was the western and northern boundary of a receding shallow sea that covered much of the US. In general, the latest dinosaur bones lie several meters below the strata that show the change in flora. The northernmost deposits have the largest separations: up to 8 m in Alberta compared to a meter or two in Colorado and Wyoming. Assuming average sedimentation rates, Hickey concludes[6] that these represent times on the order of 10 to 100 thousand years. Mammals became dominant some time during that interval between the last dinosaurs and the change in flora.

The Alvarez group has analyzed rocks from one of the Montana sites and found the iridium anomaly there. The last dinosaur fossils found in this area come from layers about $3\frac{1}{2}$ meters below the iridium layer; between the last dinosaur and the iridium layer one finds fossil mammals and pollens from Tertiary species. The shift from Cretaceous to Tertiary pollens is about a meter below the Ir anomaly. This sequence suggests, Clemens said, that Tertiary mammals and plants became established some time after dinosaurs became extinct at this site; the asteroid hit Earth at a still later time.

The statistical significance of the $3\frac{1}{2}$-m distance between the last dinosaur bones and the iridium layer is disputable, Alvarez told us. He pointed out that dinosaur bones that are clearly associated with geologic strata (and not just accidentally moved there by weathering or some other process) are quite sparse, and a vertical gap of more than $3\frac{1}{2}$ m between fossils is not unexpected on purely statistical grounds. Given the continuous existence of dinosaurs for 150 million years up to that point, as well as the relative infrequency of preserved skeletons, the 30 000-year gap is insignificant, Alvarez told us.

Effects. A large cloud of dust or steam thrown into the stratosphere should have sizeable effects, cooling and darkening Earth by reflecting and absorbing incident sunlight. Depending on how great these physical effects are and on how long they last, one can expect either mild or catastrophic effects on the biosphere. The impact of a 10-km asteroid would release an energy of 10^{14} tons of TNT equivalent.

In the Alvarez group's original scenario, Earth was appreciably darkened for several years. The resulting drastic decrease in photosynthesis led to a collapse of marine and terrestrial food chains, thus leading to a massive wave of extinctions—including the dinosaurs. Small animals and plants able to survive long periods of deprivation would have survived, to become the founders of Tertiary species.

Later calculations, based on more complete data, have shortened the darkening by a factor of ten. This would have produced problems for the worldwide dispersal of the meteoritic material via the stratosphere, Alvarez told us, but computer modeling by Eric Jones at Los Alamos shows that the impact itself can send material around the world in ballistic orbits. Several months of darkening and worldwide meteoritic fallout would still have had disastrous consequences on the biosphere.

Both Hickey and William Clemens, a paleontologist at Berkeley, believe that the fossil record cannot support such a catastrophic event. It is much more likely, Hickey told us, that a gradual change in the general global climate together with a gradual withdrawal of the shallow sea covering North America produced a gradual (on the order of 10^5 years) change in flora and fauna. Near the end of this period an additional sudden change in marine and some terrestrial flora is associated with the iridium layer.

This sequence of events, although plausible, has not yet been confirmed in enough different regions, and has enough difficulties with the data in hand, that it cannot be considered as more than a potentially useful working hypothesis, Clemens told us. In other parts of the world, outside the Eastern Rocky Mountains, the late Cretaceous is not nearly as well preserved, not nearly as rich in fossils, and therefore much more difficult to interpret.

The Alvarez group is now meeting weekly with Clemens and other paleontologists to focus on the research problems and to develop programs for field investigation this summer. Ideally, Clemens said, one would like to have data from the Cretaceous–Tertiary boundary along a line running from Texas to Alberta, looking for fossils, pollens and the iridium layer at many different latitudes. Money, of course, is a problem, and it will probably be quite some time before enough data are in hand to clarify all the questions raised by the iridium anomaly. —TVF

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Theory institute thrives in its third year

Gazing out his office window recently, J. Robert Schrieffer saw a whale blowing. That's just one of the attractions at the NSF Institute for Theoretical Physics, now in its third year of operation at the University of California in Santa Barbara. The climate and scenery are delightful, and the office space looks more like an executive suite than a collection of rooms for physicists to work in. But most important, the institute is attracting good physicists who are producing noteworthy research.

When NSF announced its concept of a theory institute in 1976, after considerable maneuvering in the academic community, 15 proposals were submitted. One of the five finalists was Santa Barbara. A feature of its proposal, which probably enhanced its attractiveness, was the offer of three permanent faculty positions plus a perma-

A discussion at the Institute for Theoretical Physics in Santa Barbara involves (from left) Walter Kohn, director, J. Robert Schrieffer (Santa Barbara) and Pierre Hohenberg (Bell Labs).

nent director's position. NSF eventually awarded a five-year grant (worth $1 million/year in 1979 dollars) to Santa Barbara (PHYSICS TODAY, March 1979, page 125).

The University has made good on its promise: The institute's director, Walter Kohn, who came from the University of California, San Diego, has a permanent faculty position. Schrieffer left the University of Pennsylvania in 1980 and at present holds a one-third-time appointment at the institute (and two-thirds in the physics department). Frank Wilczek left Princeton University in 1980, and this year James Langer left Carnegie-Mellon University, each to take a full-time job at the institute. The University still has one or two more permanent positions available for institute members.

In a related development, the University of California at Santa Barbara has just established an Institute for Polymers and Organic Solids. Alan Heeger of Penn is expected to be named director of the institute. Both Schrieffer and Heeger have been key contributors to research on polymers and other organic solids.

The theory institute's stated purpose is to contribute to progress in theoretical physics, especially in areas overlapping traditional subfields. Its budget from NSF for FY 1982 was $1.32 million. In addition, a small amount for the theory institute has come from IBM ($25 000/year) and Xerox ($10 000/year). Schrieffer told me the institute hopes eventually to increase industry support for the institute to 10 or 20% of its total budget, with a given industrial contributor providing $50 000–$100 000 per year.

Typically about forty physicists are in residence at any one time. Besides the permanent members, roughly half the visitors are considered visiting senior members and half are postdoctoral members, who hold appointments ranging from one to five years. The institute helps find housing for its temporary visitors and provides a partial housing allowance to cover the additional expense connected with living in Santa Barbara. Its proximity to the Western White House also makes it difficult sometimes to obtain hotel space.

Each year Kohn and the national advisory board, with Michael Cornwall (UCLA) the current chairman and Richard Blankenbecler (SLAC) the current vice chairman, select three to five research programs for special emphasis. The programs typically last 6–15 months, with visiting scientists encouraged to spend three months or preferably longer at the institute. In 1982–83 the institute will have four programs, each with a couple of coordinators to push the program along (see box). Besides the lengthy programs, the institute holds shorter conferences and workshops, some of which tie in rather well with the programs.

Institute for Theoretical Physics: Programs and Workshops 1982–1983

Dynamics of macromolecules with Sam F. Edwards and Philip A. Pincus, coordinators, July-December 1982. The topics are reptation in polymer solutions and melts, topological constraints in viscoelasticity, kinetics of gelation, chemical reactions in polymer solutions, irreversible phenomena at polymer interfaces, applications of field-theoretic methods.

Lattice-field theory with Peter Hasenfratz and Michael Nauenberg, coordinators, August 1982–June 1983. Topics are mathematical foundations, applications to particle and condensed-matter physics, Monte Carlo techniques and problems associated with fermions.

Nuclear many-body theory with Steven Koonin and John W. Negele, coordinators, July 1982–January 1983. Topics are application of functional integral methods to collective motions, fission, scattering and the equation of state; semiclassical quantization; bosonic excitations; Monte Carlo methods; density functionals; the interface with field theory.

Many-particle aspects of solid surfaces with David Langreth, Denis Newns and Harry Suhl, coordinators, January 1983–August 1983. Topics are structure, electron correlation effects, collective excitations, theories of inelastic probes, reactions, chemisorption.

The workshops are: low-energy tests of high-energy particle physics (held in January), kinetics of phase change (held in March), space and astrophysical plasmas (28 June–2 July), functional integral methods (9–20 August), computational methods for theoretical physics (23–27 August) and dynamics of macromolecules (15–18 December).

The institute occupies the top floor of Ellison Hall, which has 9000 square feet of space. Director Kohn has taken great care with the esthetics of the working environment. The floors are thickly carpeted, the chairs are modern leather slings, the walls are adorned with abstract art and sculpture. When I visited the institute late in January, the weather was said to be typical—sunny, clear and in the 60s. Some of us had a bag lunch outdoors and then took a walk along the shore nearby, admiring a flock of herons and other local birds.

Nonequilibrium phenomena. After lunch Langer and Pierre Hohenberg (who is usually at Bell Labs but is spending the better part of a year at Santa Barbara) told me about the program on nonequilibrium phenomena the two have been coordinating. The institute gave them a budget of $135 000 from NSF and urged them to provide enough physicists and level of activity to occupy about a third of the institute's activity. Their budget permitted them to bring in 25 people for 8–10 man-years. "So it only pays a fraction of their salaries. Most people come with other money, such as sabbaticals or fellowships," Hohenberg said. Last summer Hohenberg and Langer ran a four-week workshop. In the first two weeks 75 people participated, many of them graduate students and recent postdocs; five hours/day of lectures were provided. Paul Martin (Harvard) "said we ran it like a marine boot camp."

Langer says the field of nonequilibrium phenomena is stimulating a renewed interaction between pure mathematicians and physicists. Thus the workshop had mathematicians (such as Oscar Lanford), theoretical and experimental physicists, and mathematical biologists. During the last two weeks, one-third of the participants continued as a working session, with an Aspen-style schedule—a seminar each day intended for workers in the field. This March another workshop was held—on kinetics of phase change—with the emphasis on experiments.

Among the more interesting accomplishments of the nonequilibrium phenomena program is a mathematical and numerical study on the onset of chaos in a dissipative system with two incommensurate frequencies. At last summer's workshop Leo Kadanoff (University of Chicago) described how renormalization-group techniques could be applied to a related problem involving area-preserving maps. Two of the participants—Eric Siggia (Cornell University) and David Rand (a mathematician from the University of Warwick, U. K.), who were interested in the onset of turbulence in fluids, recognized that similar techniques could be applied in this context. Both Siggia and Rand remained at Santa Barbara and collaborated with two postdocs at the institute, Stellan Ostlund and James Sethna. They found that if they fix the frequency ratio at an appropriate irrational value, the transition to chaos has universal features quite analogous to the one discovered by Mitchell Feigenbaum (Los Alamos) for period doubling (PHYSICS TODAY, March 1981, page 17). Meanwhile, Kadanoff, Feigenbaum and Scott Shenker (University of Chicago) reached similar conclusions simultaneously and independently.

The day of my visit, Albert Libchaber from Ecole Normale Superieure in Paris was also visiting, and about 30 of us gathered to hear his seminar on convection and the transition to chaotic behavior. Earlier, he and J. Maurer had observed a period-doubling sequence in Rayleigh–Benard convection leading to chaos (PHYSICS TODAY, March 1981, page 17). In the new experiments, Libchaber and Fauve used mercury and applied a longitudinal magnetic field. As they increased the field, the experimenters found that at first two modes locked, then with further increase in field the modes unlocked, and with still more field the oscillatory instability disappeared. When the modes are unlocked, a third mode is present, and noise is observed.

Guenter Ahlers (who left Bell Labs two years ago to join the Santa Barbara physics department) has started experiments with a system involving, among other phenomena, two incommensurate frequencies. He studies a fluid contained between two concentric cylinders with the inner one rotating (the Couette–Taylor system). I enjoyed watching the regularly spaced Taylor vortices slowly disappear as Ahlers varied the rotation speed of the inner cylinder.

Fractional quantum numbers. A beautiful example of the institute's interdisciplinary interactions is the work on fractional quantum numbers. Last year Roman Jackiw visited the institute and learned that his work on fractional quantum numbers in field theory was closely related to that of Schrieffer's work on solitons in polyacetylene (PHYSICS TODAY, July 1981, page 19). Meanwhile, when Jackiw's MIT colleague Jeffrey Goldstone spent some time at the theory institute, he collaborated with Wilczek on the appearance of fractional quantum numbers in various quantum field theories. Since then, Wilczek told me, he has also considered two-dimensional systems. He finds that when a particle of charge q orbits around a tube with magnetic flux ϕ, its orbital angular momentum l_z is quantized in units $l_z = \text{integer} - q\phi/2\pi$. In certain kinds of particle theories involving stringlike particles, this quantization concept means that $l_z = 1/3 + \text{integer}$.

Another application of Wilczek's idea is for superconducting vortices. For a unit vortex in a superconductor, the magnetic flux is quantized as $\phi = 2\pi/2e$, where e is the electron charge (and $2e$ the charge of the condensate). So the orbital angular momentum of an electron around a unit vortex is $1/2 + \text{integer}$, and the composite entity is a boson. Although this result is implicit in previous work, Wilczek feels it has not been appreciated before.

Another result, Wilczek told me, concerns monopoles: He speculates that if you scatter particles off monopoles, because the baryon number of a monopole is indefinite, you might be able to catalyze baryon-number violation.

Two young theorists at Santa Barbara—John Richardson and Doug Toussaint—told me about their work with Robert Pearson (who was away when I visited). They're building a hard-wired special-purpose computer for Monte Carlo simulation of the three-dimensional Ising model. The device, IMP (for Ising Model Processor), will be able to do the Monte Carlo updating algorithm on 30 million spins per second on lattices as big as $64 \times 64 \times 64$. For comparison, they told me, a CDC 7600 can calculate 3 million spins per second. They built IMP with off-the-shelf electronic parts that cost a couple of thousand dollars. IMP will be coupled to a VAX computer, which will measure the appropriate parameter (such as magnetization, energy or correlation function) while IMP continues the next updating algorithm. Pearson, Richardson and Toussaint realize that the Ising model is fairly simple, so if they want to make special-purpose devices for more complicated models they should take advantage of VLSI technology. They're looking into so-called silicon compilers, which allow one to specify the design of a circuit at a high level, leaving the details of implementation and layout to the computer.

What of the future? When NSF asked the National Science Board to approve the founding of the theory institute, NSF agreed that in its fourth year of operation it would conduct an in-depth review of the institute's operations. The review is to evaluate the institute's effectiveness in fostering research that is not only of high quality but which would not have been done if the institute had not existed. Recognizing that the experiment could not be repeated without the institute's existence, however, NSF says the criteria should be: quality and impact of work produced by the institute, the degree to which the physics has been new and has crossed subfields within physics, the degree to which excellent potential visitors are eager to participate, and the extent to which the physics community believes the institute has made a positive contribution to American theoretical physics.

Boris Kayser, who spearheaded the founding of the theory institute and heads the theory program within the NSF physics division said (dating himself and those who know what he's talking about), "The $64 question is should we continue to fund them beyond the fifth year?" A preliminary review was made last fall by four theorist reviewers, to identify any potential problems. The full-scale review will be made this fall with about ten reviewers involved in the evaluation.

One problem the theory institute had to deal with, which is not a problem for the summers-only Aspen Center for Physics (PHYSICS TODAY, October 1981, page 54) is the difficulty in getting senior physicists to spend substantial time in Santa Barbara in seasons other than summer. Another problem may be, what do you do for an encore? After the institute has had programs in a dozen or so interdisciplinary topics, will appropriate topics be exhausted, and then can these previous programs be repeated successfully in three or four years? In reply, Kohn told me that one of the most exhilirating things about theoretical physics these days is that the subjects of interest evolve and change very rapidly. He said that five years ago almost none of the topics studied at the institute could have been predicted.

Despite the initial skepticism of many leading theorists, the institute is attracting superb scientists to its programs. As one noted theorist who had been critical of the institute at first said to me recently, "Boris Kayser was right. It's a good thing. It works. There are good people there writing good papers." —GBL

Plans for Spain to rejoin CERN

Spain has applied for readmission to CERN. The Director General, Herwig Schopper, and the President of the CERN Council, Sir Alec Merrison, have been authorized to negotiate the conditions for Spain's readmission. Spain had been a member nation from 1961 to 1968, when it resigned, saying it could not afford its share of the CERN budget, which was increasing linearly to support the construction of the Super Proton Synchrotron. The CERN budget is now flat (corrected for inflation) for the next four years while LEP is being constructed. (LEP is the acronym for the Large Electron–Positron colliding-beam device.)

Once Spain becomes a full member, its share of the CERN budget, which is roughly proportional to the Gross National Product, is expected to be 7.3%. The CERN budget for 1982 is 644 million Swiss francs. Early in April Schopper and Merrison visited Spain to negotiate Spain's contributions, which might grow step-by-step from a fraction the first year to the full contribution in five years. Although Spain has several groups participating in CERN experiments, the rationale for a step-by-step growth in contributions is that Spain wants to strengthen its particle-physics activities in the universities.

The final arrangements for admitting Spain are expected to be approved by the representatives of the present 12 member nations at the CERN Council meeting in June. —GBL□