REVIEW

OAK RIDGE NATIONAL LABORATORY · SPRING 75

THE COVER: The traffic was thick and the lines of two-way communication were active last fall and winter when three divisions incorporated poster sessions into their information meetings. For those divisions still pondering the possibilities, there is an article on the effectiveness of this new medium on page 9.

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REVIEW

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Features

OAK RIDGE NATIONAL LABORATORY

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Editorial

National Facilities and User Funding

The concept of large national facilities for research probably originated with the astronomers of Babylon. Its most recent manifestation was in high-energy physics when it became evident that large accelerators were needed, that only a few could be built, and that they should be available to all competent scientists. Equity of access was preserved through scheduling committees, and at each accelerator the physicists soon organized themselves into self-help groups known as user organizations. Large telescopes, for example, are also national facilities, but the idea is now spreading to many other fields. There are now at least two national heavy-ion laboratories, at Berkeley and at Oak Ridge, and clearly, any new large accelerator must be a national facility. The same arguments are advanced for the various synchrotron radiation facilities, pulsed-neutron sources, research reactors, and even such modest devices as high-voltage electron microscopes.

Several forces are operative. First, in many fields, if research is to be truly pioneering, it requires large experimental devices, of which the country can afford only a small number. Second, a major research installation built by public funds should be available to all qualified scientists, not only to those who happen to work on the site. Third, it becomes clear to managers of large research devices that a transformation to national status may help assure continued funding, get broad scientific support, and generally improve the health of their enterprise. All these phenomena are natural consequences of both the need for larger machines and less growth in research support.

The funding process for large machines is by now familiar. A need is perceived, proposals are written, and, when approved, a truly useful and often beautiful device appears in due time. Funding and review procedures now ensure that cost estimates and construction times approach reality, that the need is real, and that scientific results are likely and important.

Construction costs are easily budgeted; once the money is approved and appropriated, the project is in the bag. But now another problem starts. Steady research support for many years is necessary if the new device is to fulfill the promises of the proposal writer and the hopes of the scientific community. Moreover, there is a tendency for several groups of scientists to propose similar devices, partly because success breeds imitators and partly because a real need is often simultaneously perceived by several groups. If the price tag is acceptable, if there is construction money in a particular budget category, a project may be funded without real assurance that money can be obtained in subsequent years to support a full research program.

It would seem prudent, therefore, for science administrators to assign national status to a device in an explicit and deliberate way:

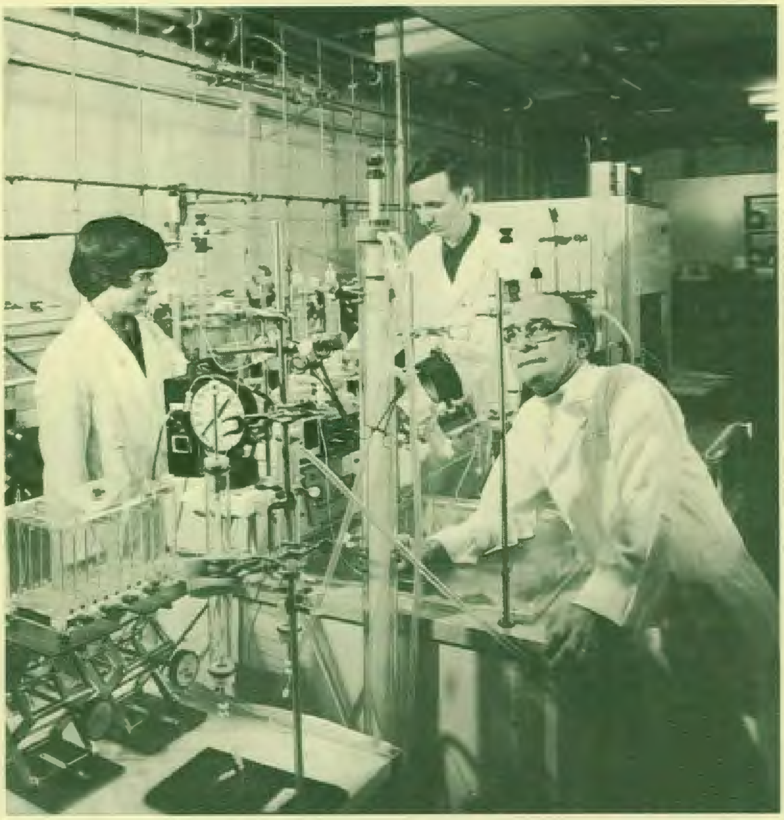
(1) before an existing or new facility is given national status, the funding agency should ascertain that a real need exists and that existing or approved devices do not, in fact, now fulfill the national requirements;

(2) when a facility becomes national, a realistic estimate should be made of the cost of operation and research with the same detail and precision and the same provision for escalation and contingencies that are now required for line-item funding;

(3) before an agency goes forward with a line-item proposal to Congress for a new facility, the OMB should formally agree, barring the most dire circumstances, that it will accept the research costs that must be borne over a specified number of years.

The scientific community will have to give up something for this kind of guarantee. To support national facilities at the forefront of science, we have been shutting down some of the older and more limited installations. This process is likely to accelerate. The scientist in many cases will have to give up the commodious life; very few will have the experimental means in their own institution. The various science funding agencies will have to establish closer ties and a real working liaison with each other, and the Congressional committees with jurisdiction in science funding will have to agree to the principles involved.

Are all of these adjustments possible? We suggest that they are essential for the health of science in the U.S. Other countries certainly act in such a concerted way: they build a few selected science facilities and support them in a manner that reflects the value of the initial investment and the scientific activity in the field. In fact, some European installations are multinational: if other countries can overcome the administrative obstacles, surely we can do the same in this country.—A. Z.



Dave Novelli shared his enthusiasm for the research he is currently engaged in last January at a Bimonthly Colloquium. This is a slightly edited transcription of that talk, brought out in the *Review* to give it wider distribution. Dave, a senior research staff member of the Biology Division, has been a member of the Laboratory staff since 1956. He has served as chairman of the American Cancer Society's Advisory Committee on Research on the Etiology of Cancer. He is shown here, r., with his two colleagues in the research he describes, Helen Sellin and Guy Griffin.

Transfer Factors of Cell-Mediated Immunity in Control of Cancer

By G. D. NOVELLI

MY TWO COLLEAGUES, Dr. Helen Sellin and Guy Griffin, and I have been performing some experiments during the past year on the isolation and purification of a substance from human peripheral white blood cells. This substance is important for its capability of transferring specific immunity to certain diseases from one individual to another. The cases I wish to discuss concern the potential application of this material in the control and treatment of certain types of cancer. Before going into the specifics of our experiments in Oak Ridge and to assure a common level of understanding, I will review briefly some background information regarding immunity.

Everybody has two genetically distinct, mutually coexistent immunological systems. The better understood of these is the humoral system, which involves circulating antibodies that protect us from bacterial infections like pneumonia or from toxins of microorganisms like diphtheria and tetanus. The other system, which is less understood, used to be called "delayed hypersensitivity" but is now known as "cell-mediated immunity" and appears to be the more important of the two. This immune system protects us against tuberculosis and viral diseases, it is involved in the graft-versus-host reaction that causes the rejection of organ transplants, and it acts in the surveillance against cancer.

Most of the research work done in cell-mediated immunity has dealt with the study of the skin-test reactivity of individuals following the intradermal injection of tuberculin. This procedure has become a standard test to determine whether an individual is immune to tuberculosis and is one of the skin tests that is routinely applied by our Health Division here at the Laboratory.

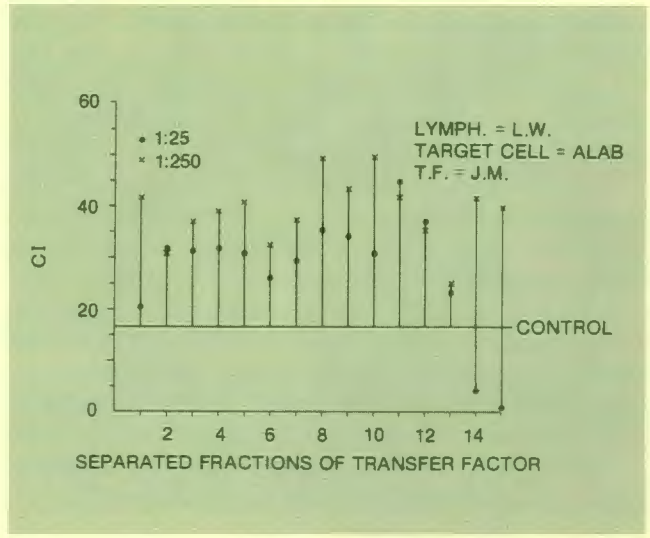
The curious thing about these skin-test sensitivities is that they are often positive under conditions in which circulating antibodies to the agent can be shown to be absent. One main reason why the advancement of our knowledge of cell-mediated immunity has lagged behind our knowledge of antibody-mediated immunity is that no method has been established for the passive transfer of cell-mediated immunity from one individual to another by means of subcellular material.

What appeared to be a significant breakthrough in this field was a report by Dr. Sherwood Lawrence of NYU in 1953-54 to the effect that delayed hypersensitivity to tuberculin could be transferred from a TB-positive to a TB-negative individual by means of a dialyzable extract prepared from the peripheral white blood cells obtained from the TB-positive individual. This material, which Lawrence named "transfer factor," is the subject of the rest of this article.

This material is obtained by breaking down white cells from a TB-positive individual and subjecting them to successive processes of incubation and dialysis. The dialyzate, which has a low molecular weight, is then freeze-dried, and the resulting material is the transfer factor. Lawrence found that 24 hr after injection of this material into a TB-negative individual, a test taken at another site would show that individual to be TB-positive. In effect, the immunity to tuberculosis was transferred from a TB-positive to a TB-negative individual with the subcellular material.

At the time of Lawrence's report in 1954, I happened to be teaching a course on TB in the infectious disease curriculum at Western Reserve University Medical School, and I thought that his observation would greatly accelerate

Cytotoxic assay of separated fractions of mammary carcinoma-specific transfer factor.



developments in cell-mediated immunity. However, in the 12 to 15 years following Lawrence's initial report, skepticism grew among the members of the immunological community about the possible significance, or even the existence, of a transfer factor. There were several reasons for these doubts. One was that Lawrence's experiments were difficult for others to duplicate; secondly, there was no way to demonstrate the transfer in any species but humans—that is, there was no animal model with which to work. This condition persists today, and I think our recent experiments throw some light on the reason for that.

The evidence for a transfer factor was largely dependent on the reading of skin tests, which are difficult to quantify. Both the positive donor and the negative recipient have to be sought in the population by means of a skin test. This means that they are each subjected to the antigen. Subsequently, the negative individual may be challenged a second time with the antigen. Because many immunologists thought that this second skin test was nothing more than a booster of a previously undetected sensitivity in the recipient, its results were largely discarded.

Lawrence's laboratory, however, continued doggedly to work on transfer factor, whereas relatively few other laboratories took up the work. My own interest in transfer factor became rekindled in 1970 quite by accident. At that time I was serving as chairman of the Personnel Committee for the American Cancer Society and was asked to interview Dr. Alan Levin of the University of California-San Francisco Medical Center, because Dr. Hugh Fudenberg, Levin's supervisor, had applied to the American Cancer Society for a faculty research award for him. During the interview, I learned that they were successfully treating patients suffering from Wiskott-Aldrich syndrome with transfer factor prepared according to the Lawrence procedure. Wiskott-Aldrich is an X-linked genetic disease that is characterized by a marked deficiency in cell-mediated immune functions by all available measurements. This disease is almost invariably lethal by puberty, the patients succumbing to repeated infections or to hemorrhagic complications.

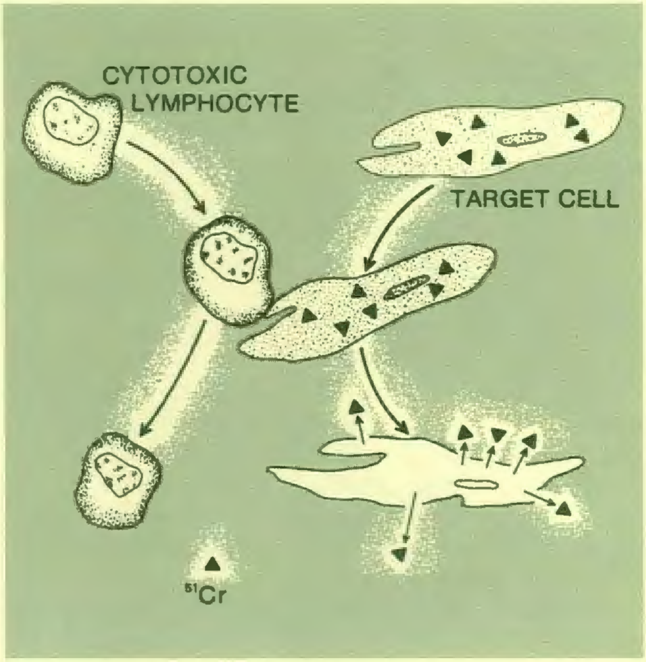
Dr. Levin and his colleagues were treating young patients with transfer factor prepared from a donor who was particularly and exquisitely sensitive to tuberculin, because they believed that this donor must have strong cell-mediated immunity. One injection of transfer factor produced an immediate response; within 24 hr each child's skin tests would begin converting to positive, the eczema would clear, and he would become free of infection for up to six months, after which he would begin to deteriorate again. A subsequent injection could bring him back to near-normality, and these children now have been repeatedly injected at intervals of four, five, or six months over the past three or four years. Prior to that time, they were missing something like 100 days of school each year; now they are essentially normal children. This is a dramatic demonstration of the reality of transfer factor, because it eliminates all the objections and doubts of Lawrence's previous experiments.

I had my own reasons for getting excited about these observations. As deduced by Lawrence and his colleagues, the transfer factor is of relatively low molecular weight—less than 10^4—and appears to be of a polypeptide-polynucleotide composition. This interested me because during the previous eight years here at ORNL we had a macromolecular separations technology program in which we developed some six or eight new, reversed-phase, column chromatographic systems that had superb resolving capabilities for tRNAs (molecules not unlike this) and for polynucleotides. Because our techniques seemed to be applicable here, I was eager to see the macromolecular separations group accept the challenge to attempt purification and characterization of transfer factor. However, one critical element was missing: there was no suitable in vitro assay by which we could follow the fractionation procedure other than the children suffering from Wiskott-Aldrich syndrome. The absence of an in vitro assay is a serious problem, not only because Wiskott-Aldrich syndrome is a rare disease, but also because one has strong ethical reservations about using diseased children for an assay procedure. During the next several years when I had a number of occasions to see Dr. Fudenberg, I pressed him to try to develop an in vitro assay for transfer factor, because I was convinced that at ORNL we had the necessary expertise to solve the purification problem.

We waited patiently while interest in transfer factor began to mount among immunologists and clinicians. In October 1973 I was again asked by the American Cancer Society to return to San Francisco to reinterview Dr. Levin, who had applied for a renewal of his previous award. On this visit I learned that they were now treating patients who had osteogenic sarcoma—bone cancer—with transfer factor. Even more important, however, was that they had developed an in vitro assay for tumor-specific transfer factor. There were several reasons for choosing bone cancer for such a study, but mainly because the disease in children and young adults has such a dismal prognosis. Amputation of the primary tumor and resection, conventional chemotherapy, and radiation therapy of metastatic lesions offer a two-year survival rate of about 20%; the survival of patients with metastases is counted in weeks. Dr. Levin reasoned that surgery could remove the greater part of the tumor mass, and transfer factor therapy therefore could be applied to any residual mass that was present. The first patient treated was a 15-year-old girl, and Dr. Levin found that two of the household contacts of this individual had specific cell-mediated immunity to the patient's tumor. He made this discovery by taking white blood cells from the household contacts and flying to Seattle where, at the University of Washington School of Medicine, Drs. Karl and Ingegaard Hellström had developed a colony-inhibition test for cell-mediated immunity to a given donor.

Subsequently, Dr. Vera Byers (Dr. Levin's wife and an excellent immunologist) developed a microcytotoxicity assay for transfer factor. We now had in our hands an assay for the chromatography. Chromatographic fractions

Schematic diagram of a cytotoxic lymphocyte attacking a chromium labeled target cell.



could be exposed to naive lymphocytes, and if the fractions were active, the lymphocytes would be converted to "killer" cells that would specifically lyse the tumor cells.

Now we were ready to go. We got our first sample of crude osteogenic sarcoma-positive transfer factor in November 1973, and after some preliminary trials with various chromatographic methods, we settled on Aminex A28 as the column and ran a gradient from 0.1 to 1.0 *M* ammonium acetate at pH 6.8. The chromatography showed a variety of things. Because we did not know what to look at, we monitored the column by ultraviolet absorption spectroscopy, under the assumption that there might be either polypeptide or polynucleotide material present. In any case, these fractions were all pooled, freeze-dried, and shipped off to San Francisco, where they were subjected to that cytotoxic assay. Dr. Levin's own lymphocytes, serving as the naive cells with a background cytotoxicity of 10, were incubated with each of these fractions for three hours. At this point, the work, not having been included in my previous request for funds, was not funded and was in danger of being cut off when, lo and behold, a great thing happened: the Laboratory decided to start the seed-money program. I was first in line.

Fortunately, the seed-money review committee looked on our proposal favorably, and in April 1974 we were funded for the next three months—a tremendous boon for the program. It allowed us first to go to California and talk to the people at the Radiobiological Laboratory at Davis, an ERDA-supported facility that had been studying osteogenic sarcoma in beagles. Together we set up a collaborative program that is still in progress, and for the next fiscal year both the Davis work and the ORNL work will be funded by ERDA.

Several things happened at the June 1974 meeting at the Radiobiological Laboratory at Davis. One of the problems we encountered, of course, was that osteogenic sarcoma is a fairly rare disease. They see perhaps ten new cases a year in the Greater San Francisco area. Now only about 20 to 25% of the household contacts are positive. Getting a positive household contact into the hospital to undergo leucophoresis to produce enough material, not only for the treatment but also for our fractionations, is a complicated procedure. We asked ourselves, If it works in this tumor, why don't we try it on another tumor that is more frequent? As a result, we decided to work with breast carcinoma.

One of the problems with transfer factor is that, if the tumor mass is large, the lymphocytes are not numerous enough to attack it adequately. In both osteogenic sarcoma and mammary carcinoma, the greater mass of the tumor can be removed surgically, leaving a small residual mass for the transfer factor and the lymphocytes to attack. Vera Byers, using her assay, started looking into the households of women who had breast carcinoma and she found, much to our surprise, that 50% of the household contacts have positive lymphocytes, and they are much more strongly positive than they are in cases of osteogenic sarcoma. We began to work on transfer factor for mammary carcinoma immediately.

Recently, I received a crude sample of transfer factor taken from J. M., the husband of a woman who has a fulminating breast carcinoma, and found that he is very strongly positive. Again we ran through our fractionation procedure, pooled these fractions, and sent them out to San Francisco, where Levin's group assayed them against a mammary carcinoma cell line. The interesting thing, of which I was completely unaware, was that the crude transfer factor does not respond in the original assay; it is inhibitory.

Only after a fractionation has been done at ORNL can the San Francisco laboratory perform the assay to obtain a cytotoxic index. By incubating naive lymphocytes with dilutions of our fractions of 1:25, we see that every single fraction contains inhibitory material, and if we dilute it further (1:250), we can see the increased expression of the positive material.

While I was at Davis in January 1975, we discussed this process—they have half of that material and I have half of it here. Recently I got a phone call from the Levins, informing me that they had completed a new assay. They had gone out to 1:5000 dilution, and the activity was continuing to increase. In other words, by diluting the inhibitor away, the response is getting stronger. They did one other thing: they took all of these fractions and repooled them to reconstitute the original nonassayable material they sent me; even at a 1:5000 dilution it is still inhibitory. This possibly explains why no one had been able to set up an in vitro assay or even an animal model for transfer factor before: all preparations made by the Lawrence procedure contain this inhibitory material.

Transfer factor has been known now for 20 years, and the total peripheral white blood cells are still being used in preparing the material. There are at least four different cell types present in the peripheral white cells, and no one today has even attempted to find out which cell type contains the transfer factor material. We know that the T-lymphocytes can be made into killer cells. We do not yet know whether transfer factor is produced by T-lymphocytes. Levin is sending me the separated cells from a positive donor, and soon we should know which cell type has the transfer factor material. If it turns out to be a lymphocyte, that involves only about 20% of the total population, and that knowledge alone allows a tremendously significant fractionation improvement—just by selecting the correct cell type. Also clear from this investigation is the fact that the Aminex process is not fractionating transfer factor. I have never seen a fractionation in which the activity is observed in every fraction with a gradient from 0.1 to 1.0 *M*. We have been fractionating the inhibitor and allowing the active material to be expressed.

Two papers will have come out in the *Journal of Clinical Investigation* by the time this article is in print, one of which reviews 18 patients with osteogenic sarcoma that have been treated for almost three years now. Also, some patients in the test have lung metastases. In the past, when a lung metastasis was diagnosed, that patient normally had 6 to 8 weeks to live. Those patients receiving treatment are still alive, two years later, with no new metastases. Moreover, they are getting impurities, and I mean really crude stuff, injected into them, and I think it is sinful.

I want to conclude with a quotation from an article published last July in the *Journal of Allergy and Clinical Immunology* by the Nobel Laureate, Sir Frank MacFarlane Burnet, in which he discusses transfer factor, calling it a theoretical discussion:

> It is self-evident that the most urgent research need at the moment is to identify the chemical nature of the active agent and the way in which specificity ... is expressed at the chemical level .... Clearly chemical study of transfer factor will eventually call for the cooperation of biochemists, skilled in the chemistry and enzymology of tRNA.

We anticipated Sir Frank by over a year. We have the expertise in tRNA. I agree with him; I think that we can go ahead and do it.

Staff quote:

"... Finally, although it is possible to exist and function in the Soviet Union without having any proficiency in the Russian language, it would be rather helpful in both the technical and non-technical aspects of the exchanges if more (yea, any?) of us spoke some Russian. The need for a highly trained technical interpreter at detailed, informal conversation hinders close-in questioning and the lack of even rudiments makes contact with officials almost traumatic. I, personally, believe I now have the incentive to attempt some acquisition of the Russian language for use in forthcoming exchanges. I was able to learn to count from one to 999, which served me well in getting hotel room keys."—**Mike Roberts,** *after a recent trip to the U.S.S.R.*

BOOKS

Information and Evolution

***Life: The Unfinished Experiment,* by S. E. Luria. Lyceum Edition, Charles Scribner's Sons, New York (1973). 167 pages, $2.95. Reviewed by David E. Fields.**

SALVADOR LURIA has written a series of eleven essays on how the mechanisms of life, together with those mechanisms of societal organization we call culture, impel and structure our development. In *Life—The Unfinished Experiment,* the well known Nobel Laureate leads one to the recognition of the power of information and change—how these forces have made man what he is today and may be tomorrow.

The influence of change was unrecognized either emotionally or intellectually two centuries ago. Technological progress was sufficiently slow that it seemed all knowledge might have been set down, to be used or forgotten and later intuited, just as all species might have been brought into being in some remarkable and brief series of actions termed Creation. In his first essay "Evolution," Luria suggests that only after man accepted the concept of history as a process of cultural evolution embodying progression and change did he become ready to consider and to question his own origins. Might not some analogous evolutionary process apply to himself as well? This question was answered by Charles Darwin in 1859.

In his discussion of environmental change, Luria identifies the driving forces of evolution clearly: If a mutated gene increases the reproductive success of an organism even to a slight degree, natural selection will tend to preserve and increase the frequency of occurrence of this altered gene. Gene value is judged by the level of performance of the resulting protein products; through the relation of protein function to cellular performance in a given environment, the suitability of an organism is determined.

Information as a force became to me, as I read Luria's book, a key factor in understanding the basis for evolution. Evolution, the embodiment of change, is a process that selects and preserves genetic information in accord with its relevance to information presented by the physical (and, for man, the cultural) environment. The basis for judging relevance is the reproductive success of the species—the manner in which the quanta of genetic information are combined, replicated, and expressed is as beautiful in its complexity and efficiency as one could imagine.

There are several levels of genetic information coding within a cell, each having its own utility in explaining cellular reproduction and evolution. The most basic informational "bit" of genetic coding is the nucleotide, of which there are in the DNA molecule four types, in contrast to the two-state bits processed in a modern digital computer. A series of three nucleotides constitutes a single "codon," each of which, in the process of protein synthesis, corresponds either to one of the twenty types of amino acids comprising the protein or to a synthesis "initiator" or "terminator." These codons are chained along the DNA molecule, parts of which have an informational uniqueness and are labeled "genes." The gene is the basic combinatorial element of genetic information; gene exchange prior to cell division is responsible for a rapid divergence of phenotypes as well as for a heightened probability that the result of a mutation will ultimately lead to an improved species. Several strands of the double-fibered helical molecules, abbreviated DNA, may clump together as a cellular "chromosome."

A helix may be characterized according to its pitch and its handedness. This latter property is quite basic, as one who has tried to mate a bolt having a "right-handed" thread with a nut having a "left-handed" thread knows. What, I wondered, is the handedness of the DNA spiral, and could the answer be related to the frequent preference of living organisms for levorotatory (left-handed) molecules over their mirror-image dextrorotatory (right-handed) form? A biologist friend, after a trip to his bookshelf, confirmed for me that DNA was right-handed, but he could not answer my second question.

Proteins are chains of 50 to 100 amino acids made in accord with the DNA template through a replication process involving "messenger" RNA. In serving as enzymes for regulating cellular processes and as regulators of chemical transport through cell walls, these proteins determine to a large extent just what a cell becomes. Thus, a bacterial cell develops quite differently in one environment than in another, just as a cell of a higher-level species becomes part of a nerve, a muscle, or a kidney in response to combined genetic and environmental information.

Just as evolutionary change began when the survival information expressed in coded molecules could be accumulated, replicated, and modified through differential reproduction, the process of cultural evolution began with the invention of a language that could be recorded, transmitted, and altered to reflect information acquired through experience. Luria notes that, due to its comparative swiftness, cultural evolution has superimposed itself on the development of man and now obscures the effects of biological evolution. I prefer to think of the culturally determined part of our evolution as an extension of the more general biological process. Differential reproduction includes differential survival, and these factors operate on a social as well as an individual basis.

The dilemma of intellectual specialization is that, in emphasizing the development of one segment of the mental mosaic that serves as his internalized world model, one must to some extent neglect other segments. In having chosen to specialize in one subfield of physics, for example, I have ceased to keep abreast of even the most relevant developments in other areas. It is satisfying to feel that in reading Luria's book, a few of the more blatant gaps in this mosaic have been partially filled. Even in his eloquent discussion of molecular biology, a discipline that owes its progress largely to linear, analytic thinking in the finest tradition, Luria manages in his essays "Man" and "Mind" to bring out its relevance to eugenics, cultural evolution, and even—with only slight strain—to ethics. I found the former discussion fascinating and the latter topics highly germane.

***Fundamentals of Mathematics**, in three volumes: Vol. I, Foundations of Mathematics, the Real Number System, and Algebra; Vol. II, Geometry; Vol. III, Analysis. Behnke, Bachmann, Fladt, and Kunle, editors. Translated by S. H. Gould, MIT Press, Cambridge (1974). Total pages 1775, each volume $15.95, all three $40. Reviewed by L. J. Gray.*

These books are neither classroom texts nor advanced technical treatises, but they form what can best be called a dictionary of modern mathematics. Each chapter (32 in all) discusses a particular area of mathematics; the fundamental definitions and concepts of the subject are introduced, and some of the basic theorems of the topic are then discussed. Volume I is concerned mainly with algebraic structures—groups, rings, fields, and lattices—and includes a chapter on the algebraic aspects of number theory. Volume II considers all aspects of geometry, and the last volume covers a large part of analysis: measure and integration; real, complex, and functional analysis; and the analytical part of number theory.

The point of view throughout is modern. Thus, Volume III contains discussions of filters, distributions, Riemann surfaces, and alternating differential forms. However, in many cases, a brief historical development of the subject is presented. The style is expository in that detailed proofs are given only when it is convenient to do so; the emphasis is on explaining the basic outlook of each subject. References to current literature are provided so that anyone wishing to pursue a particular topic will have no trouble.

In any work such as this, there are going to be omissions. Lie groups and algebras are not touched upon, and neither is point set topology. In addition, certain topics do not lend themselves to this type of presentation; for example, the chapters on complex analysis and partial differential equations barely scratch the surface of these subjects. However, the material presented is quite lucid. For people who are interested in a readable introduction to a particular subject or people interested in a broad overview of modern mathematics, these books are a good place to start.

Several divisions are currently considering the use of displays and one-to-one presentations as a way of reporting some or all of the year's work at their information meetings. Here is how it was done recently by three ORNL divisions.

R. W. Swindeman, in the M & C Mechanical Properties Laboratory, holds forth to visitors and colleagues on the behavior of stainless steel for design methods.

J. M. Robbins' hand holds a graphite femur designed as a prosthesis for a dog. The display is part of M & C's Carbon and Graphite Technology presentation.

Poster Sessions Information Meetings: The Hot Medium

By BARBARA LYON

THROUGHOUT THE RABBIT warren that comprises the geography of the Metals and Ceramics Division, down in the western end of 4500-S and in the labs behind offices within shops that make up 4508, there was, last fall, a sophisticated version of a mini-science fair.

Laid out in a sort of paper chase, with signs standing in the halls to direct the unoriented, the displays offered a mixed-media demonstration of what the multidisciplinary and multiprogrammatic division had accomplished in the year just passed. It was the second poster session information meeting to be held at ORNL, the first having been in the Thermonuclear Division a month previously, in what is seen by nearly everyone as the beginning of a new trend in scientific communication.

Whereas the poster displays at Thermonuclear were supplemental to oral presentations, the experimental format in Metals and Ceramics was the first to offer the audio-visual show in lieu of the conventional slide-illustrated talks. Only five broad, programmatic talks were given in the auditorium, which was engaged only for the morning of the first day. The remaining two half-days saw 29 presentations, many of them offered simultaneously, at the locations of as many exhibits.

The advantages that have been cited for such a novel format are many: each author can gauge the length and detail of his presentation to the interest of the audience at hand; the two-way communication that is thus engendered leads to quicker clarification; greater comfort for the speaker results from the more personal interaction. Many more advantages are obvious.

The new format was well received in the Thermonuclear Division. Traditionally, at information meeting time, the Division holds an ongoing open house in Building 9201-2 at Y-12, with plenary sessions schedules in the Central Auditorium of Building 4500-N at X-10. The papers usually begin the morning of the first day. At the recent meeting, however, the Division's Advisory Committee requested afternoon rather than morning plenary sessions; it was decided to offer poster exhibitions on the first morning. For one thing, it would serve to localize browsing for the visitors, who included, besides the Committee, colleagues from Los Alamos Scientific Laboratory, Lawrence Radiation Laboratory, Princeton's Plasma Physics Laboratory, the University of Texas, Gulf General Atomic, AEC-Washington, and a scattered few from U.S. industry and Russia.

Ray Wells, manager of the Division's Engineering Services Department, subsequently cleared a room in Building 9201-2, laid on a supply of display boards, peel-off letters, and some outsize labelmakers, and sent out a call for exhibitors.

Because the response was so overwhelming that space had to be rationed, many of the exhibits were confined to about half the space requested for them. The boards, made in the Division's carpenter shop, were of Celotex, with a central 4-by-8-ft panel, flanked by 2-ft wings. At the bottom was a shelf broad enough to hold preprints or other hard copy. Whereas some of the posters described work that was not to be covered in the meeting, the rest were considered to be supplemental to the paper sessions. Most staff members; judged the experiment to be the best information meeting the Thermonuclear Division had ever had. Essentially, the only criticism of the format was that, in manning stations at their own posters, scientists were kept from visiting their colleagues' exhibits.

Moved by the article in the June 28, 1974, issue of *Science* entitled "Poster Sessions: A New Look at Scientific Meetings," the Metals and Ceramics Division followed suit with its more elaborate displays last November. Because the exhibitions were set up at the actual laboratory site where each piece of work is performed, the M&C sessions were able to show the specific hardware used in the research described. The greatest problem was to chart the course, which included not only the first and second floors of the west end of 4500-S, but also the multifarious complexities constituting the floor plan of 4508. In the M&C meeting, the displays almost entirely supplanted the slide talks; only the five program managers were required to make presentations in plenary session, which was accordingly confined to the morning of the first day of the meeting. Also, instead of designing and making their own posters, the researchers resorted heavily to the services of the Graphic Arts Department of the Information Division. The result was greater variety, more graphically professional presentations, and for a nominal cost in money, a considerable savings in the scientists' time.

The third division to try out the new format was Analytical Chemistry, early this year. Sites at Y-12, Building 2026, and the 4500 area were involved, thus permitting a schedule of visits staggered among staffers and the Advisory Committee members, which allowed for the maximum possible communication. The procedure here differed somewhat from that of the M&C and Thermonuclear experiments, in that the laboratories were visited, with the scientists themselves explaining their work. These were not, strictly speaking, poster sessions, as prepared displays were not in evidence at all sites. Some displays were homemade whereas other had been prepared with the services of the Graphic Arts Department. These laboratory visits comprised the total detailed presentations, with discussion of the broader programs reserved for the one half-day auditorium session, similar to the M&C plenary meeting. The only criticism, voiced by the Analytical Chemistry staff, was that the transmission of information was dependent on the presence of the recipient: that is, there was no captive audience; the visitors had to take the initiative to be at the workbench in order to get the news.

The consensus is that the advantages of this direct means of scientific communication far outweigh the disadvantages. Particularly for large, multi-program divisions like Metals and Ceramics, adequate coverage of the broad areas of accomplishment seems to have been attained in a way never realized before. Like the Thermonuclear Division, M&C found themselves embarrassed by the riches of unexpected success. The sessions were often overcrowded. In addition to visitors from out of town, many members of the Laboratory staff attended, and even members of the Division staff looked in on what their colleagues had been achieving over the previous year. Each small audience, from the Advisory Committee to the coworkers in the Division, has its own requirements, background information, and limitations to be allowed for in the exposition of the research; such differences could best be addressed in the personal give-and-take of small poster sessions.

The M&C Division sought reactions to the experiment in a questionnaire sent to members of its staff following the fall meeting. Response was almost unanimously in favor, despite general acknowledgement of the logistics problem. By request from both the staff and the advisory committees, all three divisions will employ the format for their next information meetings.

Neighboring health physicist E. T. Arakawa, r., drops in on the smoke research laboratory during the Analytical Chemistry information meeting to get a briefing from Brad Quincy.

D. C. Goldberg, Westinghouse; H. A. Ullmaier, Julich; A. C. Shaffhauser, Shirley Waters, and J. L. Scott of M & C Div., (l. to r.) all look on as Dewey Easton discusses the superconductivity research at the M & C information meeting.

C. J. Long, foreground, and J. R. Miller, r., come over from the Thermonuclear Div. to cover the M & C session on superconductivity research. Behind Long is Walter Kohn, U. of Cal., San Diego, Advisory Committee member to M & C Div.

Jiri Jancarik, U. of Tex., (l.,) and Ellis Simon of Princeton Plasma Physics Lab examine some of the injection hardware at the Thermonuclear Div. meeting. Will Stirling (back to camera) stands by.

R. W. Hendricks, in the M & C Div., holds forth on small-angle x-ray scattering to M & C Advisory Committee members William C. Leslie of the U. of Mich. (l.) and Joseph A. Pask of the U. of Cal., Berkeley, (behind Hendricks). Between them is S. M. Wolf, US-AEC Div. of Physical Research.

(Foreground) F. Joanne Helton of Gulf General Atomic, and R. D. Hazeltine from the U. of Tex. confer at the Thermonuclear Div. poster session. Behind them, on the left, is James Rome, of ORNL, and on the right are U. of Tenn. student Marshall Saylors and Brendan McNamara of Lawrence Livermore Lab.

W. J. Lackey, Jr., holds forth at the M & C Division on HTGR Fuel Cycle technology, as colleague D. B. Stinton looks on.

At the Thermonuclear Division's posters, backs to camera on the left are Kang Tsang and Homer Meier; on the right, William Tang of the Princeton Plasma Physics Laboratory clarifies a point with Jim Callen.

Jim Eldridge (r.) discusses ORNL's role in the Apollo space program over a model of a moon rock during the Analytical Chemistry Information meeting. His guests are Neven Karlovac (l.) and Daniel Bartell, both from ORTEC.

Take A Number.....

BY V. R. R. UPPULURI

DIVISIBILITY BY 9, 19, 29, 39, . . .

Suppose we wish to find whether or not 19 divides 4256 evenly. Take the last digit 6, multiply it by 2, and add the product 12 to the first three digits 425 to obtain 437. Take the last digit 7 of this new number, multiply it by 2, and add the product 14 to 43 to obtain 57. Take the last digit 7, multiply it by 2, and add the product 14 to 5 to obtain 19. If we take the last digit 9, multiply it by 2, and add the product 18 to 1, we get back 19 again. If we arrive at 19 by these operations, then the original number 4256 is indeed divisible by 19. The following is an illustration of divisibility of 578113 by 19:

```
578113
     6
------
57817
   14
-----
5795
  10
----
589
18
---
76
12
--
19
```

If this process does not end in 19, the original number is not divisible by 19. Take the number 227 for example: By following the above steps, we obtain $227 \rightarrow 22 + 2 \times 7 = 36 \rightarrow 3 + 2 \times 6 = 15$. Hence, 227 is not evenly divisible by 19.

Thus, to test the divisibility of a number by 19, we use the above algorithm with the factor 2. Let us denote this by (19; 2). Similarly we have (29; 3); to test whether a number is divisible by 29 or not, we use the above algorithm with the factor 3. Consider the number 3277. After one operation we have $327 + 3 \times 7 = 348$; after the next operation we have $34 + 3 \times 8 = 58$; and finally we get $5 + 3 \times 8 = 29$. Hence, 3277 is divisible evenly by 29. If we do not end in 29, we conclude that the original number is not divisible by 29.

We always have (9; 1), since we know that, if 9 divides the sum of the digits of the number, it also divides the number itself. Similarly, we have (39; 4), (49; 5), (59; 6), etc.

MORE ON PRIMES

Finding two prime numbers p and r such that $p + r$ is a perfect square is easy; for example, if $p = 23$ and $r = 13$, then $p + r = 23 + 13 = 36 = 6^2$. Similarly, we can find two primes s and t such that $s - t$ is a perfect square; for example, if $s = 23$ and $t = 7$, then $s - t = 23 - 7 = 16 = 4^2$. One may ask whether there exist two odd primes such that their sum and difference will be (simultaneously) perfect squares. It can be proved that this is impossible. More generally, it can be proved that there exist no two odd primes p and q such that $p + q = m^k$ and $p - q = n^k$, where $k > 1$ and m, n, k are natural numbers.

In a similar vein, given a prime number p, one may ask whether $p - 2$ and $p + 2$ can be simultaneously expressed as higher powers (>1) of natural numbers. The author will appreciate some simple proofs of the impossibility of this situation. It is easy to find examples where one condition is met. Take $p = 23$, for which $p + 2 = 25 = 5^2$, but $p - 2 = 21$; or take $p = 83$, for which $p - 2 = 81 = 9^2$, but $p + 2 = 85$; neither 21 nor 85 is a higher power of any natural number.

Jim Turner, shown here, right, with coauthor Klaus Becker, is Associate Director of the Health Physics Division. His formal education was received at Emory, Harvard, and Vanderbilt, where he received his doctorate in physics. In addition, he spent a year in Göttingen, Germany, as a Fulbright scholar. He is certified by the American Board of Health Physics, is a Fellow in the American Physical Society, and a member of Phi Beta Kappa and Sigma Xi. He and Becker, who is a frequent writer for the *Review,* felt that the international activities of the ORNL Health Physics staff were impressive enough to document for the record.

Around the World with ORNL Health Physicists

Information for this article provided by J. E. Turner and Klaus Becker

THE RAPID ADVANCEMENT of nuclear technology has led to the worldwide use of a large number and variety of radiation sources in research, medicine, industry, and education. Emphasis on safety requires a correspondingly rapid development of instruments, techniques, and procedures to assure that the benefits of radiation are realized without endangering workers or the public. This development, dubbed "health physics" by Karl Morgan, had its birth about 30 years ago at the Oak Ridge National Laboratory. The desire of Morgan, first director of the Health Physics Division, and other local scientists was to share the accumulating knowledge and experience as widely as possible. In the ensuing years, the Laboratory's Health Physics Division has gained a reputation as a world leader in providing advanced training, technical know-how, and on-the-job experience in applied health physics to more than 1,000

The late Elda Anderson at a Health Physics information meeting reception, flanked by C. S. Shoup, l., and F. P. Cowan.

American students and to persons from many other countries. This article describes some of the Division's activities throughout the world.

The late Elda Anderson conducted courses in Sweden, Belgium, and India under the joint sponsorship of the World Health Organization (WHO), the U.S. Atomic Energy Commission, and ORNL. In addition to Dr. Anderson, L. C. ("Doc") Emerson and Myron Fair assisted in one or more of these courses. More recently, Walter Snyder and Karl Morgan taught summer courses in Yugoslavia. Together with John Poston, they conducted a training program in Sao Paulo, Brazil. Snyder also spent a three-month period of teaching and research in Brazil following his retirement in February 1974. John Auxier, the present Division Director, taught a course at the National University of Mexico, and in March 1975 Fair and Harry Hubbell presented a three-week course there. Rufus Ritchie participated in similar activities during 1972 at the Bhabha Atomic Research Centre near Bombay, India, and in 1969 he lectured at the Simon Frazier Summer School on Solid State Physics at Banff, Canada. He has also lectured at schools in Istanbul and Taormina, Sicily. He spent a year in research at Aarhus University in Denmark. Ritchie currently holds a Senior Visiting Fellowship at Cavendish Laboratory and an Overseas Fellowship at Churchill College, Cambridge University, England.

Many students from foreign countries have received degrees under the supervision of ORNL health physicists, and hundreds of foreign visitors have come to Oak Ridge to discuss radiation problems with local specialists in research and in applied health physics.

Several ORNL health physicists, including Morgan, Snyder, Auxier, and Klaus Becker, have served on international committees that have established the radiation-protection standards in general use today. These organizations include the International Commission on Radiological Protection (ICRP), whose recommendations form the basis for radiation-protection standards in most countries, and the International Commission on Radiation Units and Measurements (ICRU). In the field of internal exposure of humans to radioisotopes in the body, much of the work of the ICRP and many of its recommendations are based on the work of Snyder, Morgan, and their colleagues.

Because of the many specialized techniques used to detect and measure various kinds of radiation, there is a continuing need to intercompare radiation measurements performed by different laboratories. For a number of years Division personnel have conducted studies in which health physicists from laboratories throughout the world come to Oak Ridge, expose their instruments simultaneously to a certain radiation field, and compare results. The Health Physics Research Reactor is well-suited for this purpose. Fred Haywood has organized and attended similar international intercomparisons in France and, with Howard Dickson, in Yugoslavia.

Auxier, Haywood, and others have participated in several panels and task groups of the International Atomic Energy Agency (IAEA) and WHO and have helped organize a number of international meetings on radiation protection.

A long-term joint program has been maintained with the Atomic Bomb Casualty Commission (ABCC) in Hiroshima and Nagasaki. This work, which is concerned with the determination and evaluation of doses received by survivors of the atomic bombs, provides one of the most important sources for human data on radiation effects. Several Division members have worked closely with Japanese scientists. In addition to Auxier, Snyder, and Ritchie, others who have visited Japan for extended periods of time are Joe Cheka, Harry Hubbell, Troyce Jones, George Kerr, and Sam Hurst. Two Japanese statisticians recently spent a year in Oak Ridge under the auspices of the ABCC.

Don Jacobs returned in 1974 from a two-and-a-half year stay with the IAEA in Vienna. He was involved with international training programs, one leading to a study tour through radiation protection facilities in the Soviet Union. Haywood and Becker are principal investigators in research agreements between IAEA and ORNL in the field of dosimetry.

Becker has lectured extensively on modern dosimetric techniques at universities and research institutes in about twenty foreign countries. He taught courses at the request of the IAEA at the National Tsing Hua University of Taiwan and the Federal University of Rio de Janeiro and, at the request of the Organization of American States, at the National University of Mexico. He has also served as a consultant for WHO in several South American countries, helping to establish improved national radiation monitoring systems there. Visiting scientists from eleven foreign countries have worked with Becker at ORNL, most of them for one year as part of the IAEA Fellowship program. Five of his students received M.S. or Ph.D. degrees while here.

Becker has helped organize a number of international symposia, in which he has also served in various capacities. He was instrumental in planning and

Staff quote:

"My suggestion is to acknowledge at the outset that essentially no useful technical information will get transmitted from specialist to specialist in the oral presentation of invited talks. Therefore, why not use the invited talks to provide intelligible reviews for the nonspecialists? New material could get an airing in a few simultaneous sessions of short contributed papers. True, these would be hard to follow, but mainly they would show who is doing what and would be invitations for further discussions at coffee breaks."—**Charles D. Goodman,** *discussing his attendance at an international conference on nuclear structure and spectroscopy.*

conducting the Second, Third, and Fourth International Conferences on Luminescence Dosimetry in Gatlinburg (1968), Copenhagen (1971), and Poland (1974). Other international meetings co-organized by him have been held in France (1969), Germany (1970), New York (1971), Brazil (1972), and Czechoslovakia (1973). These topical conferences provide a highly efficient method for fast information exchange on an international scale.

Loucas G. Christophorou has lectured extensively in research centers and universities in many countries, including England, Germany, Holland, France, Hungary, Czechoslovakia, Israel, Canada, and his native Greece. Through these lectures and participation in many international conferences, he has enhanced the Laboratory's worldwide collaboration with scientists in the fields of radiation physics and radiation chemistry. As a member of the Greek National Research Council, Christophorou is deeply involved in an effort to restructure the Greek universities and research centers and to develop a sound science policy for Greece.

Jacob Neufeld was chairman of the Joint IAEA/WHO Consultants' Meeting on Practical Applications of Quantities, Units, and Measurement Methods in Radiation Dosimetry for Radiological Protection Purposes in Geneva in April 1971. Scientists from eight countries on both sides of the Iron Curtain attended this meeting to review and discuss health physics metrology. The proceedings were published by the IAEA.

On an invitation from WHO, Jim Turner presented a two-month series of lectures in 1967 and again in 1973 at the Directorate of Radiation Protection at the Bhabha Atomic Research Centre in Bombay. Two students from this institute subsequently came to ORNL to carry out Ph.D. research in the Health Physics Division. In 1969-70 he spent a year at CERN, the joint European high-energy physics laboratory in Geneva. His stay there was part of a continuing cooperative research project on the biological effects and possible medical applications of negative pions—subatomic particles that show high potential for cancer therapy. Harvel Wright subsequently spent a year there in exchange for Jean Dutrannois, a CERN scientist who came to ORNL for the same period. A similar exchange took place between Harry Hubbell and A. H. Sullivan of CERN in the 1960s. During 1972 Neufeld spent five months at CERN as a visiting scientist, studying the effects of high-energy radiation on mouse spermatogonia. This cooperation between ORNL and CERN exemplifies how international research efforts can complement one another.

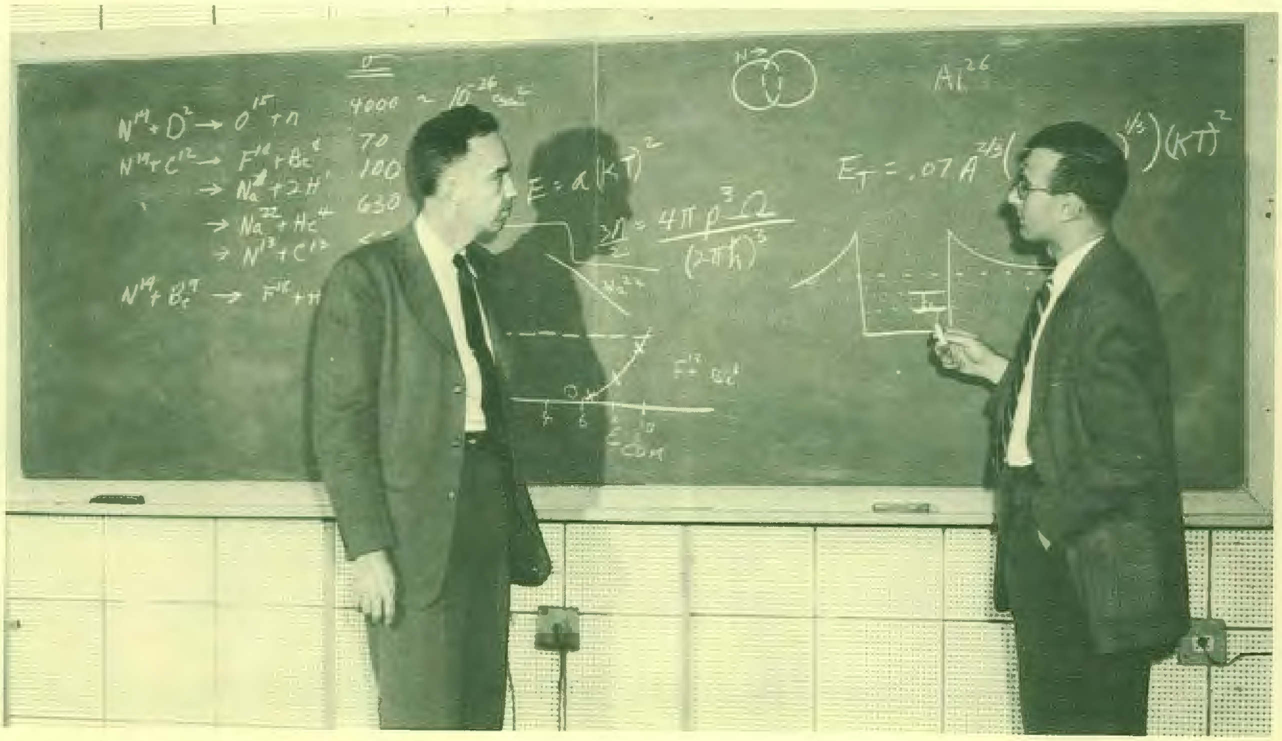
In 1972 the Office of Education and Information was formed in the Health Physics Division to coordinate activities in these areas. One of its goals is the establishment of a computerized Health Physics Information System, which is intended to streamline and formalize information collection and dissemination. The Division will undertake the preparation of up-to-date bibliographies and critical reviews in important, fast-moving areas and will help answer specific questions posed by scientists. An Information Center for Internal Emitters is already in operation under S. R. Bernard, and a Solid-State Dosimetry Information Center will soon be added. The Division staff has gathered considerable experience in compiling and condensing raw data from original publications into reviews that can be used for training, for further research and development work, and for the widespread application of new techniques.

The ORNL health physicists have helped promote radiation-protection programs in many parts of the world. They have contributed substantially to the high standards of quality in the profession, both here and abroad. In turn, they benefit from the valuable contacts within the international scientific community that enhances the excellent worldwide reputation of our laboratory.

Staff quote:

"Whether planned or through fortuitous circumstances, it is significant that the Germans have apparently gained public acceptance of non-retrievable disposal of radioactive waste into rock salt deposits by first establishing the safety and desirability of low-level disposal and then intermediate-level implacements. This experience and plan will probably allow them to progress into schemes for disposal of high-level and perhaps alpha-bearing wastes into salt formations without the extreme opposition that has accompanied some of the intentions of the USAEC in this matter."—**Tom Lomenick,** *discussing his visit to Asse II Salt Mine, West Germany, last year.*

LAB ANECDOTE/HERBERT POMERANCE



A youthful R. S. Livingston and Alex Zucker here work out some of the physics for the 63-in. cyclotron in 1953.

IF IT WON'T, IT WON'T

Will Freon spoil the ozone layer on high? Will SST aircraft spoil the upper atmosphere? These are modern questions. In 1945 the question was whether an atomic bomb would ignite the atmosphere. At that time, Professor Gregory Breit of Yale University used existing experimental data and nuclear reaction theory to assure the Manhattan Project that there would be no ignition.

About 1950 Bob Livingston's Electronuclear Division built a cyclotron that would accelerate nitrogen ions to speeds that would be found in the atmospheric reactions. The eight beta tracks at Y-12, used during the war to separate uranium isotopes, each had 36 electromagnetic coils alternating with 36 magnetic pole-face pairs for the separation units. With the uranium separation gone from Y-12, the magnets in one track were devoted to research, to ion source studies, to the Zeeman effect in atomic spectroscopy, and to the nitrogen cyclotron. The nitrogen studies gave more detail and more reassurance for the wartime problem. Of that research group, Ken Toth, Mel Halbert, Gene Newman, Alex Zucker (who studied with Breit at Yale), and Bob Livingston are still at ORNL.

Enrico Fermi thought a miracle was an event that had less than a 10% chance of coming off. In accord with these odds, his assignment of one chance in a thousand to an atmospheric ignition was a statement that it would never go. His assignment was made in an auto trip from Los Alamos to the Alamogordo Test Site along with several scientists, including Victor Weisskopf who worried about everything that might go wrong. "What is the chance," Fermi asked, "that a man with a grenade is hiding behind the rock up ahead, ready to blast this car?" And he answered, "Maybe one chance in a thousand." "What is the chance that this car will be in a collision before we get back to Los Alamos? Maybe five chances in a thousand. But we have a GI driver; better make it ten chances in a thousand." "What is the chance that the atmosphere will ignite? Let's say one chance in a thousand." Thus, he added up enough chances to make the trip a very dangerous trip indeed.

Frank Harris, a research ecologist, joined the Ecosystems Analysis Program in the Environmental Sciences Division in 1970, the year he was awarded his doctorate by The University of Tennessee. His particular research interest is in forest production, element cycling, and the effects of contaminants on ecosystem function. He is project leader for the NSF-Biome Studies in the Division. The following article is based on a paper written by Harris and colleagues Anders Andren and Gray Henderson for presentation at a symposium on "Coal and the Environment," sponsored by the National Coal Association, in Louisville, Ky. last fall. Submitted too late to be included in the proceedings, it is herewith published for the first time.

Trace Elements from Coal-Fired Plants

By FRANK HARRIS (with ANDERS ANDREN and GRAY HENDERSON)

THE MOST ABUNDANT fossil-fuel resource in the United States is coal, and the mandate is clear that coal must play an ever greater role in meeting the country's energy demands. By the end of this century, energy demand in the U.S. is predicted to triple the present use of coal. This projected increase poses potential environmental problems that must be addressed at an early stage. In the United States, 70% of the sulfur dioxide released to the atmosphere can be attributed to the burning of fossil fuels, especially for electrical energy production. This release and subsequent deposition on the landscape is already about twice the natural deposition rate and, in spite of improved emission control technology, is likely to increase. With increased use of coal, similar large increases in emissions of some trace toxic elements will occur.

Environmental assessment of the emissions resulting from coal burning requires

(1) *classification of emissions,* including sources, types, and quantities of materials released and the rates of emission;

(2) *determination of their distribution* in terrestrial and aquatic environments, including rates of transport and accumulation in these environments; and

(3) *evaluation of their effects* on the health of ecological systems and on human health resulting from their introduction into water and food used by man; both the potential for short- and long-term effects must be considered.

We will summarize here some preliminary results we have achieved from studies now under way on the deposition, transport, and fate of sulfur and trace elements in the environment. These results may help to evaluate some environmental consequences of certain phases of coal utilization. So far, our studies have focused only on the movement of sulfur and trace elements deposited on the landscape in the form of dry particulate fallout or rainout. The Laboratory research program on trace materials in the environment has two main components: characterization of their distribution and transport in the environment, and subsequent analysis of environmental effects of accelerated inputs of trace substances. Our initial focus on environmental transport and accumulation of trace materials stems from the need for basic information on movement (biogeochemical cycling) of trace substances to direct more effectively our research on particular components of the environment where significant problems might be anticipated.

Atmospheric discharge of trace elements from coal fired steam plants around the Oak Ridge area

Element	Atmospheric discharge (tons/year)
Al	186
As	1.24
Ba	1.86
Br	35.2 (gaseous)
Ca	62
Cd	0.06
Co	0.12
Cr	1.86
Cs	0.06
Fe	1240
Hg	0.62 (gaseous)
K	55.8
Mg	310
Mn	1.2
Na	24.8
Pb	1.2
Rb	0.43
Sb	1.2
Se	2.5 (90% gaseous)
Th	0.06
Ti	24.8
U	0.12
V	2.5
Zn	12.4
Total	1966.03

Emissions Characterized

The principal agents of emission transport are air and water. Coal utilization releases trace substances from coal storage, slag and fly ash, and scrubber waste disposal in addition to the more widely recognized atmospheric discharge following combustion. The release of 27 elements in coal-fired steam plants has been identified and quantified for one year, partially as a result of research performed by members of the Laboratory's Environmental Sciences, Analytical Chemistry, Metals and Ceramics, and Computer Sciences Divisions at the Tennessee Valley Authority's Allen Steam Plant in Memphis. Most trace elements remain in the immediate plant environs as slag or precipitated fly ash; their transport to other environments requires resuspension of particulate materials and leaching of materials from slag and ash disposal ponds. The subsequent fate and effect of the slag pond discharge has so far been studied in detail only for selenium. Investigation indicated that this element is not readily available for plant and aquatic organism uptake. Similar analyses for other trace substances are needed.

Atmospheric dispersal of emissions is an important consideration because of its impact on the surrounding area. In addition to determining the normal ecological transport of trace substances in the environment, we have the objective of acquiring data for the actual deposition and fate of airborne materials within a region to validate mathematical models of the physical movement of airborne emissions. Reliable mathematical modeling to describe the airborne transport of emissions is essential in light of the complexity of the distribution patterns in a region with numerous, distinctly different sources. In the absence of complete data, order-of-magnitude agreement between predicted and observed deposition is encouraging, because model building and testing is an iterative process. The importance of validation of these modeling efforts cannot be overemphasized, because only through this process can we expect to establish the credibility and consequent usefulness of the models.

Transport and Distribution

There are two main approaches that can be taken to determine the input and distribution of emissions. One is a detailed analysis of the input and fate of an emission within the immediate environs of its source. The other is a similarly detailed analysis of inputs in a region containing numerous sources, considering not only inputs but also the accompanying hydrologic output pattern such as obtains on experimental watersheds. Our studies of the Allen Steam Plant at Memphis, in cooperation with TVA, exemplify the intensive study of a plant, whereas investigations on the US-ERDA Oak Ridge Reservation illustrate the watershed approach.

Plant Site Monitoring. Intensive in-plant monitoring of the Memphis power plant provided estimates of trace-element emissions. However, intensive monitoring of soils and biota near the plant failed to detect evidence of the emissions. No trace element enrichment of surrounding soils was measurable, with the possible exception of zinc. Even after 14 years of plant operation, trace-element contents of soils were nearly always within the world average concentrations. While the intensity of measurement was subject to various constraints, whether further attempts would have yielded more precise data is questionable. The area is heavily agricultural, and the annual mixing of soils within the plow layer appears to effectively dilute the annual deposition of small, but finite, amounts of trace elements. This direct measurement at the plant site would require 1000 times as much trace element in the fly ash as in the soil—a condition rarely if ever met—to detect a fivefold increase in trace element content in the affected soil.

Very few elements showed concentrations in fly ash more than a factor of 10 greater than those measured for Memphis area soils. These considerations clearly indicate why no enrichment in soil was observed in sampling a mile or more from the plant. The only possibility of seeing enrichment would appear to be very close to the stacks.

If these calculations are accepted, it is difficult at first glance to explain the results reported by scientists who found measurable amounts of soil enrichment several miles from a steam plant on the shores of Lake Michigan. However, there were two significant differences between their study area and the Allen Steam Plant study. First, the soil concentrations of elements of interest were much lower in the Michigan area—almost two orders of magnitude for many elements. Second, the Michigan measurements were made on soil samples collected under trees, whereas almost all the Allen soils were collected in the open farmland of the Mississippi River floodplain. Apparently, trees act as efficient scavengers for suspended particulates. The amount of particulates found in one bucket placed under a tree in the Memphis area was almost 10 times as great as that found in any of the buckets located in the open. However, scanning electron microscope examination, performed by Les Hulett in Analytical Chemistry, showed only a relatively small concentration of spherical fly-ash particles in the Memphis sample, leading to some question about the extent to which the Allen plant contributed to the total particulates collected.

Watershed Analysis. With the watershed landscape approach to measuring trace-element emission input and transport, we sacrifice the ability to characterize emissions from a limited number of sources to gain the capability to view the landscape and its hydrology as an integrated unit. This means that much additional research is needed to distinguish input materials of natural origin from those introduced by man. However, a certain amount of characterization of input is necessary to either approach.

Establishing the trace-element input-output balance for an entire landscape unit requires measurement of such input parameters as wet and dry deposition, both from sedimentation and impaction; and such output parameters as transport by dust and by stream in both dissolved and particulate forms.

Measurements on Walker Branch Watershed have been confined to inputs of wetfall and total dry deposition and to outputs of dissolved and particulate material. Since the catchment is forested, dust transport out is unlikely. Research is in progress here to establish the contribution of fly ash to trace-element inputs. Estimates of emission from coal utilization near ORNL, derived from U.S. average characteristics of coal, plants, and abatement procedures, indicate that in the Oak Ridge area, the discharge to the atmosphere is 1900 tons of trace element. At present, we do not know what fraction this source contributes to the total trace-element input of the watershed, *Kingston Steam Plant, coal-fired, with the town of Kingston in the distance.*

although current research indicates that arsenic, cobalt, copper, mercury, selenium, vanadium, and zinc are more abundant in air particulate matter over Walker Branch Watershed than in the soils below. Furthermore, this enrichment is very similar to that of fly ash and can tentatively be attributed to the three coal-fired steam plants in the Oak Ridge area. However, the questions addressed by our research are not specific to a single emission source, but are concerned with determining the distribution, biogeochemical cycling, and fate of trace substances. Our premise is that a basic understanding of the biological and physical processes affecting trace-element transport and accumulation is an essential prerequisite to answering specific questions about the environmental consequences of a particular technology.

Sulfate. According to a study performed by Henderson on the Walker Branch Watershed in 1974, the annual budget of sulfate shows a total input of 67 kg/hectare (59 lb/acre) per year against the loss in streamflow of 33 kg/hectare (29 lb/acre) per year. The conclusion is that sulfur is accumulating in the landscape. Research is in progress to measure the sulfur distribution in the biotic and soil components of the watershed. The landscape effectively buffers the acidity associated with the strong sulfate anion. Much remains to be resolved about the nature of this buffer system and the potential consequences to soils of leaching a strong anion such as sulfate. Studies of the capacity of soils to renovate acid strip mine drainage indicate that soils leave only a finite capacity to buffer acidic leachate.

Another observation about sulfate movement in the environment is the response of sulfate to streamflow, especially under storm conditions when the flow carries large amounts of dissolved elements, organic matter, and sediment. Rather than showing an initial flushing or dilution of dissolved material, which are typical responses of other ions studied, sulfate concentration corresponds, in nearly a one-to-one ratio, with the increase and decrease of the streamflow. The interactions of atmospheric and soil chemistry leading to this behavior are not yet well understood.

Trace Elements. In addition to sulfur, many trace elements are accumulating on the landscape. In summarizing the input–output budgets for dissolved zinc, chromium, cadmium, nickel, copper, and lead on Walker Branch Watershed, it was observed that, over the six-month period, inputs exceed outputs by significant amounts. Zinc showed the greatest movement (an average 18% of monthly input flux) while lead had the smallest loss (only 1.7% of average monthly input was discharged). Even in this undisturbed soil, concentration increases in the mineral soil were not detected; trace-element enrichment by input particulates apparently is not enough for deposition of the small total trace-element input to be detected. This is comparable to the situation encountered at the Allen Steam Plant.

Additional studies on this watershed are designed to determine the role played by biological systems on the retention and accumulation of trace elements. Determining this biological distribution and cycling in ecosystems serves to identify sites of accumulation and pathways of trace-element transfer through the environment. These more detailed studies yield information on the dynamics of trace elements necessary to the establishment of guidelines for acceptable element release. In addition, such studies identify biological components that could accumulate toxic levels influencing man's intake of trace elements in food and water. Information of this nature cannot be generalized a priori, but must be gained by rigorous study of fundamental biogeochemical cycles and food chain dynamics.

If trace elements move passively in biogeochemical cycles, we would expect the trace-element accumulation to be proportional to the increase of organic matter as the forest grows. For the most part, organic matter does act as a simple "carrier" of trace elements, but there are exceptions; these exceptions are points in the biogeochemical cycle where trace-element accumulation is likely to occur. For example, roots comprise only 11% of living biomass, but they contain from 28% (cadmium) to 40% (lead and zinc) of the total trace-element accumulation in living tissue. A second point of accumulation is the dead litter on top of the soil surface; this component represents only 13% of the total organic matter (excluding soil humus), but contains from 34% (cadmium) to 71% (lead) of the total trace element associated with organic matter. With this information on accumulation, specific research can be implemented to determine how accelerated input of trace elements (irrespective of sources) will affect ecosystems. Possible trace element toxification of ecosystem processes over broad regions is currently a concern in Sweden, where the presence of high concentrations of trace elements may be responsible for observed decreases in decomposition rates.

The extent to which a particular trace element in coal poses the potential for environmental enrichment must be considered relative to "natural" weathering rates. In an attempt to understand the magnitude of elemental mobilization due to coal combustion, Dave Klein, Anders Andren, and Newell Bolton have generalized data from the Allen Steam Plant to other boiler types and projected elemental mobilization potential for coal atmospheric and landfill discharges to compare with natural weathering rates. For 27 elements considered, flows due to coal consumption are never less than 1.5% of natural weathering mobilization, and selenium, arsenic, vanadium, and zinc represent 100, 33, 22, and 13%, respectively. If only the atmospheric discharge is considered, arsenic, selenium, mercury, and bromine represent 17, 14, 8, and 4%, respectively, of the natural weathering flux. Given the modes of release to the environment (both point and area sources), coal utilization results in significant alterations of the mobilization and transport of many trace elements.

Conclusions

Studies of the consequences of environmental releases of trace elements from coal utilization should include quantification of major sources. For point sources these data can be obtained by calculating mass balances for element flow through the combustion cycle. The mass balance approach has been applied to TVA's Allen Steam Plant, and the results indicate that atmospheric discharge is small relative to total flow through the plant. However, potential problems may be associated with localized element releases from storage and disposal sites; these releases and their possible effects require further investigation. Atmospheric discharge, while small on a national scale, may be significant on a regional scale in the vicinity of power plants.

Moreover, the deposition, transport, and accumulation of sulfur and trace elements on the landscape can be evaluated with watershed studies focusing on element cycling. Measurements of deposition as dry particulate fallout and rain-scavenged washout allow evaluation of the integrated inputs to a landscape from numerous sources. These data are valuable for validation of atmospheric transport models that consider the contributions of different sources to landscape deposition. Measurement of element discharge in streamflow, when combined with input measurements, leads to evaluation of the role of the terrestrial landscape in accumulating elements. Most trace elements are accumulating in the landscape, but sulfur deposited as sulfate is transported through terrestrial ecosystems to aquatic bodies. This transport is enhanced by storm events. Additional research is needed to assess the long-term effects of the sulfate ion on leaching of nutrient and trace elements from terrestrial ecosystems.

Finally, investigations of trace-element distribution and cycling within ecosystems identify points of accumulation where detrimental environmental effects could occur. Evaluation of these biogeochemical cycles for lead, zinc, and cadmium has shown that these elements accumulate in organic soil horizons and small roots. Additional studies are required to establish distribution patterns for other trace elements and to evaluate the effect of accelerated accumulation on the "health" of these ecosystem components.

Awards and Appointments

In a recent competition held jointly by the East Tennessee chapters of the Society of Technical Communicators and Industrial Graphics International, seven entries from ORNL received certificates qualifying them for entry in the national competition to be held in May. Best of Show in the graphics categories was an exploded view of a toroidal fusion reactor by **John Tudor.** Other winners: Technical Reports category—"Hydrolysis," Technical Publications Department, ORNL, second place; Annual Reports category—"Biology Annual Progress Report," ORNL Biology Division, first place; Technical Journals category—"Nuclear Safety," ORNL and Technical Information Center, ERDA, first place; House Organ category—"ORNL *Review,*" **B. K. Lyon,** editor, first place; Illustration (Line Art) category—**Bill Clark,** Graphic Arts Dept, ORNL, first place; Illustration (Cutaway View) category—**J. T. White,** Graphic Arts Dept, ORNL, first place; and Promotional Graphics category—**Bill Clark,** second place.

Laboratory Director **Herman Postma** was received as an honorary member of Sigma Pi Sigma in April last year. Sigma Pi Sigma is the honor society associated with the American Institute of Physics. Later in the year he was also elected to membership in Beta Gamma Sigma, an honorary society for people who have distinguished themselves in the field of business administration.

W. D. Shultz was appointed Associate Director of the Analytical Chemistry Division.

W. R. Grimes was invited to present the H. H. King Memorial Lecture at Kansas State University in Manhattan. The annual distinction, accorded to a chemist of national reputation who is selected by the current chemistry department chairman of the University, offers an honorarium of $500 plus expenses. The subject of his talk was "Primary Energy Sources."

V. R. R. Uppuluri has been elected Ordinary Member of the International Statistical Institute, one of approximately 100 people from the U.S. to be so honored. The distinction is bestowed at irregular intervals upon professional statisticians who have made outstanding contributions to the development or application of statistical methods.

Elected fellows of the American Association for the Advancement of Science in January were **Roy E. Thoma** and **John Papaconstantinou.**

Elected Fellow of The American Physical Society in its January meeting was **James E. Turner.**

Elizabeth B. Johnson was cited by the Nuclear Technical Advisory Board of the American National Standards Institute for her outstanding contributions to the field of nuclear criticality safety and to the preparation of nuclear safety standards.

The current (fifteenth) edition of the Encyclopaedia Brittanica has chosen **P. S. Baker** to author its entry on Applications of Radioisotopes. The entry, five double-column pages in length, carries two ORNL photographs.

Mario Fontana was elected chairman of the American Nuclear Society's Technical Group for Nuclear Reactor Safety. **H. W. Hoffman** was elected to the Executive Committee of the Heat Transfer and Energy Conversion Division of the American Institute of Chemical Engineers.

Joe T. Thomas became the first to receive the American Nuclear Society's Nuclear Criticality Safety Achievement Award, comprising an engraved certificate and a cash stipend of $75, in recognition of his outstanding contributions in the field of neutron interaction analysis, and his development of calculational models for the improved safety criteria for storage and shipment of fissionable materials.

On April 5, 1975, ground was broken for the Heavy Ion Laboratory. When this facility is completed in 1979, it will be the largest electrostatic accelerator in the world. Among the officials present at the ceremonies, which were held adjacent to the Laboratory's isochronous cyclotron building, were, l. to r., Energy Research and Development Administrator Robert C. Seamans, Jr.; Dr. John M. Teem, Assistant Administrator, ERDA; Laboratory Director Herman Postma; and Associate Director for Physical Research Alex Zucker. (See editorial page 1).