6 September 1974, Volume 185, Number 4154 SCIENCE

University Isotope Separator at Oak Ridge: The UNISOR Consortium

Several universities and a national laboratory are cooperating to study nuclei far from stability.

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The UNISOR consortium is a unique cooperative venture between a group of public and private universities, a national laboratory, a state government, and the Atomic Energy Commission (AEC), formed for the primary purpose of making and studying new, extremely unstable radioactive nuclei. To do this, the universities, the state of Tennessee, and the AEC have collectively purchased the University Isotope Separator at Oak Ridge (UNISOR), a magnetic isotope separator placed on-line to the Oak Ridge Isochronous Cyclotron (ORIC). The separator is owned by the universities and installed at the AEC national laboratory at Oak Ridge, Tennessee. The venture is unique because it is the first time a group of universities, a state government, and a federal agency have collectively purchased a major piece of capital equipment for installation in an AEC national laboratory and pledged to provide continuing support for its operation over an extended period.

Most of our knowledge of nuclear structure has been gained from studies of the nuclei in the valley of beta stability—nuclei that do not normally undergo beta decay. As we move away from the valley floor, nuclei become unstable to beta decay. While many nuclei have been theoretically predicted to exist in the regions far from the valley, that alone is not sufficient reason to make the journey. There are, however, many new phenomena that can only be studied far from the valley, such as neutron emission, proton emission, double proton emission, high energy beta decay, and delayed particle emission. Then there is the theoretically interesting $N = Z$ line to be explored to higher Z. (In a plot of N, the neutron number, against Z, the proton or atomic number, the isotopes of the lighter elements fall on the line $N = Z$, while those of the heavier elements diverge upward away from the line.) There are new regions of deformed and transitional nuclei, and there is the question whether the so-called magic numbers of protons and neutrons characteristic of closed energy shells persist in nuclei far from stability and whether they are the same as those in the stable nuclei. The many areas of research (*1*, *2*) and the advantages of using heavy ions in such research (*1*) have been discussed in some detail previously.

In this article I will concentrate on the cooperative aspects of the new UNISOR project and how the venture is working in practice. This model of research offers much promise for the future, particularly in a time of restricted budgets, and a review of our rapid progress and significant accomplishments in this period may help to stimulate other such projects. Many of the more technical details of UNISOR have been reported briefly elsewhere (*1*, *3*).

UNISOR officially began in July 1971 with joint capital and operating funding from 14 institutions—University of Alabama at Birmingham, Georgia Institute of Technology, Emory University, Furman University, University of Kentucky, Louisiana State University, University of Massachusetts, University of South Carolina, University of Tennessee, Tennessee Technological University, Vanderbilt University, Virginia Polytechnic Institute and State University, Oak Ridge Associated Universities, and Oak Ridge National Laboratory—as well as the state of Tennessee and the AEC. The universities pledged to provide more than 40 percent of the total operating funds for 5 years to give the project sufficient time to prove itself. The motivation for the universities was the opportunity for their scientists to participate in a new area of nuclear research through a facility which no single university could develop in a day of restricted budgets. The combination of isotope separator and heavy-ion cyclotron is particularly convenient for use by university groups since large quantities of data can be taken in relatively short times (1 to 2 days). Most of the data reduction and analysis are done by the users at their own institutions.

In drawing up the operating budget three ingredients were considered essential if the project was to succeed in offering all the participants opportunities for research: (i) an on-site UNISOR staff to be responsible for the separator and data acquisition facilities, (ii) some travel support for faculty and students, and (iii) provision for one or two summer appointments and one academic year appointment so that university personnel can spend extended periods at Oak Ridge to fully develop

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their use of the facility. The first requirement guarantees that one has a working system. Of course, university personnel still must arrive ahead of time to select the detectors and set up the electronic system necessary for their experiments. The second point ensures that everyone in the project has support to travel to UNISOR for research. The final point is very important in maximizing the usefulness of the facility. In-depth knowledge of the facility will lead the group to propose and carry out more imaginative research. It has been particularly helpful to have Oak Ridge Associated Universities, through the guidance of W. G. Pollard, assume the responsibility of fiscal agent for the group.

The Facility

In any heavy-ion nuclear reaction involving energies of 5 to 10 million electron volts (Mev) per nucleon, numbers of radioactive isotopes are produced. As one moves far away from the stable isotopes, the half-lives for radioactive decay of nuclei rapidly decrease from minutes to seconds to fractions of a second and less. Thus, to study the products of heavy-ion nuclear reactions one needs an isolation facility and arrangements for looking at the isolated products in times down to about 0.1 second. A magnetic isotope separator is ideal for isolating all the elements of a given mass, and the high-quality x-ray detectors now available allow one to identify the different elements present in each mass chain. Coincidences with x-rays are an added tool for assigning the observed radiations to a particular isotope. In a coincidence experiment with x-rays and gamma rays, the x-rays from each chemical element in the mass chain can be resolved and used as a gate signal to select the gamma rays in each element (for example, coincidences with x-rays and gamma rays were used to help assign gamma rays to levels in Hg, Au, and Pt in the 188 and 189 mass chains studied at UNISOR). To get to very short lifetimes the target must be located near the separator ion source. Heavy ions are ideal for elements with very short half-lives because thin targets can be used, and with the large linear momentum transferred product atoms can recoil out of the target, a much faster process than diffusion out of a thick target.

Table 1. Summary of first activities studied and gamma-ray data analyzed at UNISOR.

Half-life	Parent element	Reaction used
2.9 seconds	^{116}I	^{104}Pd(^{16}O,p3n)*, ^{103}Rh(^{16}O,3n)
12 seconds	^{115m}I or ^{115}Xe	^{104}Pd(^{16}O,5n)
23 seconds	^{115}I or ^{115m}Te	^{104}Pd(^{16}O,p4n)*, ^{103}Rh(^{16}O,4n)
28 seconds	^{115m}Te or ^{115m}Sb	^{104}Pd(^{16}O,2p3n)*, ^{103}Rh(^{16}O,p3n)*
61 seconds	^{117}Xe	^{104}Pd(^{16}O,3n)
2.2 minutes	^{117}I	^{104}Pd(^{16}O,p2n)*, ^{103}Rb(^{16}O,2n)
63 seconds, 77 seconds	^{188}Tl	^{181}Ta(^{16}O,9n)
84 seconds, 2.3 minutes	^{189}Tl	^{181}Ta(^{16}O,8n)

* Different reactions of *X* neutrons (n) and *Y* proton (p) plus decays of the elements listed may also contribute to the production of the parent in column 2.

The magnetic isotope separator was ordered with funds from the universities matched by the state of Tennessee, and construction on the UNISOR wing to the ORIC building was started in July 1971. The building was completed the following January and the separator was delivered in March. The circular path of the isotopes in the separator has a 150-centimeter radius of curvature, and the isotopes are drawn off at 90°. The device has a resolution of $\Delta m/m < 1/2000$, where m is mass, and it provides well-focused beams in a mass range of ± 8 percent of the mass in the central beam (*1, 3*); for example, at mass 100 one can collect separated beams from mass 93 to 108. It was successfully tested in the off-line mode in May 1972. In the off-line mode, the separator is operated independently of the cyclotron. Isotopes (stable or radioactive) are placed directly into the separator ion source, where they are thermalized, ionized, and extracted (by high potential) into the separator magnet. An overall view of the UNISOR facility is shown in Fig. 1.

Fig. 1. UNISOR laboratory wing on the Oak Ridge Isochronous Cyclotron (ORIC) building. The target and ion source is behind the wall in the upper center, the separator control console is in the center, and the end of the separator magnet and the collection box are on the left, with the extracted beam tube leading to the tape transport unit in the foreground. There are four detector stations on the tape transport unit. In operation, this area is filled with detectors and shielding. The new Tennecomp system is installed now where the older systems are on the right in the photograph.

The UNISOR facility was dedicated formally in June 1972 during the Heavy-Ion Summer Study at Oak Ridge. At that program Alvin M. Weinberg, then director of Oak Ridge, said of UNISOR, "In these days of austerity in the physical sciences, it's a particular pleasure to be able to point to a project that goes counter to that trend. UNISOR is remarkable not only for its sheer existence but also for the extraordinary measure of cooperation between so many institutions that it represents." Next P. G. Hansen, director of the isotope separator project ISOLDE at CERN, Geneva, Switzerland, spoke highly of this "first serious effort" to make and study nuclei far from stability with heavy ions. He added that the ISOLDE researchers, who are using 660-Mev protons, and the groups using isotope separators with reactors were pleased not only to contemplate the new things to be seen with heavy ions, but also to have the added stimulation of a new research group.

Since many mass-separated beams are focused into the collection box in a typical experiment, some additional separation is necessary in order to study one mass chain without interference from the others. For this purpose the collection box has an extension that allows one mass chain at a time to be extracted, carried 3 meters away, and deposited on a plastic tape with a conducting coating. At this point, a wide variety of experiments can be performed on this chain with the aid of a fast tape transport unit with four counting stations, each with ports for a number of detectors. The extracted beam line, tape transport, and detector port system can be seen in Fig. 1. The tape transport unit was designed by the UNISOR staff, and its electronic control system was constructed in consultation with W. Talbert, J. McConnell, and the Iowa State separator group. The direct collection station where the extracted, mass-separated beam stops on the tape has five detector ports, two for particle detectors—for positrons, conversion electrons, or alpha particles—and three for photon detectors. Each modular detector port can be easily redesigned to fit specific requirements for new experiments. With all the options described above, the system has great flexibility.

The first successful on-line test separations were made on 2 and 11 September 1972. In the on-line mode the separator is connected to the cyclotron, which provided 100-Mev nitrogen ions to bombard thin ^{93}Nb foils. The foils were mounted to cover a hole in the wall of a Swedish-designed ion source of the Pingis type (*4*), which was modified as shown in Fig. 2. The radioactive atoms recoiled out of the target foil because of the large linear momentum transferred by the heavy ions and were stopped in the ion source or catcher foil. Cadmium isotopes of mass 101 to 103 were identified. Following a shutdown period for the cyclotron in the late fall, development began in earnest in the winter and spring of 1972–1973. In this period, foils such as ^{58}Ni, ^{104}Pd, and ^{103}Rh were used with beams of ^{16}O. In May a ^{181}Ta foil was tried and high levels of activity were observed. In these early tests the experiments were limited by various problems, ranging from maintaining the foils at high temperatures and high beam currents to getting sufficient beam intensity with the temporary switching magnet that was being used in the beam line. The UNISOR facility and the first experiments have been described in an earlier paper (*3*).

New Research

By the summer of 1973 we were ready to move from developmental and test runs to new on-line experiments. On the basis of our experience with the ^{104}Pd and ^{181}Ta targets and the good activity levels observed, we chose to emphasize two types of studies: (i) the mass chains with parent elements ^{115}Xe to ^{117}Xe and (ii) new thallium isotopes with light masses, beginning with the reported isotopes ^{190}Tl and ^{191}Tl and going down in mass as low as 185, which seemed possible. Very good spectra of gamma rays, x-rays, and positrons were recorded for mass chains 115 to 117 from the reactions $^{104}\text{Pd} + {}^{16}\text{O} \rightarrow X$ neutrons + Xe, abbreviated in nuclear shorthand ^{104}Pd(^{16}O,Xn)Xe, and for thallium isotopes of mass 188 to 192 from the reactions ^{181}Ta(^{16}O,-Xn)Tl. A summary of the initial or shortest-lived activities observed in each of these mass chains is given in Table 1. Note that decays with half-lives as short as 2.9 seconds have been observed. Isotopes in both these regions are particularly interesting. One of the most surprising new results of the ISOLDE group is evidence for a possible very sudden onset of large deformation (*5*) in the lighter mercury isotopes below mass 187. Mercury, with $Z = 80$, is very near the closed shell with $Z = 82$, and all previous evidence had shown that nuclei in the region of doubly magic $^{208}_{82}\text{Pb}_{126}$ ($Z = 82$ and $N = 126$) were nearly spherical. In the region of mass 115 to 117, delayed proton emission has been observed in the light xenon isotopes (*6*) and there is only limited knowledge of level properties in the light iodine and tellurium isotopes of mass 115 to 117.

The data on the mass chains with parent isotopes ^{116}Xe and ^{117}Xe (*7*) and the identification of the new isotope ^{188}Tl (*8*)—the first new isotope seen in the UNISOR work—have been reported. Both high (7+) and low (2−) nuclear spin states were observed in ^{188}Tl decaying to ^{188}Hg. The Yrast band of energy levels (where each band member is the lowest energy state for a particular spin) is observed to spin 8+ in our work. The data indicate that, while the mercury isotopes are nearly spherical in their ground states, there are low-lying energy states where the nuclei are deformed. In ^{188}Hg we see, in addition to the Yrast band, other states with nuclear spin $I \leqslant 6$ attributed to both deformed and spherical shapes. The deformed states move down with decreasing neutron number (*9*), supporting the earlier evidence (*5*) for sudden onset of deformation in ^{185}Hg. With the 200-Mev $^{16}\text{O}^{6+}$ ions now available,

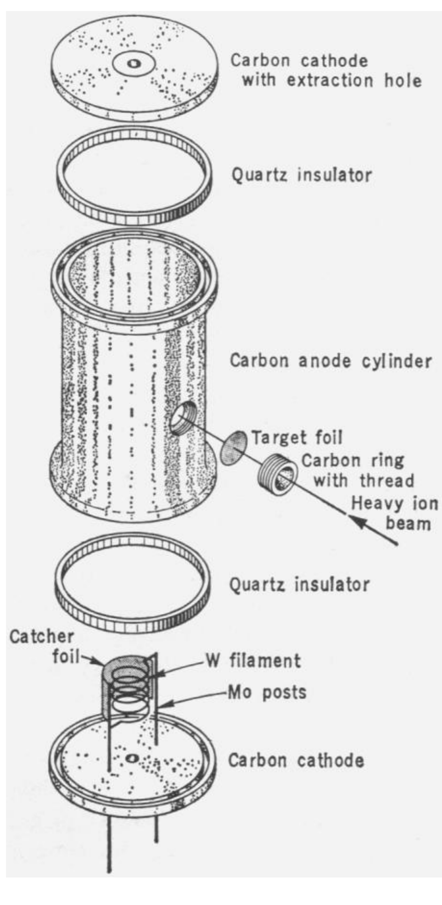

Fig. 2. Target and ion source of the Pingis type (*4*) for the UNISOR separator. The target foils can be removed a small distance from the opening in the ion source to allow cooling of the foils. The recoils from the target are caught in the ion source or catcher foil.

Table 2. Comparison of average operating characteristics in UNISOR experiments before 30 August 1973 with characteristics in three experiments on 30 August, 1 September, and 7 September 1973. For Ag and Ta targets the common isotopes are meant.

Characteristic	Before 30 August (av.)	30 August	1 September	7 September
Beam		119-Mev $^{16}O^{5+}$	84-Mev $^{12}C^{4+}$	142-Mev $^{16}O^{5+}$
Target		^{104}Pd	Ag, ^{142}Nd*	Ta
Scheduled time (hours)	24	24	15	23
Cyclotron preparation (hours)	4	6.5†	2.5	4.5‡
Change ORIC ion-source electrode (hours)	3	2	1.5	3.5
Separator down (hours)	2	0	1.2§	0
Target changes (hours)‖	4	1.5	0.3	0
Cyclotron beam transmission (%)	10–50	75–90	75	60–75

* Helium jet system developmental test run. † Includes time for transmission experiments (~ 4 hours). ‡ Includes repair of quadrupole power supply. § Filament loss under extreme test conditions. ‖ Less time for cyclotron ion source change.

one can reach the maximum cross section for producing light thallium isotopes. The new isotope ^{186}Tl has been identified with high and low spin isomers with half-lives of 25 ± 4 and ~ 60 seconds, respectively. The ^{115}Xe decay chain (*10*) and confirmation of the new ^{189}Tl isotope and the ^{189}Hg decay (*11*) have been reported. The report on ^{115}Xe was prepared by researchers from several institutions, who met in Atlanta to discuss their analyzed data and write up their combined results.

In addition to on-line work, off-line studies are now proceeding. The magnetic moment of the first excited state in ^{126}Xe has been studied at Vanderbilt (*12*). The UNISOR separator was used to implant radioactive ^{126}I atoms as a dilute impurity in an iron foil, and the foil was magnetized. The strong internal magnetic fields of the iron exert a torque on the nuclear magnetic moment while the nucleus is in the first 2+ state, populated by a preceding gamma ray. This torque rotates the nuclear spin direction, and the precession of the spin alters the directional correlation between the populating gamma ray and the depopulating $2 \rightarrow 0$ transition. Measurements of this precession can yield the magnetic moment of the 2+ state.

The atomic physics group at the University of Tennessee have built a station on the second of the three extracted beam lines and have already completed some experiments. In their work, the separator is used as a low energy accelerator.

An improved helium jet target system has been developed (*13*) which can, in principle, be used with any target since the targets need not be self-supporting (for example, the target can be a powder pressed onto a supporting backing). The recoil products from the target mounted on one wall of the chamber are caught in a high-speed helium jet, which moves the activities toward the ion source. The light helium gas disperses more than the activities and can be skimmed away by use of a conical orifice to keep it out of the ion source. Spectra of gamma rays and alpha particles have been measured on-line with this system. At present, the overall efficiency is 0.7 percent for tellurium and antimony isotopes and 0.1 percent for dysprosium. These data show that the system is now usable for certain problems. Other targets used with the helium jet system to date are Ni, Rh, Ag, Pr_2O_3, Nd_2O_3, and Th; however, virtually any element can be used as a target. With further work it should be possible to increase the efficiencies. For our ion source of the Pingis type, the Ta target works very well ($\gtrsim$ 24 hours) with no problem; Rh and Pd targets require replacement every 4 to 8 hours and Ni targets require more frequent replacement. From limited experience, Zr, Nb, and Mo targets show no problems. Other targets which have not been used but should be quite suitable are W, Re, Os, Ir, Pt, and Th. A target cooling arrangement is now being added to this ion source and is expected to extend its usefulness to other elements like Ag and Cu. One of the fascinating new areas to be explored is fission of elements like silver induced by angular momentum transfer with heavy ions. Symmetrical fission of silver has been produced by bombardment with Ne ions at ORIC (*14*), yielding neutron-rich nuclei in a previously unaccessible region around semi doubly magic $^{68}_{28}Ni_{40}$ (28 protons or neutrons close a major shell to give great stability, while the effect of shell closure at 40 is less dramatic, and this number is considered semimagic).

The overall performance of the separator system and its present operating performance show that full-scale operation is now going on. After some problems in the beam line in summer 1973, the ORIC and UNISOR staffs made a careful investigation of the beam line parameters. A number of modifications were made to the beam line, the last one just before an experiment on 30 August. In Table 2, three recent experiments are compared with the averages for the previous ones. There have been marked increases in the amount of beam current on targets and striking decreases in downtime from each of the possible sources, particularly from target and separator problems. Also, Table 2 shows that typical UNISOR experiments are for 1 day (the longest to date has been 2 days). Such short periods are highly advantageous because there is minimal interference with the other work of experimenters, such as teaching. From the many beams available from ORIC, Table 3 shows the ones that are most useful for UNISOR. Included are some beams of heavier particles, like ^{15}N and ^{18}O, which could be used to study the neutron-rich, light isotopes in the future. The Russian separator group (*15*) have identified many new isotopes with such beams, but have done little spectroscopic work.

In earlier work on mass chain 117, we demonstrated that isotopes with half-lives as short as 2 minutes can be removed from the collection box and studied off-line while isotopes from mass chain 116 are studied on-line; that is, more than one problem can be studied at one time. All the other masses being collected can be removed from the main collection box and placed in an off-line detector system in less than 1 minute without appreciably interrupting the on-line work on the one mass chain at the extracted beam station. In recent work ^{189}Tl and ^{190}Tl were both studied off-line while ^{188}Tl was studied on-line.

In September 1973 the first on-line coincidence studies were done on the mass 117 chain. For this work the Vanderbilt Nuclear Data ND-3300 dual-parameter analyzer system was taken to UNISOR, since the Tennecomp system was not ready for coincidence work then. The Vanderbilt system remains at UNISOR to provide a second system for coincidence work, so that one mass chain can be studied on-line and another off-line simultaneously. For the first coincidence experiment, two Ge(Li) detectors from UNISOR and Vanderbilt were used; the detectors had efficiencies of 18 percent and the time resolution was 7 nanoseconds. The gamma-gamma coincidence rate was about 200 events per second. More than 1 million gamma-gamma coincidence events were stored on-line for the decays of ^{117}Xe and ^{117}I, while more than 2 million were obtained for the decays of ^{117}Te and ^{117}Sb for off-line studies. The ^{16}O beam current was 1.5 to 2 microamperes, and the beam energy was degraded to 66 Mev to maximize the cross section. In addition to the gamma-gamma coincidence studies, conversion electrons were studied on-line for the first time to get intensity ratios for K and L shell electrons. Also, maximum beta energies and beta half-lives were measured with equipment brought by the group from the University of Kentucky. Thus, a full range of experiments has been done on the mass 117 decay chain to show that all aspects of the system are now being used.

The move of the Vanderbilt ND3300 system to UNISOR might suggest that on-campus research will stop. While there is certainly a shift to primarily off-campus data acquisition, on-campus facilities have been improved at several UNISOR institutions and will continue to be important in UNISOR. For example, Tennessee has a new Tennecomp multiparameter system and Vanderbilt now has the Nuclear Data ND-4420 system. The Vanderbilt system, which was purchased in 1973, has a memory of 28 kilobits and can read tapes from the ND3300, Tennecomp, and Oak Ridge computers. Thus, data acquired at UNISOR can be analyzed and longer-lived isotopes can be studied at Vanderbilt. Such on-campus facilities will continue to be important, particularly in graduate student training.

The Consortium in Practice

A brief review of the way university and AEC scientists and staff have participated in UNISOR will help to illustrate the scope and cooperative character of the project and to show how the plans for an on-site staff and rotating appointments have worked in practice. As one can imagine, in any project where so many institutions provide funds problems will arise, especially in such a new venture. Successful cooperation requires a somewhat different outlook than is involved in planning a personal research program. Nevertheless, our experience has shown that problems can be overcome and real cooperation developed. The first step is to have some governing body. For UNISOR, an executive committee oversees all the work. This committee is composed of one representative from each of the founding institutions, and each institution can appoint its representative on a yearly basis or otherwise. The initial plans for UNISOR were drawn up by technical and bylaws committees, and scientific programs and scheduling committees were added in the next 2 years. These committees have included members of the executive committee and others. In 1972, two permanent on-site UNISOR staff members were appointed. One-year appointments were given in 1972–1973 to two researchers—one from Furman University and one from Gottingen—to help develop the tape transport and the helium jet target system, respectively. These two appointments were extended a second year during which the American scientist was supported directly by Vanderbilt University but had the same responsibilities. The new executive committee chairman, E. F. Zganjar of Louisiana State University, is spending his sabbatical leave at Oak Ridge supported jointly by his university and UNISOR, and six professors have spent summers. We expect this type of sabbatical support to continue to provide on-site participation by as many people as possible.

Table 3. Particle beams, approximate energy ranges, and extracted beam intensities (in particle microamperes) most useful for UNISOR from the beams available at ORIC in September 1973.

Particle	Energy range (Mev)	Extracted beam ($e\mu a$)
$^{12}C^{4+}$	80–120	>12
$^{14}N^{4+}$	70–103	>20
$^{14}N^{5+}$	107–161	2
$^{16}O^{4+}$	60–94	> 3
$^{16}O^{5+}$	107–143	20
$^{16}O^{6+}$	140–210	~0.7
$^{20}Ne^{5+}$	75–115	> 1
$^{20}Ne^{6+}$	110–162	3
$^{11}B^{3+}$	50–74	30
$^{15}N^{4+}$	64–96	3
$^{18}O^{5+}$	83–125	20
$^{19}F^{6+}$	115–170	1

The procedure for doing research at UNISOR now begins with a proposal to the scheduling committee, who decide which experiments will be done and when. All the mass chains now being studied have been assigned to one coordinator, who is responsible for planning further experiments and moving the problem to completion and publication. As each new proposed project is approved and scheduled, a coordinator is appointed by the scheduling committee to oversee the work. All members of UNISOR are invited to contribute to any proposed experiment, and since UNISOR comprises such a large group of institutions it is vital to have a coordinator to bring together those who definitely plan to work on a particular problem and see that the work is completed. In practice, one university group may do the positron spectra, another the electron work, and still another the coincidence work. Initially, we distributed the measurements to allow all those who were interested to participate in the experiments. As more projects are instituted, the number on any one experiment will decrease considerably. In every project, the coordinator will see that the data are analyzed, and will bring the various people together to discuss all the results and finally prepare abstracts and papers.

As part of the strong Oak Ridge support, UNISOR is guaranteed an average of one shift a week on ORIC, and additional requests may be made. In the initial stages of operation, the cyclotron labatory provided gererous additional portions of time to encourage the project.

Summary

The UNISOR cooperative project, envisioned more than 3 years ago, is now successfully working. Research problems that involve a full range of experiments on nuclei far from beta stability are being investigated jointly by groups of scientists from several institutions. Some of the first work reported (*16*) included the identification, half-lives, and decay schemes of three new isotopes, ^{186}Tl, ^{188}Tl, and ^{116}I; the first or new decay schemes of ^{189}Tl, ^{190}Tl, ^{117}Xe, and ^{117}I; and the results of the perturbed gamma-gamma directional correlation work in ^{126}Xe.

UNISOR is already stimulating international interest. A report (*1*) on the new research being planned with an isotope separator on-line to ORIC was presented at a Soviet Academy of Sciences meeting on nuclear structure in 1971. At an international nuclear physics conference in Munich in August 1973, Academician G. N. Flerov, director of the heavy-ion laboratory in Dubna, said the UNISOR project had inspired his laboratory to secure funds for a new, much improved isotope separator which is now installed on-line to their heavy-ion cyclotron to be used for detailed studies of nuclei far from stability.

The UNISOR model for research has inspired a second such project, the Atomic Physics Consortium at Oak Ridge (APCOR). After an exploratory conference at Oak Ridge, scientists from ten institutions met in November 1973 to form an organizing committee for APCOR. As with UNISOR, the universities and the AEC will each provide a significant portion of the capital and operating costs. Heavy ions have opened up much new research in atomic physics, but such accelerator-based research represents a real "shift from traditional approaches concerning how, where, and on what time scale atomic physics experiments should be done" (*17*).

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18. Deep thanks are due to several people who helped significantly in bringing UNISOR into being. First are the late Governor Buford Ellington of Tennessee and S. H. Roberts, his administrative assistant. The support and encouragement of university administrators and department chairmen and of those at every level at Oak Ridge National Laboratory, Oak Ridge Associated Universities, and the Atomic Energy Commission have been important. In particular, I thank H. W. Davis, W. G. Pollard, E. E. Gross, P. H. Stelson, J. L. Fowler, A. Zucker, and Alvin Weinberg. The many efforts of the ORIC staff are gratefully acknowledged.

Behavioral Regulation of the Milieu Interne in Man and Rat

Food preferences set by delayed visceral effects facilitate memory research and predator control.

John Garcia, Walter G. Hankins, Kenneth W. Rusiniak

The Dichotomous Environment

In 1968, it was proposed that there is, in animals, a theoretical distinction between behavioral adaptation in the milieu externe and behavioral regulation of the milieu interne (*1*). It was pointed out that mammals, in particular, face two vastly different survival problems. First, in coping with the external world, an animal's survival depends upon its accurate utilization of information received by its telereceptors. For example, it uses vision, audition, and olfaction to discover predators at a distance so that it may avoid painful attacks upon its body surface. The animal uses the same telereceptors to locate food and mates at a distance, and to guide its motor responses toward these attractive goals. Thus, time and space discriminations measured in milliseconds and millimeters provide the animal with crucial vector information for avoiding naturally punishing features and for approaching naturally rewarding features of the milieu externe. Second, in coping with the internal homeostatic environment, the animal's survival depends primarily upon its accurate responses to demands from internal receptors. For example, it uses gustation to select the nutrients demanded by the monitors of the internal fluid environment and to avoid the malaise caused by ingested toxins. Because the rewarding effect of a nutrient and the punishing effect of a toxin may occur hours after ingestion, time discriminations measured in milliseconds are of little value. Similarly, because motor movements after a particular nutrient has been consumed cannot help the animal to escape toxicosis or achieve well-being, space discriminations measured in millimeters are not of much value either. On the basis of previous experience, the animal must be able to accept or reject food in the mouth before ingestion if it is to avoid distress in the milieu interne. The simplest way to accomplish this is to acquire a taste for nutrients and an aversion for toxins.

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