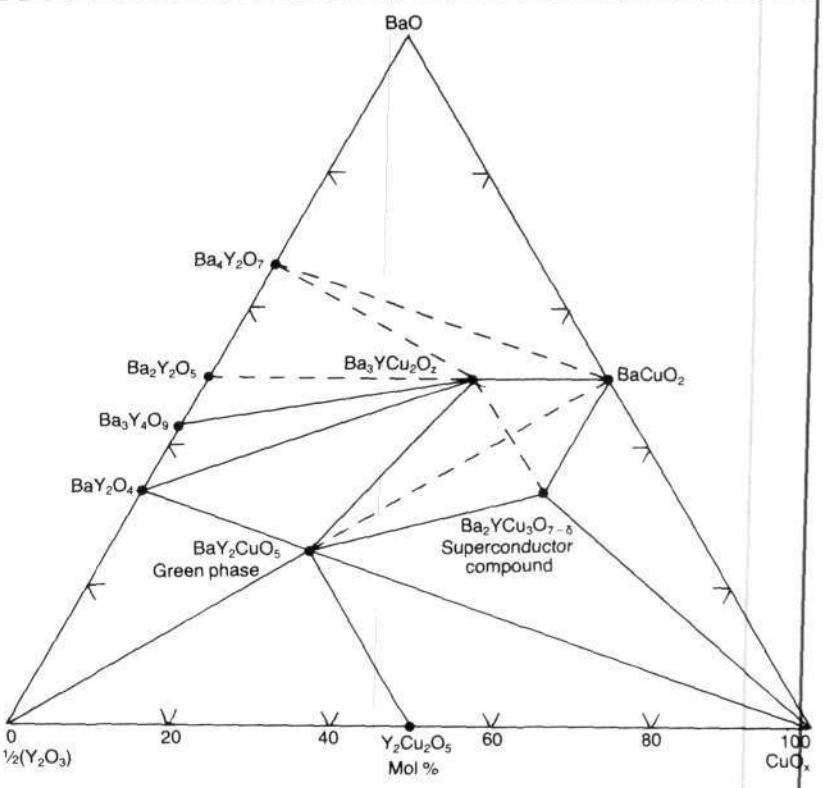
compounds used. (O_x means that the proportion of oxygen is unknown or variable, or both.) The following lines are a list of the ingredients and amounts that were actually cooked together to produce the proportions on the first line.

Mix #1 is the basic formula. It is known as the 1-2-3 superconductor because yttrium, barium, and copper are combined in those proportions. Mix #2 and Mix #3 both involve the substitution of lanthanum for some of the yttrium, and Mix #4 substitutes lanthanum for all of the yttrium in the basic formula.

Phase diagrams are a convenient way of picturing how changes in superconductive behavior (and other kinds of behavior) correlate with changes in the formula. The phase diagram in the figure illustrates this. Two of the triangle's vertices are labeled BaO and $\frac{1}{2}(Y_2O_3)$. Imagine for a moment that the line between these two points is the entire diagram. Under varying conditions, these two compounds will combine to form one or more of four other compounds, each requiring a different proportion of the two ingredients as measured by molecular weight (moles). The four compounds are shown as dots on the line, each placed according to the necessary proportions of BaO and $\frac{1}{2}(Y_2O_3)$.

To make the superconductor, however, a third ingredient, copper oxide, CuO_x, is required. It can be added to the diagram by assigning it to a third point that turns the figure into an equilateral triangle. Suppose there were compounds that all required $BaCO_3$ and $\frac{1}{2}(Y_2O_3)$ in a ratio of 2 to 1 by molecular weight, but varying amounts of CuO_x. These compounds would be represented as points on a line that began at BaY_2O_4 [two thirds of the way between BaO and $\frac{1}{2}(Y_2O_3)$] and ended on the point labeled CuO_x. Actually only one compound is known to have these specifications—it is identified as BaY_2CuO_5, also known as the Green Phase of this system, because the compound is actually green.

There are nine points in the diagram (apart from the vertices of the triangle), each representing an actual compound formed by nature from either



A PHASE DIAGRAM FOR THE 1-2-3 CERAMIC SUPERCONDUCTOR

A phase equilibria diagram shows which compound will result when changes are made in the proportions of the reagents. This phase diagram is valid only in the temperature range 950°-1,010°C and in the presence of air.

The diagram is marked off in percentages of a gram molecule (mol), the compound's molecular weight in grams. For example, on the base of the triangle at about 50 percent is the compound $Y_2Cu_2O_5$: this compound is thus formed from 1 half mol of $\frac{1}{2}(Y_2O_3)$ and 1 half mol of CuO_x.

Adapted from R. S. Roth, K. L. Davis, and J. R. Dennis, "Phase Equilibria and Crystalline Chemistry in the System Ba-Y-Ca-O," *Advanced Ceramic Materials* **2:3B** (July 1987), pp. 303-312.

Table 1
SUPERCONDUCTOR FORMULATIONS

Mix #1 is the basic 1-2-3 formulation. In mixes #2 and #3, the experimenter has partially substituted lanthanum for yttrium. Mix #4 includes no yttrium.

Mix #1

$Ba_2YCu_3O_x$

$BaCO_3$	= 7.94g
CuO	= 4.80g
Y_2O_3	= 2.27g

Mix #2

$Ba_2Y_{0.93}La_{0.04}Cu_3O_x$

$BaCO_3$	= 7.94g
CuO	= 4.80g
Y_2O_3	= 2.12g
$La(OH)_3$	= 0.15g

Mix #3

$Ba_2Y_{0.87}La_{0.08}Cu_3O_x$

$BaCO_3$	= 7.94g
CuO	= 4.80g
Y_2O_3	= 1.97g
$La(OH)_3$	= 0.30g

Mix #4

$Ba_2La_{0.59}Cu_3O_x$

$BaCO_3$	= 7.94g
CuO	= 4.80g
$La(OH)_3$	= 2.27g

Table 2
TEMPERATURES AT WHICH MAGNET NO LONGER FLOATED ABOVE SUPERCONDUCTOR

Temperatures (given here in Kelvin) were measured with a T-type thermocouple hooked up to a millivolt recorder. What could cause these readings to be inaccurate?

Mix	Top of sample	Middle of sample	Bottom of sample
#1	165.5	167.5	139
#2	194.5	145	173
#3	174	125	88
#4	<77	<77	<77

two or all three of the constituent compounds. The entire diagram is, however, only a description of what will happen within one temperature range, 950°-1,010°C. Outside that range other phase diagrams must be constructed.

In order to describe the phases of a system in which there are four compounds, as when Robins only partially substituted lanthanum for yttrium (Mixes #2 and #3 in Table 1), the phase diagram requires an additional dimension, becoming a tetrahedron in place of a triangle.

Testing the Result

Robins used the Meissner effect in two tests to measure the quality of his superconductors. When a material reaches its superconducting temperature, any magnetic field lines that are penetrating it will be expelled, an effect first discovered by Walther Meissner in 1933.

Robins placed a samarium-cobalt magnet on top of his superconductor and then cooled the combination in liquid nitrogen. As superconductivity began, the magnet actually floated in midair above the superconductor because of the Meissner effect. A neodymium-iron-boron magnet works even better. Robins measured the height of the magnet float for each superconductor. This is principally a test of how much of the disk is actually the superconducting compound.

He also sought to measure the highest temperature at which the superconductors would still work, using a T-type thermocouple hooked up to a millivolt recorder. A thermocouple is a device that translates a temperature into a voltage. Robins submerged a superconductor in liquid nitrogen long enough for it to reach the coldness of the nitrogen. Then he allowed the nitrogen to boil off. So long as some nitrogen remained, its temperature was that of the nitrogen boiling point, 77 K. When it was gone, the superconductor would steadily rise in temperature. When conductivity dropped off, Robins applied the thermocouple to the top, bottom, and center of the disk of superconducting material. A dentist's drill was used to make a tiny hole in the center.

This method gave readings that were much too high; they are shown in Table 2. When checked at the National Bureau of Standards with a test known as AC magnetic susceptibility, Mixes #1-3 had upper limits of 92-93 K, and Mix #4 an upper limit of 28 K, which agree with previous knowledge of these superconductors. The reader may wish to offer hypotheses as to why Robins's method gave values so far off.

Robins's mentor at the National Bureau of Standards commented that 1-2-3 superconductors made with lanthanum sometimes don't show any superconductivity at all. There are some very good scientists out there, he said, who did what Robins did and did not get it to work! A perfected lanthanum superconductor would be particularly valuable in the United States, he added, since lanthanum is the rare earth that is most abundant in this country.

Robins's project won one of the two Best of Fair prizes at the Loudoun County, Va., Regional Science Fair, and he was sent to the International Science and Engineering Fair in Knoxville, Tenn., where he won alternate status in a U.S. Department of Energy competition for a trip.

*The Kelvin temperature scale begins at absolute zero, which corresponds to −273.16°C.

Resources

Bruce Schechter (1987). "How to Make Your Own Superconductors," *Omni*, Nov. 1987, p. 72.

"Nuts and Bolts of Warm Superconductors," *Chemical Business* Feb. 1988, pp. 21-24.

Daniel C. Harris, Marian E. Hills, and Terrell A. Hewston (1987). "Preparation, Iodometric Analysis, and Classroom Demonstration of Superconductivity in $YBa_2Cu_3O_{8-x}$," *Journal of Chemical Education* **64**:10 (Oct. 1987), pp. 847-850.

Levitation kit: Project 1-2-3. $25. Order from the Institute for Chemical Education, University of Wisconsin, 1101 University Avenue, Madison, Wis. 53706. Includes a superconductor, a magnet, and literature on superconductivity projects. Liquid nitrogen not included.

Superconductivity demonstration and measurement kits: Superconductive Technologies, Inc. of Golden, Colo., markets 3 kits through the Sargent-Welch scientific equipment company (1-800-SARGENT) for $29, $69, and $165. The latter includes a resistive probe, power board, and thermal probe. A 17-minute video for an additional $30 shows the taking of measurements and demonstration of the Meissner effect, quantum mechanical effect, and so forth.

Video on superconductivity: The Nova series produced by the Public Broadcasting Service includes a one-hour program entitled, "The Race for the Superconductor." It may be rented from Coronet MTI (1-800-621-2131) for $125 for a 3-day period.

How a 16-Year-Old Built a Laser in 1961

by Dr. Paul Tremblay

The author in 1962 (top center), holding his science fair award. Below, Tremblay today, still ready to "roll up his sleeves to dip out the answers." An engineering specialist, he is now doing advanced research on communications systems.

Editor's Note

Today we take lasers for granted, but back in 1961, 16-year-old Paul Tremblay built one of the first lasers in the country, an ionized argon laser, for his high school science project. At the time, leading scientists were winning Nobel Prizes for what Tremblay accomplished.

We asked Dr. Tremblay, now a scientist at the Idaho National Engineering Laboratory in Idaho Falls, to describe how he came up with the idea and what he did.

* * *

I became interested in electronics at an early age. One of my uncles began taking a course in radio/TV servicing from the National Radio Institute at about the time of my 13th birthday. As he'd finish a lesson, he'd pass the book to me and I'd follow along. We did the course in parallel all the way through.

By the time we finished that course, I was repairing radios and televisions for all the family and neighbors. For my 14th birthday, my parents gave me the first of what has grown to be a large collection of instruments, a vacuum tube voltmeter.

My father was a professional photographer whose absorbing interest in his career was an early inspiration. He readily took the time to explain the intricacies of optics to me and to my brother and sister as we expressed interest in different facets of the subject. A lot of the skill I was to acquire for making careful observations can be directly attributed to the care he took in making sure we understood the topic under discussion.

Frequently he would attempt a photo experiment that was outside the bounds of common practice, just to see what would happen or to observe the reactions of the people looking at the result. One in particular I remember was his experiment with peanut shells. He enlarged a close-up of a pair of peanut shells so that they were more than a foot long in the resulting picture. On exhibit, more people than you would imagine identified the picture as that of a pair of bedroom slippers.

My mother, who was (and still is) an avid reader of science fiction and who followed closely the developments of science in general, was also an early influence. She attended college while I was in my early teens, earning her teacher's certification in science and math. An avid reader, she had subscriptions to several books and magazines, one of which was *Scientific American*.

The first issue of *Scientific American* that I can recall reading was one in 1955 or 1956, which had an article about masers, an acronym for microwave amplification by stimulated emission of radiation. That introduction to the physics of energy exchanges between electronic levels of neighboring atoms seemed a fascinating topic and provided the focus for studies retaining my interest to this day.

Building an Atomic Clock

By the summer of 1960, I had put together a small home lab with a modest stock of necessary shop equipment, and I attempted to recreate some of the phenomena I had read about earlier in that magazine. An article on atomic clocks had recently been published, and as some of the technology seemed reasonably within reach of my resources, this became the endeavor of choice for that summer.

The atomic clock article illustrated several methods of approach, one common one being use of a light source using a rubidium vapor arc-lamp whose light was passed through a polarizer and absorption chamber containing the same vapor. A second analyzer and detector of light intensity demonstrated the metastable nature of the light/electron interaction of rubidium. This made possible the storage of energy as a population inversion whose creation was evidenced by the measurement of an increased light intensity at the detector.

A simple electronic circuit known as the Schmitt trigger could be made to sense this increase in light intensity and

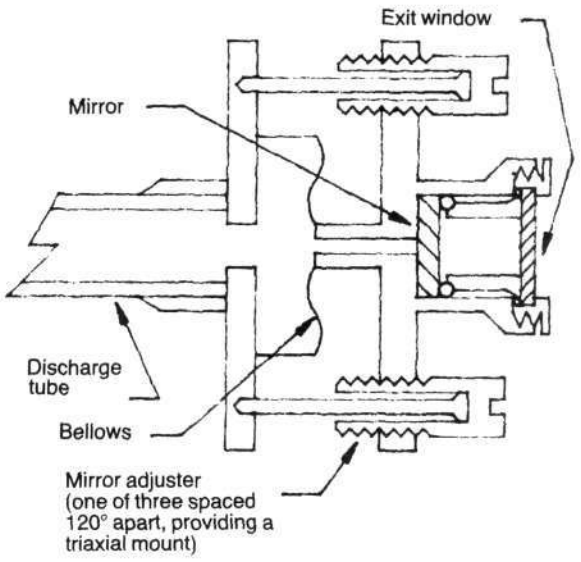


Figure 1
LASER MIRROR MOUNT

The assemblies for the laser were put together with parts from old military vacuum tubes, which Tremblay had used to make an interferometer. These were JAN 417A Reflex klystron tubes with three posts that were used to adjust the drift space between the buncher and catcher grids in the device. It had glass seals on both ends, which he broke to attach to a solid piece of glass to make the mirror for the interferometer.

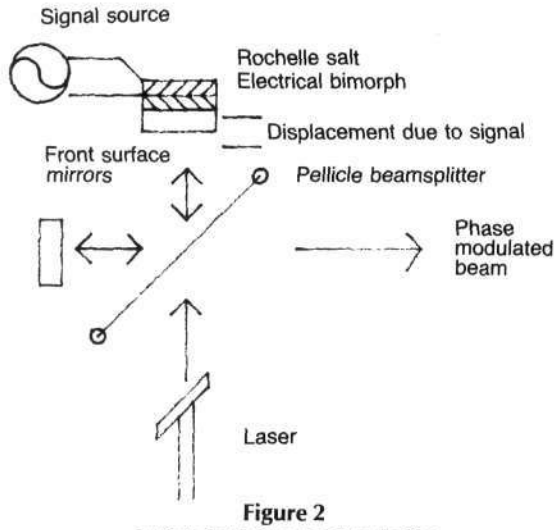


Figure 2
LASER PHASE MODULATOR

In this method of modulation for the laser, Tremblay used a Michelson-Morley interferometer, which makes use of a pellicle window. The pellicle is half-silvered, so that half of the light coming in is reflected and half is transmitted. The part that is reflected is made to impinge on a mirror, which causes it to pass back to the pellicle, and again half the beam is returned to the light source and half passes through. A small salt crystal was put behind one of the mirrors, causing it to move a minute distance. At that point, the light beams could be modulated with audio frequencies.

subsequently to cause a pulse of current to pass through a winding placed around the absorption chamber. This would stimulate the excited rubidium vapor to release its absorbed energy and begin anew the cycle just described. As long as the energy input to the lamp was closely regulated, the time interval between pulses was stable and made a reasonably accurate clock.

This primitive method did not use an oscillator as in the quartz-crystal-regulated clocks common today. I had no access to rubidium, but knew that mercury also had long-lived metastable electronic states and could easily be made into arc lamps. The first device I made that summer was of this type; it really didn't work very well but gave me valuable experience working with metal and glass.

The atomic clock article also described ammonia and cesium beam clocks that used an electronic oscillator having excited states of ammonia or cesium vapor as the energy transfer media. These energies could be released precisely in time with the fields within an oscillator cavity amd made to sustain these oscillations with extreme time stability.

The next clock I made used cesium and was very much more an accurate timepiece. I did not have access to rubidium, but the late Dr. Oakberg, a friendly chemistry professor at the North Idaho Junior College, gave me a small amount of cesium and other materials that had been mentioned in the article on atomic clocks. He influenced my studies of metal and glass configurations leading to development of optical oscillation cavities and devices called interferometers.

Moving on to Build a Laser

The interferometer is normally used to measure dimensions very precisely. I used this device as a convenient optical cavity for a mercury-absorption-type atomic clock. Not quite a year later, *Scientific American* published an article about the helium-neon optical maser (laser) developed by the laboratories of General Telephone. Comparing this device with the mechanical and electronic configurations of the clocks I'd previously assembled revealed that there were few differences. The laser was a more stable oscillator than any of the clocks I had put together with coils and capacitors or cavities, so reproducing this exciting device became a new obsession.

The Fabry-Perot interferometer used as the optical oscillator cavity seems a simple device, but it is no simple matter to assemble. It consists of a pair of optically flat windows aligned plane-parallel with one another, separated physically by an optical path ranging from a few inches to several meters, depending on the required size of the device. The idea is that if you pass a beam of light of a single wavelength through the windows, a set of fringes may be observed illustrating the degree of parallelism of the window surfaces, the degree of distortion of the light path caused by intervening materials, or the deviation from flatness

of the surfaces of the windows relative to the wavelength of light illuminating the path.

Figure 1 shows the mirror mount assemblies made with parts from some old military vacuum tubes that comprised the heart of that first interferometer.

In the laser, the windows are coated with metal or multiple dielectric films to act as selective mirrors made to reflect the light generated in the path between them by an electronic excitation process similar to that used in the arc lamps discussed earlier. An arc is avoided to prevent contamination of the optical path and/or mirror surfaces by electrode materials. This is accomplished by excitation of the requisite atoms in a vacuum with currents and voltages controlled to maintain a "soft" discharge whose power density is low enough to prevent electrode erosion by the electron impact.

My attempt to build a helium-neon device was quickly redirected by the high cost of neon—$30.00 per liter was a bit beyond my normal budget as a grocery delivery boy in those days. The proprietor of the welding supply shop, from whom I had obtained other materials on occasion, suggested I try a cheaper alternative, argon. At the time, it cost around $4.00 for 30 cubic feet in a little medical cylinder. I decided, what the heck. . . . Time to break new ground.

Success!

An argon-helium mixture seemed the logical combination to start with, but it frustrated all attempts to obtain the desired beam of light. Adjusting the gas mixture ratio had little effect until I inadvertently filled the tube with pure argon. This took considerably more power to obtain a stable gas discharge, but had the desired effect in that a spatially coherent beam of blue light was produced from the exit window of the mirrored interferometer.

Success. . . . it feels good even if it's nearly blind luck!

I was not able to prove for over a year that the device operated with the argon ionized. The helium-neon laser operates without ionizing the neon, and I had assumed that the energy states of an ionized atom would have been too high for any reasonable population inversion to occur. Argon was the first of the laser gases to disprove this assumption.

The date for this fortuitous "accident" was early in the month of October 1961. By the spring of 1962, I had started to experiment with methods of modulating the light beam for line-of-sight communications.

The device used for these early attempts was very similar in functionality to the absorption chambers of my early atomic clocks. They were still in my junkbin, so it was natural to use what was at hand. While the depth of modulation these were able to impress on the beam was less than 30 percent of beam intensity, it was possible, through fine control of the population inversion in one of these cells, to obtain this depth at a modulating frequency of 450 megacycles, the limit of my equipment at that time.

I demonstrated this equipment and my method to a public relations man from the Spokane General Telephone office just about a week before they showed *their* method on the Gary Moore Show in February 1962. A later device is shown in Figure 2, which was used to produce a phase-modulated beam at low audio frequencies.

Science fair time in our area came soon after, and the laser, a hefty pile of components, won the top award in Spokane and soon was on its way to the National Science Fair, held that year at the Seattle World's Fair. An Army Brigadier General, General Clark of the Harry Diamond Ordnance Fuse Laboratory, situated on the grounds of the National Bureau of Standards in Washington, D.C., was at the National Science Fair as a judge. He invited me to visit the lab during the summer, courtesy of the U.S. Army. I was a bit too young for the draft, but that was an offer I just couldn't refuse.

The visit is still a fond memory. What young person, interested as I was in the sciences, wouldn't have been in seventh heaven to see things like the Smithsonian exhibits, the standards and workshops of the Harry Diamond Lab, and even a visit to the TRIGA-MARK IV nuclear reactor out near Rock Creek. It was fantastic!

The high point of the trip, though, was discovering during my first "oral board," that the laboratory had so far been unsuccessful in constructing a laser of its own! They stood me up in front of a blackboard and invited me to talk at length in front of some 15 scientists bent on extracting every shred of information I possessed. At some point I suddenly figured, "Doggone it, I'd better cover this up—this doesn't sound right; they're going to steal it from me."

I had already told them too much, and I asked myself, "what can I do to throw them off?" So I told them that the color was in fact red instead of blue. But it didn't take them long to find out that blue was really the color that came out. Their equipment was of the very finest construction, and it was just a short while before they had one on line.

I don't know if they attempted to reproduce my efforts, but I do know that it wasn't too long afterwards that a fellow by the name of R. I. Gordon, who I understood had some association with the lab, obtained a patent on the Ionized Argon Laser.

It's interesting to watch the developments now surrounding Mr. Gould of Patlex Corporation who managed to obtain the patents on gas lasers after so many years of being denied access to his lab notebooks. I certainly had no priority with respect to Mr. Gould, but still feel good that at 17 years of age I was able to establish myself on the ground floor of this emerging technology.

Scientific Discovery

Any young person who aspires to the joy of discovery will find many doors open. Quite frequently, these early starters, having no preconceived notions or biases pounded into them by stodgy old professors, will observe a phenomenon from a totally unique standpoint and point the way to a better understanding for us all.

This is the way scientific discoveries work. Making my own equipment through self-taught metal working, glass blowing, and always asking questions provided me with firsthand knowledge of how things work. It's not the only way, but I feel our effort should ever be to encourage, support, and acknowledge the accomplishments of our young people and pray that they'll never be afraid to ask "Why?" and then roll up their sleeves to dig out the answers.

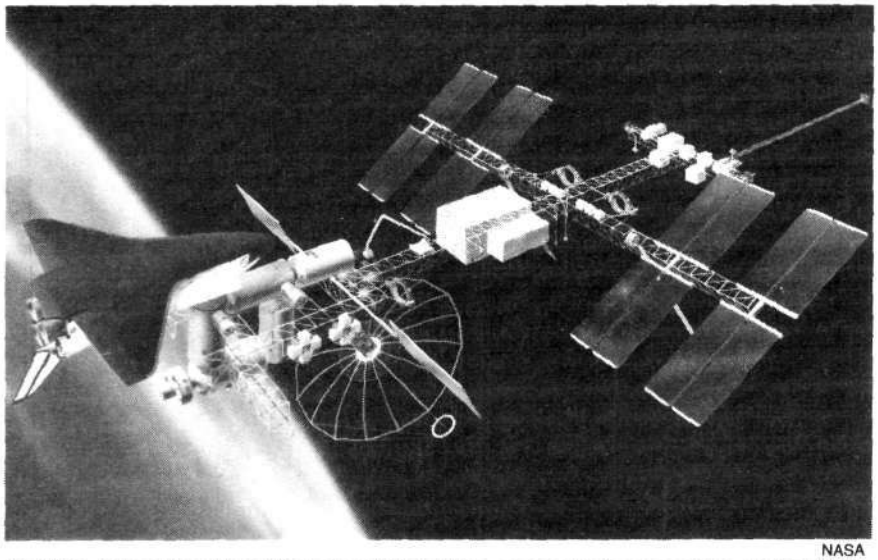
Space Station Faces Cancellation

by Marsha Freeman

In a major foreign policy and technology disaster, the elected representatives of this nation have voted to put an end to the international space station that the National Aeronautics and Space Administration (NASA) and its allies have been designing for four years.

Since President Reagan's announcement of the space station project in 1984, the White House has refused to launch an all-out fight for funding of the program, and Congress, under the pressure of producing a "balanced-budget," has slashed even those inadequate funding levels requested by the administration.

Until now, niggardly funding levels have barely kept the space station program alive. With the amounts being discussed for fiscal year 1989, it will not make any sense to continue to pay people's salaries just to have them sit at desks without building anything.



NASA

In 1984, when President Reagan initiated the space station program, this artist's drawing was the reference configuration and the target date was 1994. Now, in 1989, the next president will decide the station's fate.

Congressional Tricks

In January the White House submitted a fiscal year 1989 budget request for NASA of $11.48 billion, which included $967 million for the space station. Without a funding level at or near $1 billion, the industrial contractors, who were chosen last November, will never be able to start building the modules and other equipment for the station.

There was never a good chance that such a funding level would make it through the chaotic Congressional budget process. On May 12, the House Science, Space, and Technology Committee, which consists of members who represent major aerospace and NASA centers, voted up the full request. However, it is the House and Senate Appropriations Committees that have to come up with the money.

On the same day, May 12, the House Appropriations subcommittee on Housing and Urban Development (HUD) and Independent Agencies cut the request to $10.7 billion, taking $65 million from the space station. NASA spokesmen stated that with the budget for the station still above $900 million, they could "live with" the decision.

In the Senate, however, storm clouds were forming, as the Budget Committee doled out less than the anticipated amount for all of the Appropriations subcommittee's programs. That the nation cannot have both a space program and a "balanced" budget was becoming clear.

On June 16, the axe fell at the Senate Appropriations subcommittee mark-up of the NASA budget. The entire budget was slashed to $10.1 billion, and the space station nearly zeroed out. In the end, $200 million was perfunctorily included for the space station, to be used either to *terminate* the industry contracts or to carry the program along only until January.

At the same time, the House Appropriations subcommittee also ran into trouble when a new budget resolution forced its members to slash an additional $438 million from their programs. Rep. Edward P. Boland (D-Mass.), who chairs the subcommittee came up with what he described as a "gimmick" to approve $387 million for the space station, to last until April 15, 1989.

This money has been "fenced off" to prevent any further cuts in the NASA budget. It will allow about $60 million per month to be spent on the station, compared to the $50 million per month that is being spent now—clearly not enough money to start construction.

Both the Senate and House have decided that since federal spending money is dear, and this administration has made no effort to fight for the program to continue, the next president will have to decide whether there is a "go" or a "no-go" on the space station.

Presidential Malfeasance

Where was President Reagan while his space station and Strategic Defense Initiative were being decimated by the congressional budget mania in Washington?

By accepting the voodoo economics of his advisers and their accompanying

fantasy of 60-odd months of economic recovery, President Reagan was in no realistic position this year to make a fight over the disastrous funding levels of either of these programs.

On June 14, after months of negotiating on Capitol Hill on the NASA budget, the White House announced that it would launch an "offensive" to fund the space station. "You'll see the President himself targeting members of Congress," the *Defense Daily* quoted one pompous official as saying.

Two days later, when the Senate subcommittee was making its decisions on the budget, a letter written by the President and addressed to both House and Senate Appropriations Committees, failed to arrive before the mark-up was completed!

In trying to explain why this program, which the President had personally initiated in a State of the Union address, has gone down the drain, one administration official complained that the "time-consuming Moscow summit" was responsible for the President's apparent lack of knowledge of the funding crisis facing the space station. It is hard to imagine that the Soviet space program would go down the drain because Gorbachov was so busy during the same summit!

An International Disaster

In terms of collaboration on space programs, this is not the first time the United States has kicked its allies in the teeth. Abandoned space science projects—such as the International Solar Polar Mission that was eliminated from the U.S. budget—have left our European collaborators in the lurch before.

The space station, however, is a multi-billion-dollar investment. The European Space Agency (ESA), Japan, and Canada have all signed on to provide the station with major capabilities that the United States could not afford. Each nation and group has already started spending part of the $7 billion of the foreign money committed to build these components.

Only the United States and Soviet Union have manned space programs now and for the near future. If this country takes the advice of the Congressional Budget Office, and pulls out of manned spaceflight altogether, any other nation that recognizes spaceflight as a crucial activity for the 21st Century, will have to turn toward the East.

The reaction from U.S. allies on the possible cancellation of the space station has been justifiably angry. As *Defense Daily* reported June 15, one official said his country will "raise the roof." Protest notes from the ambassadors of the affected countries are likely.

Whatever protest is made, the Europeans and Japanese have not been waiting for the final curtain to fall to make provision for a possible U.S. pullout. ESA plans to enter the manned space flight business in the mid-1900s, with the operation of its Hermes space plane.

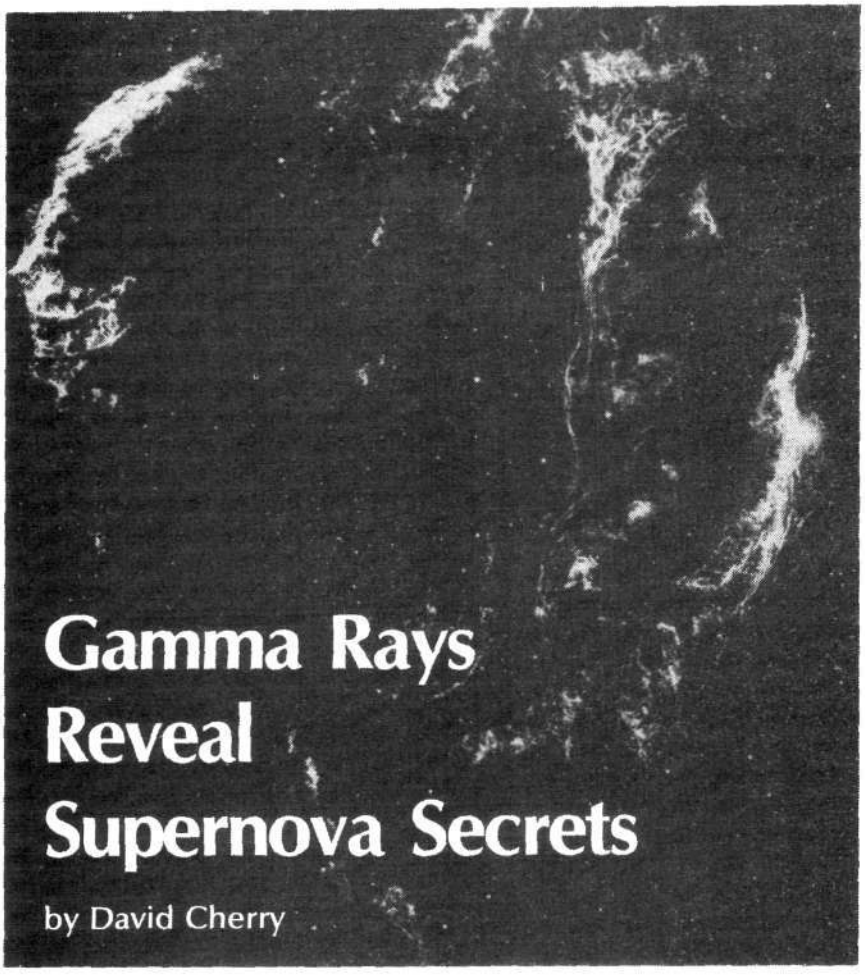
Much smaller than the U.S. Space Shuttle, Hermes will be launched on an Ariane 5 expendable booster. It will be able to carry a small crew into orbit and could rendezvous with a space station. ESA will then have its own manned transport capability.

It would be senseless for either the Europeans or the Japanese, who are both building major laboratory modules for the U.S. station, not to use that expertise and experience in designing their own independent—perhaps man-tended—station.

It would be difficult, but it could probably be worked out, to use the Shuttle (or perhaps the Soviet Energia rocket) to launch European and Japanese modules to their own stations.

The irony in the timing of the U.S. budget disaster is that on June 8, after four years of negotiations, NASA announced that the final framework for international cooperation on the station was completed. Presidential ceremonies at the White House had been planned for the summer to celebrate the future of this major international program could bring the Western world into the next century.

In the past two decades, the United States has given up its lead in nuclear power technology, thermonuclear fusion energy research, advanced transportation systems, and even materials and computers. Without a space program that is geared toward people living in space—first on the station and then on the Moon and Mars—this nation has no future for the children of that generation of citizens who watched the first man walk on the Moon in 1969.



Gamma Rays Reveal Supernova Secrets

by David Cherry

The detection of certain gamma rays with energies around 1 million electron volts from the supernova has now confirmed that new elements are created in supernovae. Other, higher-energy gamma rays of about 1 trillion electron volts are now being sought to confirm that the supernova has produced a pulsar—a spinning, magnetized neutron star that emits a beam of light as it rotates, while giving off a wind of electrons and positrons in all directions.

Shown here is a supernova remnant of luminous gas, the Cygnus loop, in the constellation Cygnus. There may well be a pulsar at its center, but we have no way of detecting it today.

For those who believe in the Big Bang theory of how the universe began, a supernova is principally the death of a star—in the last analysis, a minor contributing drama in the inexorable running down of the universe. In the actual universe, however, a supernova is like a flower. Its brilliance is extinguished as it releases the seeds by which life is developed ever further.

A supernova explosion both creates and scatters into the interstellar medium numerous elements necessary to life—some of them elements for which no other genesis is known.

This feature of the most recent supernova, Supernova 1987A, came to the fore last Dec. 14, when two teams of astrophysicists reported the hoped-for detection of gamma rays at predicted wavelengths. These gamma rays are the first direct confirmation of *explosive nucleosynthesis*—the creation of new nuclei as part of the supernova explosion process. Even though our understanding of the fundamental processes of supernovae is still very imperfect, the detection of these gamma rays is an important milestone (Figure 1).

The astrophysicists reported their results to the Workshop on Nuclear Spectroscopy of Astrophysical Sources in Washington, D.C., sponsored by NASA and the Office of Naval Research.

The supernova shock wave, according to the theory these researchers have just confirmed, produces radioactive nickel-56, which quickly decays (half-life 6.1 days) to cobalt-56. The cobalt then decays (half-life 77 days) to stable iron-56. This sequence leads to the prediction of gamma-ray emission lines at a dozen different energies, and there are still other nucleosynthesis processes entailing their own gamma-ray emissions. Low-energy gamma rays are the form of energy characteristic of changes of energy levels in the nucleus; hence they are called nuclear gamma rays.

Each of the two experiments detected gamma rays at 847 kiloelectronvolts (keV) and 1,238 keV. These are the strongest of all the predicted lines, and both arise from the decay of cobalt-56 to stable iron. Donald Clayton of Rice University, an old hand in the supernova business, commented that Supernova 1987A had produced cobalt-56 equal to 20,000 times the mass of the Earth. If every supernova did this, he added, they would make all the iron in the universe.

Clayton's comment was not facetious, since iron and its family of elements are thought to be created exclusively by explosive nucleosynthesis rather than in the humdrum, daily activities of stars. Since nickel-56 and cobalt-56 are both short-lived, the appearance of the gamma-ray signature for cobalt-56 decay is proof that new nuclei have been brought into being by the supernova explosion itself.

The Missions

The results reported in December 1987 were those of the German-American Gamma-Ray Spectrometer or GRS (Edward Chupp, University of New Hampshire, principal investigator) aboard NASA's Solar Maximum Mission, a spacecraft that has been in Earth orbit for several years, and from a

gamma-ray telescope (Thomas Prince, Caltech, principal investigator), lofted by a NASA high-altitude balloon from Alice Springs, Australia, in November.

In the first of these results, (*Nature*, Feb. 4, 1988), the 847 keV line was detected as a flux of 1 photon per 1,000 seconds per square centimeter, at 843 ±5 keV, after subtracting the abundant background noise. There are no other gamma-ray sources in the neighborhood of the supernova, and the emissions peak very nicely at the position of the supernova itself. Comparing the observation with the preceding years of data, the experimenters write, "This feature [the observed 847 keV line] cannot be explained by any statistical or systematic fluctuations observed in the seven previous years of GRS data."

They calculate a statistical significance level of greater than 5σ (5 standard deviations—3σ is a 98 percent level of confidence in the significance of the result). The detection of the 1,238 keV line is less certain, but is seen clearly in other researchers' observations yet to be published. The GRS detection testifies to the importance of getting telescopes into space—in this case because gamma rays cannot be detected through the atmosphere at all.

Surprisingly, the gamma rays made their appearance in early August. The GRS data reported in December run to Oct. 31, and show an early August onset. It had been generally agreed that it would take several additional months for the supernova envelope to expand and thin out enough for the gamma rays to get out. "Gamma rays by Christmas or Easter," as Stirling Colgate had put it. Of course X-rays had escaped from the envelope 75 days ahead of predicted schedule also. It is guessed that the envelope may not be uniform, and that, through turbulence, a certain amount of cobalt-56 has gotten out beyond most of its depth. That is consistent with the brightness of the two lines as observed by the GRS experimenters. The lines are so faint, they say, as to correspond to only about 1.3 percent of the cobalt-56 that the light curve indicates is present; this observed amount is completely free of the envelope.

History of a Breakthrough

The origin of our solar system and of solar systems in general is one of the most challenging questions that astronomers and space scientists confront, and is fundamental to the question of the origin of life. It is really a complex of questions: How were the planets formed? What determines their orbits? *What processes determined the relative abundances of the elements and their isotopes?* This last question is the one that leads to the puzzle of nucleosynthesis.

In the 1930s, it was finally established that the source of energy by which the Sun and the stars shine is nuclear fusion—the creation of larger nuclei through the fusing of smaller ones. Was it not therefore possible that the range of naturally occurring elements in the universe is created by the steady burning of the stars and was not determined "primordially"? Perhaps, but the conditions then known to exist in these fusion furnaces were not sufficiently intense to account for the abundances of many of the heavier elements (Figures 2 and 3).

Meanwhile, it was also in the 1930s that a new astrophysical phenomenon was identified—the *supernova*. For some centuries, astronomers had studied novae—Latin for "new stars." Novae are not really new stars, but they do increase in brightness very dramatically. They may brighten by as much as 16 magnitudes (an intensity increase of a million times) in just a few hours. After peaking, the nova's light curve slopes gently downward over a period of months. Finally the star settles down and looks much like its former self.

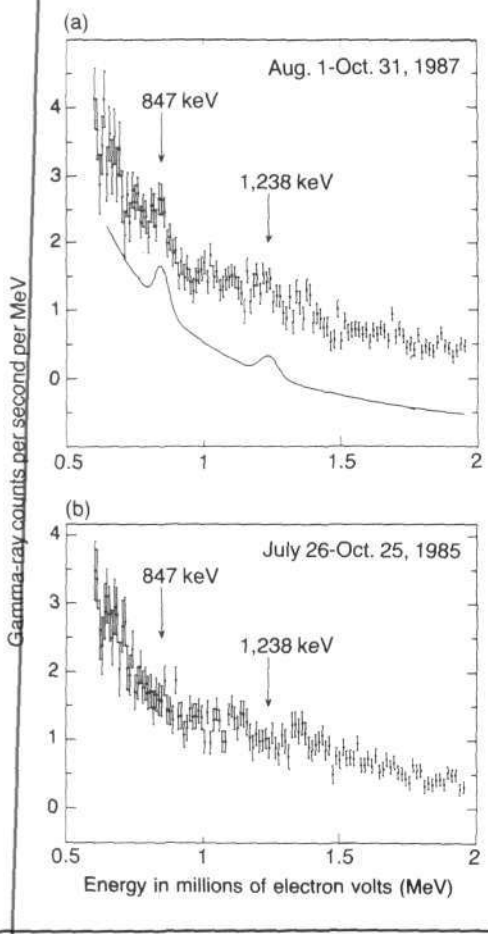
Walter Baade and Fritz Zwicky, in the early 1930s, noticed that an occasional nova seen off in another galaxy was really something else. These were very bright novae that peaked, faded, and left apparently nothing behind. They had simply exploded! Zwicky dubbed these *supernovae*. Historical records made it possible to identify as super-

Figure 1
GAMMA-RAY SPECTRUM OF SUPERNOVA 1987A

The two peaks noted in (a) appeared as predicted about six months after the supernova explosion. This segment of the gamma-ray spectrum was recorded by the GRS from Aug. 1-Oct. 31, 1987. The solid curve is the predicted spectrum. The peaks, at 847 and 1,238 keV, arise from the decay of newly-created cobalt-56 to stable iron.

For comparison, an equivalent spectrum accumulated in 1985 is shown in (b). In both spectra, the background flux has been subtracted, but residual atmospheric gamma-ray continuum emission remains.

Source: S.M. Matz et al., *Nature* Feb. 4, 1988, pp. 416-418.



novae the spectacular events of 1054 (recorded by Chinese and Japanese astronomers, its remnant is still visible today as the Crab Nebula), 1572 (recorded by Tycho Brahe), and 1604 (recorded by Johannes Kepler). All three had exploded in our home galaxy, brightening the sky even by day and provoking terror even in hardy souls.

Supernova explosions, then, might account for the creation of some heavy elements, making up theoretical deficiencies. Moreover, the explosions would scatter the newly created nuclei into interstellar space, making them available, for example, to our solar system.

The detailed study of nucleosynthesis began in earnest with a seminal paper by the British cosmologist Fred Hoyle in 1946, and further work over the following decade. The development of the hydrogen or fusion bomb aided the process of understanding supernovae, not least because of the study of bomb-generated shock waves. The creation of heavy elements in a supernova explosion is a shock-wave phenomenon. Stirling Colgate studied both kinds of shocks, and had the advantage of discussions with other bomb scientists at Lawrence Livermore National Laboratory such as Tom Weaver, George Chapline, and Edward Teller.

It was Colgate and Chester McKee in 1968 who discovered that supernovae must create nickel-56, which then decayed to stable iron-56 while giving off gamma rays, correcting Hoyle's initiating paper. Hoyle had supposed that the iron abundance peak came about through supernova creation of the iron directly. It was then immediately realized that the gamma rays might well be detectable.

Donald Clayton of Rice University developed the idea of detection, and in a 1973 paper, "Confirming Explosive Nucleosynthesis with Gamma-Ray Telescopes," went further to propose the detection of the universal gamma-ray background that must surround us from the totality of supernova nucleosynthetic activity. He suggested that one might be able to sample historical rates of nucleosynthesis by sampling the background at different distances. Because of the expansion of the universe, the background at greater and greater distances (greater redshifts) would reflect conditions ever further in the past. Clayton's provocative proposal must be brought to fruition in the 1990s.

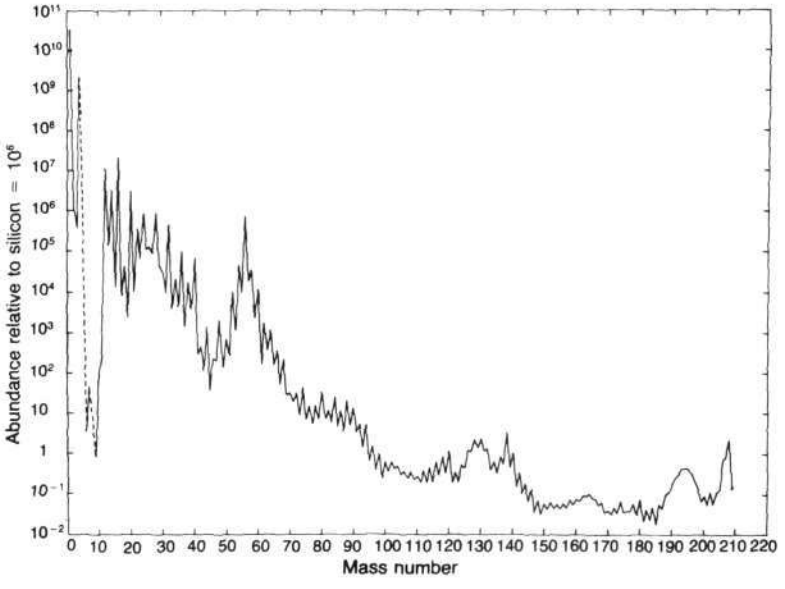


Figure 2
NUCLEAR ABUNDANCES IN THE SOLAR SYSTEM

Estimated abundances of nuclear species (elements and isotopes) are shown as a function of their mass numbers. The abundances are given in numbers of nuclei relative to silicon, with the number for silicon set arbitrarily at 10^6. Silicon is one of the most abundant elements. These estimates are based on the composition of meteorites and some solar data. Supernovae account for the creation of numerous nuclear species.

Source: A.G.W. Cameron, "A Critical Discussion of the Abundances of Nuclei," in *Explosive Nucleosynthesis*, D.N. Schramm and W.D. Arnett, eds., 1973, p. 10. These values were revised by Cameron in 1981.

Has the Supernova Left a Pulsar?

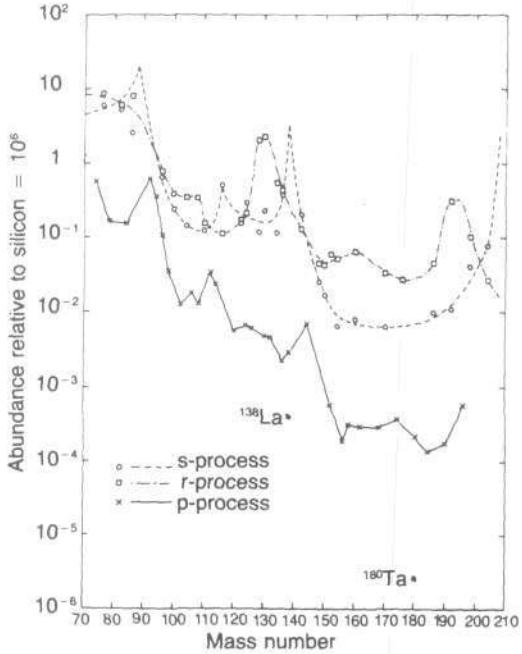
Cosmic ray scientists are now engaged in a search for gamma rays of much higher frequencies—in the teravolt range (1 teravolt is 10^{12} volts)—that may disclose the existence of a pulsar left behind by the exploding star. A pulsar is a neutron star, a tiny star of inconceivable density that sends out a powerful lighthouse beam as it rotates.

One key in the study of the universe is the behavior of matter under extreme conditions. The tiny pulsar gives us access—albeit limited access—to some very extreme conditions.

The pulsar, if it is a pulsar, may be discovered by detection of these very high energy gamma rays in the coming months, or, failing that, by low energy gamma rays that we probably will not see for a few years. Longer wavelength radiation will peek through the supernova's thinning envelope even later. Scientists operating cosmic ray detectors across the southern hemisphere are already looking for the very high energy gammas.

It will be the first time that a pulsar has been detected virtually at birth, and the pulsar may produce—in combination with the exploded envelope of the original star—"a small Crab Nebula," in the words of Alice K. Harding, a pulsar theorist at the Goddard Space Flight Center. The Crab Nebula, remnant of a supernova explosion almost a thousand years ago, is continuously lit by the energy from the pulsar within it.

That pulsar in the Crab Nebula, one of the first pulsars to be discovered, was found in 1968. But the story more properly begins in 1933, when Walter Baade and Fritz Zwicky first distinguished the supernova phenomenon from that of the much less cataclysmic nova. They soon found by computa-



Source: A.G.W. Cameron, *op. cit.*, p. 11.

Figure 3
THEORETICAL ABUNDANCES PRODUCED BY NUCLEOSYNTHESIS

These are computer calculations of the relative abundances produced by each of the three nucleosynthetic processes believed to be involved in creating the elements heavier than the iron group (Cr, Mn, Fe, Co, and Ni). The s- and r-processes (s for slow, r for rapid) are neutron-capture processes in the presence of a neutron flux.

The slow process is so called because the neutron flux is weak and it takes long times for neutron capture to occur relative to the rate of beta-decay in radioactive species. As a result, a nucleus gains neutrons only until a radioactive species is formed. Beta-decay then occurs, and the nucleus—with an incremented atomic number—resumes neutron capture. The products of the slow process are the species of high "beta stability," that is, they are nuclei not characterized as neutron-rich or proton rich. The s-process occurs during the normal burning of stars of sufficient mass.

In the rapid process, conversely, multiple captures can occur more quickly than beta-decay, and do occur until the neutron binding energy becomes too low for further captures. Only then must the nucleus wait until beta-decay occurs before neutron capture can resume. This process requires a supernova explosion. The result is neutron-rich isotopes of the elements. Some isotopes can be created by either the s- or r-process.

The p-process (p for proton) is dimly understood, but is guessed to be similar to the r-process, with the difference that there is a high proton *flux producing rapid* proton *capture. The products are proton-rich isotopes—generally of low abundance.*

tion that the supernova process might leave behind a previously unknown creature, which they called a neutron star. The supernova explosion, they said, could be triggered by the collapse of the star's core, when fusion in the star began to exhaust its sources of fuel. But the core itself would not explode, only the star's outer layers. Gravitation would become so overwhelming that electrons would no longer hold their orbits, but would merge with protons to form neutrons. Having no charge, neutrons would not repel each other, and would pack densely. The result would be a sphere with a diameter of 10 or 12 kilometers, but with the mass of the Sun! One cubic centimeter of pure neutronic matter would weigh as much as all of humanity. The neutron star is the generally accepted conception of the outcome of the core collapse process.

Baade and Zwicky's hypothesis that some types of supernovae left neutron stars behind, although very interesting, had no known observational reference point in 1934. It was not until 1967 that a neutron star was suddenly required to account for an unprecedented observation.

That observation was the work of Cambridge University graduate student Jocelyn Bell, who participated in building a large radio telescope under the direction of Anthony Hewish. Hewish was interested in studying the scintillation of radiowaves coming from quasars—scintillation caused by the interplanetary medium. Bell was in charge of taking all the data, and noticed the appearance of recurrent blips made by the recording needle every time the antenna was pointed toward a certain part of the sky. The pulses kept coming 1⅓ seconds apart, with varying amplitude.

The clocklike precision in the timing of the pulses caused Hewish and his colleagues to conclude that the signals must either be man-made (such as from space probes), or else produced by other intelligent beings from somewhere in space—"little green men," as they were jokingly called. Both ideas were reasonable enough. Bell—less fixed in her ideas of what to expect from the stars—did not see why the source could not be astrophysical. She turned out to be right.

When Hewish and Bell published their initial report in *Nature*, Feb. 24, 1968, they included a model based on the idea of beamed radiation coming from a white dwarf or neutron star that was rotating with a period equal to the time between pulses. The detection by Bell of three more widely separated sources of such radio pulses gave impetus to the idea that the phenomenon was astrophysical in nature.

The theory of the pulsar that survived—when tested against a cascade of new pulsar discoveries—was that of the Austrian-American astrophysicist Thomas Gold. In 1968, Gold proposed that the pulsar was a rapidly spinning neutron star with a high magnetic field

on the order of 10^{12} gauss that spins with it. The neutron star results from the collapse of the core of a star, he said, whose magnetic field is compressed when the core collapses and whose angular momentum is conserved, causing the neutron star to "spin up" at the time of the core collapse. Gold predicted that pulsars should subsequently spin down very slowly, owing to the conversion of their spin energy into emitted radiation, and this has been confirmed by observation.

The discovery of pulsars at the centers of supernova envelope remnants completed the broad outlines of the picture. The most exciting of these was the discovery in 1968 of a pulsar in the Crab Nebula with a period of only 33 milliseconds, making it the fastest, and hence probably the youngest, pulsar known. The Crab Nebula is known to have been created by a supernova that exploded in 1054. Within months, it was found that the Crab pulsar was also emitting pulses of optical light, and that it coincided with the star that Baade had identified as the remnant of the supernova that fathered the Crab Nebula. Baade had seen the pulses as continuous emission.

Were Earth to lie in the path of the beacon of a new pulsar, we would have no difficulty in seeing it. We see the Crab Nebula Twin that lies within the Large Magellanic Cloud, despite its distance of about 170,000 light years. But on the basis of simple probability, Earth is more likely not to lie in its path. How, then, can we detect it?

Despite the stupendous power of a pulsar beacon, calculations show it can be carrying off only 1 percent, or a fraction of 1 percent, of the pulsar's total spindown energy. Meanwhile, as seen in the case of the Crab Nebula, a supernova remnant nebula is apparently kept bright by some large amount of the spindown energy. How is this energy transferred? In the last few years, magnetohydrodynamic wind models of the pulsar—on the analogy of the solar wind—have been developed to explain how the greater part of the spindown energy is carried off and deposited in the nebula.

The Pulsar Wind—and Detection

The wind phenomena are the key to detection because the wind comes off in all directions. How is the wind formed? Magnetic dipole energy is its source. The rapid rotation of the strong magnetic field would produce magnetic dipole radiation if the star were in a vacuum. If one rotates a dipole—for example, a bar magnet with positive and negative poles—in a vacuum, it will give off radiation having the frequency of the rotation. That is magnetic dipole radiation, also known as radiowaves.

It seems clear, however, that the star is surrounded by plasma of sufficient density to prevent the propagation of this radiation, and the result is the conversion of that energy into electron and positron pairs. Perhaps they stream out only along the open field lines initially; but the rapid rotation of the magnetic field causes the lines to wind up, so that the electrons and positrons are sent out in all directions. This, then, is the pulsar wind.

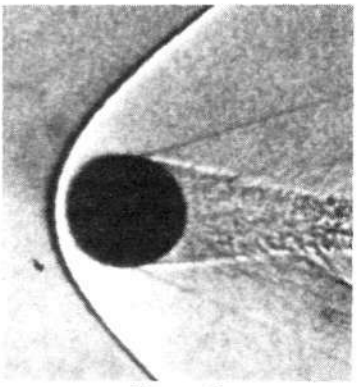


Figure 4
SHOCK WAVES AND ČERENKOV RADIATION

This bow shock wave, produced by a ball traveling through air at supersonic speed, provides a useful analogy to Čerenkov radiation, predicted by P.A. Čerenkov in 1934 and detected soon thereafter. Čerenkov radiation consisting of light at visible wavelengths is produced when a charged particle traverses a medium at greater velocity than the speed of light in that medium. *A Čerenkov detector may have a specially chosen medium in it to trigger the emission of the radiation, or may rely upon the atmosphere itself as the trigger. Air Čerenkov detectors are now in place in the southern hemisphere to detect the pulsar wind.*

The wind phenomena relevant to detection of the pulsar are two: There is, first, a shock-wave phenomenon that is predicted in the pulsar wind theory of Gaisser, Harding, and Stanev (as reflected in their paper in *Nature*, "Particle acceleration and production of energetic photons in SN1987A," Sept. 24, 1987, pp. 314-316. Its detection is predicted to become possible about 18 months after the supernova event, and to remain possible for several years.

Second, there is the lighting up of the nebula by synchrotron radiation (seen first in low energy gamma rays) that should become detectable after a few years, and continue to be visible as long as the pulsar continues to spin. This is a phenomenon well known from the Crab Nebula.

The shock-wave phenomenon requires detailed analysis. The pulsar wind is a magnetohydrodynamic plasma of electrons and positrons propagating outward at relativistic speed—some significant fraction of the speed of light. It is confined, however, by the supernova envelope, since the envelope is expanding more slowly than the wind. Where the two meet, a standing shock wave forms—a discontinuity of velocity and density. The pulsar wind piles up against the inside wall of the supernova envelope. According to theorist Harding and her co-authors, protons and electrons are accelerated within this discontinuity.

The phenomenon is apparently analogous to the trapping of a bouncing ping-pong ball between paddle and table, when the paddle is brought down on the ball gradually—the ball oscillates faster and faster. In the region of the shock, however, the particles are accelerated and then escape, thanks to irregularities in the magnetic field. With a range of velocities acquired in this manner—in the teravolt and petavolt range (10^{12} and 10^{15} electron volts, respectively)—the particles eventually penetrate the envelope. The accelerated protons are of primary interest from the standpoint of detecting the pulsar. Harding and her co-authors calculate that "if a proton beam

Continued on page 64

The Limits of Glasnost

Uncovering Soviet Disasters—Exploring the Limits of Glasnost
by James E. Oberg
New York: Random House, 1988
$19.95, 317 pp., hardbound

James Oberg is a recognized expert on the Soviet space program and has published a number of excellent books on this subject. In this new work, he extends his thorough and objective research into Soviet scientific and military policy to explore the way a broad range of disasters has been dealt with by the Soviet government.

Covering everything from an anthrax epidemic in Sverdlovsk and disappearing scientific station in the Antarctic to the famous nuclear disaster at Chernobyl, Oberg documents how the Soviets's lying propaganda about these catastrophes has unnecessarily put the lives of Americans and others at risk, and how, even when it could have saved Soviet lives, the Soviets did not tell the truth.

For those concerned with the willingness of the Soviets to abide by military and arms control treaties, this book poses some important questions.

—Marsha Freeman

A Classical Algebra Text

Elements of Algebra
by Leonhard Euler
New York: Springer-Verlag, 1987
(English translation of 1840 edition)
$28.00, 596 pp., hardbound

Leonhard Euler (1707-1783) was a prolific thinker, best compared with Carl Gauss in that regard. What is most surprising about his algebra is how modern it is.

This book does not deal with advanced mathematics; it is, as it says, a text whose subject is algebra from the elementary to the advanced. Yet, it is an exceptionally clear exposition and there is the joy, when one reads it, of realizing that it was one of the world's great mathematicians who prepared the text.

The average reader, who does not have an exceptional mathematics background but would like to brush up on the subject, would gain from reading this book.

The student of Euler's day would, of course, have been rigorously trained in geometry, and thus would have been expected to bring a geometric intuition to the subject matter. Since that is not the case today, it is unfortunate that the book does not draw out the the geometric implications of its subject matter. Notwithstanding, unlike most modern texts, it is eminently readable.

Springer-Verlag has done a real service in making this work available in English. It is long overdue that the great classics by writers like Euler, Gauss, and Kepler become available in English as they are in German and French.

—Carol White

BOOKS RECEIVED

Ampere-Neumann Electrodynamics of Metals, by Peter Graneau. Nonantum, Mass.: Hadronic Press, 1985. Paperback, 311 pp., $60 for libraries, $40 for individuals.

Space Resources—Breaking the Bonds of Earth, by John S. Lewis and Ruth A. Lewis. Columbia University Press, 1987. Hardcover, 448 pp., $30.

The Crab Nebula and Related Supernova Remnants, edited by Minas Kafatos and Richard Henry. Proceedings of a workshop held at George Mason University, October, 1984. Cambridge University Press, 1985. Hardcover, 285 pp., $47.50.

Spectroscopy of Astrophysical Plasmas, edited by A. Dalgarno and D. Layzer. Cambridge University Press, 1987. Paperback, 357 pp., $19.95.

Speakable and Unspeakable in Quantum Mechanics—Collected Papers on Quantum Philosophy, by J.S. Bell. Cambridge University Press, 1987. Hardcover, 212 pp.

The Invention of Memory—A New View of the Brain, by Israel Rosenfield. Basic Books, 1988. Hardcover, 229 pp., $18.95.

Supernova Secrets

Continued from page 62

of power $\sim 10^{40}$ erg/sec and spectral index $\gamma \leq 2.6$ were accelerated at SN1987A, an observable γ-ray signal would be produced."

While the envelope is sufficiently young and therefore still dense enough, there will be a significant collision rate between the accelerated protons and nuclei in the envelope, producing neutral pions (unstable particles of mass intermediate between that of protons and electrons) that quickly decay into two teravolt gamma rays each.

But at too early a time, the envelope is too dense to allow the gamma rays to get out to be observed. Hence, there is only a window for observation, beginning perhaps 18 months after the supernova event. (If the pulsar is very energetic, spinning faster than 100 times a second or so, we should expect to be seeing them even now.) After five or ten years, however, the envelope will have thinned out to the point that the collision rate drops, and the production of gamma rays falls below the observable threshold.

These very high energy gamma rays are to be observed—but still not directly. When they hit Earth's atmosphere, they trigger a photomultiplier of nature's own devising called an extensive air shower. The gamma ray collides with molecules of the atmosphere, setting in motion a cascade of secondary radiations and particles that spreads in chain-reaction fashion until it reaches the Earth's surface. There we are ready for it with particle detectors and Čerenkov detectors (Figure 4). Čerenkov detectors capture the flashes of Čerenkov light with mirrors that focus it onto photomultiplier tubes.

The energy and direction of the initiating gamma ray can be deduced from what the detectors pick up. Čerenkov detectors now use multiple mirrors to actually image the shower with 1-degree resolution.

Successful detections of these gamma rays not only would establish the existence of a pulsar in Supernova 1987A, but also would confirm a good deal of the pulsar wind and shock-wave model that predicts them. That would be a wonderful outcome that could tell us much about the extreme conditions that characterize supernovae and pulsars.

Should these observations not materialize, there is still the possibility of detecting the pulsar a few years from now, when the envelope has thinned out enough to let through the synchrotron radiation—the radiation given off by electrons in the pulsar wind as they spiral around magnetic field lines. This is the radiation that lights up the Crab Nebula, and this is the most certain means of confirming the presence of a pulsar in Supernova 1987A.

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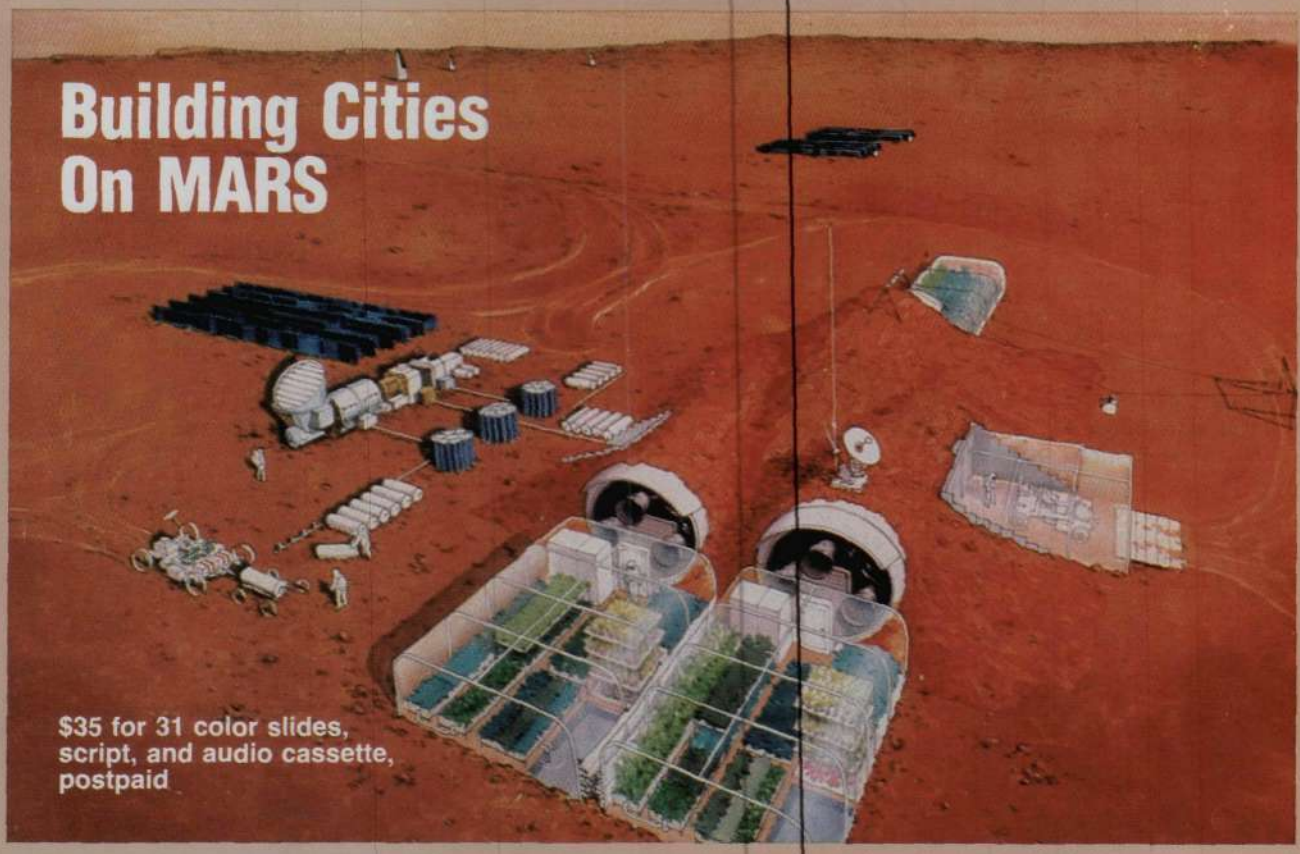

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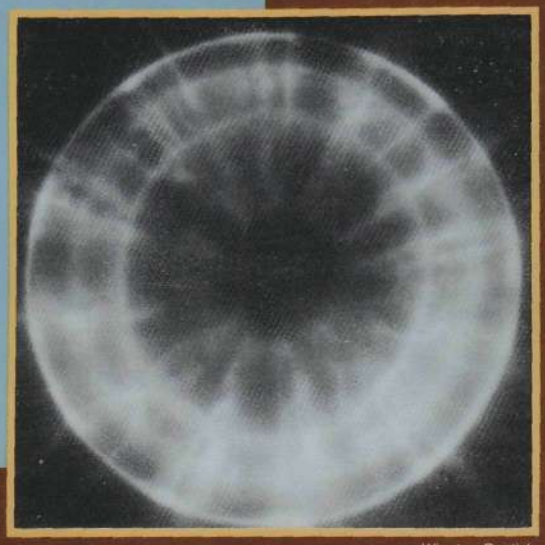
In This Issue

THE PLASMA FOCUS: A FUSION DEVICE READY FOR BREAKOUT

The most amazing thing about the plasma focus fusion device is that the scientific establishment continues to deny—or ignore—the machine's advances, because the nonlinearity involved contradicts accepted theory. As Charles B. Stevens describes in the cover story, the plasma focus is one of the most versatile fusion designs, capable in the near term of producing medical and defense spinoffs as well as energy. As with the other fusion devices, the main thing holding up progress is not science but politics—the lack of funds.

This beautiful plasma filament was photographed in an early plasma focus device at Stevens Institute of Technology. This kind of highly organized plasma structure is what traditional theory says cannot exist.



Winston Bostick

Stuart Lewis

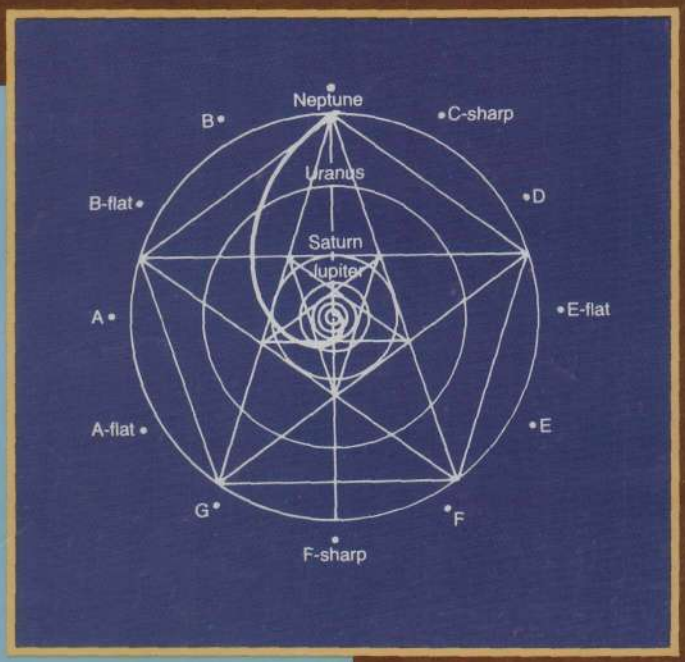
INTRODUCING: 'FUTURE SCIENTISTS'!

This issue inaugurates a new section of the magazine, "Future Scientists," that will cover—and encourage—the serious scientific experiments of younger scientists. David Cherry describes how high school sophomore Erik Robins fabricated a new high temperature superconductor that incorporates the element lanthanum. And Dr. Paul Tremblay, a scientist working at the Idaho National Engineering Laboratory, tells the delightful story of how he built a laser at age 16, back in 1961, when lasers were just being invented.

Erik Robins and his superconductor.

THE COMPOSITION OF THE UNIVERSE

Jonathan Tennenbaum takes the reader on a musical journey through the universe, from the atom to the solar system, from the human voice to the curvature of space. Along the way he presents his unique discovery that the distribution of the planets from the Sun follows the pattern of the diatonic scale. He situates this as the completion of Kepler's project to show how the universe was "composed."



Tennenbaum shows how the positions of the planetary orbits fit to the steps corresponding to the musical scale.