Chapter 11 Theory at Western Reserve

Tauber,	**Kisslinger,**	**Machlup,**	**Weinberg,**	**Zilsel,**	**Goswami,**	**Chew**
1954-68	1956-69	1956-00	1959-69	1960-70	1963-69	1964-67

Between 1954 and 1963, the Western Reserve department would emulate Case's rapid expansion. It added seven theorists to its ranks. Only one, however, Stefan Machlup, would remain for more than three years beyond the federation with Case in 1967.

Tauber: nuclei and gravity

Gerald Erich Tauber was hired in 1954. He was the first theorist in the WRU department. (Foldy, the first theorist at Case, had joined that department six years previously.) Tauber was born in Vienna in 1922. He escaped to England and subsequently to Canada during the war. He completed his BA at Toronto and his PhD at Minnesota in 1951. **Fig. 11-1**.

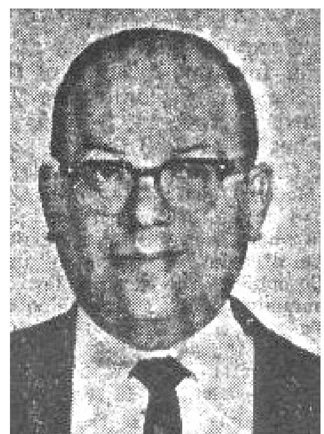

Fig. 11-1.
Newspaper photo of Eric Tauber.

Tauber did theoretical nuclear physics while at Western Reserve as represented by the following two papers. "Energy Levels of Pb^{208} " presented calculations of the energy levels in this "doubly magic" nucleus. *(This means that both the neutrons and the protons form closed shells within the nucleus.)* The second work, "Self-Consistent Treatment of the Independent-Particle Central-Field Nuclear Model", involved calculations of the nuclear energy levels in several isotopes of oxygen. *Phys. Rev*. **99** 176 1955; *Phys. Rev*. **105** 1772 1957.

A later paper, written with colleague Joseph Weinberg (whom we shall meet presently) concerned general relativity and the lower limits on the size of white dwarf stars: "Internal State of a Gravitating Gas" (*Phys. Rev.* **122** 1342 1961). This 23-page paper predicted the gravitational collapse of stars smaller than about one-third the earth's diameter. The authors may have struggled to get the paper accepted, as it was published thirty months after it was first submitted. However, the work, retitled "Gravitational Stability of Large Masses", won the 1963 $1000 prize from the Gravitational Research Foundation. The citation stated that the work was "expected to lead to a new experimental test of the theory of General Relativity". Tauber was the recipient of a two-year grant from the Army Research Office to study gravitational radiation. He took over as chair of the department when John Major left in 1964, but soon took an extended leave of absence to work as a visiting professor at the Technion in Haifa. By 1968 he had resigned his position at WRU and taken a permanent faculty position in Israel.

John Major hired three more theorists in quick succession: Leonard Kisslinger and Stefan Machlup in 1956 and Joseph Weinberg in 1959. Their principal areas were particle physics, statistical physics, and relativity respectively.

Kisslinger: nuclei and mesons

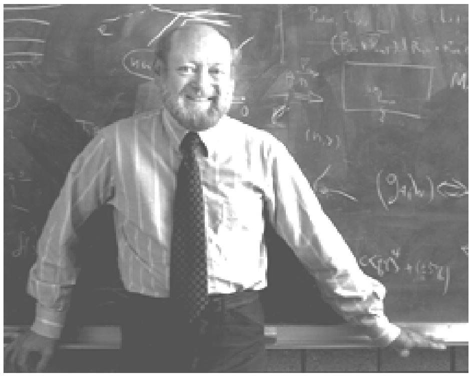

Fig. 11-2. Leonard Kisslinger.

Leonard Kisslinger was born in St. Louis in 1930. He did his BS at St. Louis University and then matriculated as a graduate student at the University of Indiana. While there he published a paper on the theory of the scattering of mesons by light nuclei. His calculated differential cross-section for elastic scattering from ^{12}C was based on an optical model potential which assumed a Gaussian distribution of nuclear material. This sort of calculation was similar to those done by the Case theorists as described in Chapter 7. Kisslinger's results compared well with experimental data from a Columbia experiment with 62 MeV pions, including agreement with the observed substantial backward scattering. "Scattering of Mesons by Light Nuclei" (*Phys. Rev.* **98** 761 1955). The potential he proposed was further explored by other authors, becoming known as the "Kisslinger potential". He completed his doctorate in 1956 and came directly to the WRU department.. His dissertation was a calculation of the spin-orbit interaction in nuclei and was published just after he arrived at WRU. "Spin-orbit Interaction in Nuclei" (*Phys. Rev*. **104** 1077 1956). **Fig. 11-2** shows Leonard in the mid-1960's.

One area of particular interest to Kisslinger and his collaborator R. A. Sorensen (at Carnegie Institute of Technology) was the study of collective motions of nucleons induced by bombarding nuclei with energetic protons, alphas or other particles. This work addressed the large amount of experimental data in the 50 MeV range which were being accumulated at accelerator laboratories. Kisslinger and Sorensen had met when they were both on sabbatical at the Nils Bohr Institute in Denmark. Their first collaborative effort was published there. *Kgl. Danske Videnskab. Selskab. Mat-Fys. Medd.* **32** No. 9, 1 1960. Subsequently a full four years of work was reported in a comprehensive 62-page paper, "Spherical Nuclei with Simple Residual Forces" *Rev. Mod. Phys.* **35** 853 1963. This paper was, at one time, one of the ten-most-cited papers in that journal. As an example of the calculations described in this paper, we show one of their figures in **Fig. 11-3**. The measured energies (open

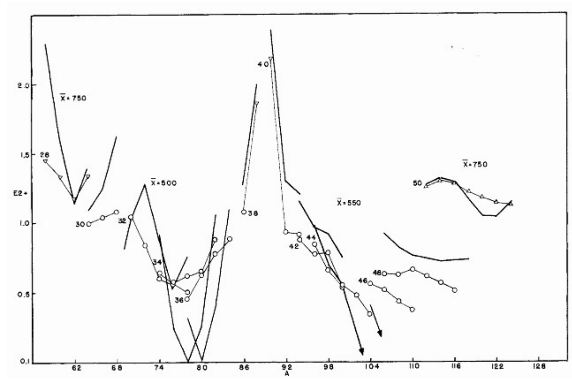

Fig. 11-3. Comparison of measured and calculated energies for nuclear excited states.

circles) and the calculated energies (dark lines) for a selected excited nuclear state are shown for nuclei with even Z from 28 to 50, for various isotopes.

Later work led to ever more detailed models for nuclear excitations over a wide range of nuclear masses. "Particle Model of Scattering from Collective States of Nuclei *Phys. Rev.* **129** 1316 1963. "Static Quadrupole Moment of Vibrational, Even Nuclei and the Coupling Scheme for Odd Nuclei" *Phys. Rev. Lett.* **19** 1239 1967.

Toward the end of the 1960's Kisslinger, along with many others in the field, was moving away from nuclei and toward "high-energy" particle physics. A representative paper from this period examined the scattering of K mesons by nuclei. Here the role of the Λ, a baryon with strangeness -1 which is formed within the nucleus, was explored. Cross sections were calculated for reactions of the type $K^- + (Z,N) \rightarrow \pi^- + (Z, N\text{-}1, \Lambda)$ for a wide range of nuclear masses. In this type of reaction, the negative strangeness of the kaon is transferred to one of the neutrons, making it into a lambda hyperon. "Tests of unitary symmetry in nuclei by meson-nucleus reactions" *Phys. Rev.* **157** 1358 1967.

Kisslinger became a leading spokesman for the study of hypernuclei (i.e. nuclei containing a strange baryon, usually a Λ or a Σ^+). With the substitution of a neutron or a proton by a hyperon, the structure of the nucleus changes drastically. This happens because the hyperon, not being constrained by the exclusion principle, resides in the lowest energy level, whereas the nucleon it replaced would usually have been in an upper level. Hypernuclei can provide an alternate path to the unraveling of nuclear structure.

In a related study, the effects of baryonic excited states were included in an analysis of proton-deuteron scattering at 1 GeV. "High Energy Backward Elastic Proton-deuteron Scattering and Baryon Resonances" *Phys. Rev.* **180** 1483 1969. This time, Kisslinger considered the role of the N(1688) baryon resonance (an excited state of the proton) as a possible intermediary in the interaction.

Kisslinger was advisor to seven Western Reserve doctoral students. Their research areas ranged from vibrational states in spherical nuclei to high energy proton-deuteron scattering. During his thirteen years on the Western Reserve faculty, Kisslinger typically spent summers at other institutions where he could interact with other nuclear theorists. Among these were Oak Ridge, Los Alamos, University of Colorado, Brookhaven Lab, and the Radiation Lab at UC Berkeley. In addition, he benefited from extended leaves at the Bohr Institute in Copenhagen, the Weizmann Institute in Israel, and at MIT. After spending two years at MIT on leave of absence from the newly federated CWRU department, he resigned in 1969 to join the physics department at Carnegie-Mellon, where he has been extremely productive in particle theory and cosmology for the past three decades.

Machlup – irreversibility and negative temperatures

Stefan Machlup joined the Western Reserve department in 1955. He was born in Vienna in 1927 and was brought as a child to America where his father, Fritz Machlup, a world renowned economist, would take a professorship at the University of Buffalo. Stefan did his baccalaureate at Swarthmore, spent a year in the navy, and one at the University of Paris before beginning his doctoral studies at Yale. His dissertation "Fluctuations and Irreversible Behavior in Thermodynamic Systems" led to two publications with his research director, Lars Onsager, the physical chemist who would subsequently win the 1968 Nobel Prize in chemistry. *Phys. Rev*. **91** 1505 and 1512 1952. This work was an elaboration of a theory of irreversible processes developed two decades earlier by Onsager. As a Yale graduate student, Machlup followed his professor to Cambridge when Onsager took a year-long sabbatical there. Subsequently, Machlup held post-doctoral positions at Bell Laboratories, at the University of Illinois Urbana, and at the University of Amsterdam, before accepting an invitation by John Major to join the WRU department. **Fig. 11-4** is a photo of Machlup from around 1980.

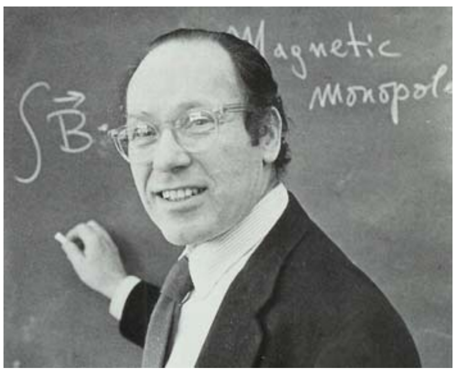

Fig. 11-4. Stefan Machlup.

The thermodynamic behavior of systems of large numbers of particles subjected to a variety of driving forces would be central to Machlup's research from the 1950's through to the 1990's. The abstract of the first 1952 paper describes the problem: "The probability of a given succession of (nonequilibrium) states of a spontaneously fluctuating thermodynamic system is calculated, on the assumption that the macroscopic variables defining a state are Gaussian random variables whose average behavior is given by the laws governing irreversible processes." The chemical-physics literature refers to the "Onsager-Machlup-Laplace approximation".

The theory applies to a very wide variety of constituents and forces: nuclei with spins aligned by magnetic fields, excited atoms in a laser, molecules undergoing chemical reactions, vortices in a liquid, ions transported through biological membranes. Machlup would explore the applicability of some of these ideas to biology: "Biological clocks share with excitable membrane (nerve, muscle) the requirement that the chemical systems that underlie them have unstable steady states and hence are capable of limit-cycle oscillations…. The oscillators responsible for biological clocks are surely not mechanical mass-and-spring systems, nor are they electrical inductance-capacitance combinations. They are chemical oscillators." "Oscillatory Chemical Reactions: the Tomita-Kitahara Model" *BioSystems* **8** 241 1977.

In a 1975 paper, Machlup discusses the common features of systems which may be described as having negative temperatures. "Negative temperatures and negative dissipation" *Amer. J. Phys*. **43** 991 1975. He writes: "If we think of absolute temperature as a measure of kinetic energy per (classical) degree of freedom, then a negative absolute temperature seems absurd. If, however, we use the (quantum-mechanical) idea of the population of energy levels and measure this population with a Boltzmann factor exp(-E/kT), then a negative T makes sense: It means higher energy levels are more populated than lower ones." The paper concludes: "This article has attempted to make more intuitive the connection between negative temperature and negative resistance, and to suggest that a large class of nonlinear systems involves negative-temperature subsystems." One such system, he suggests, might be current vortices in type II superconductors.

In a separate project, Machlup and collaborators investigated how the rules of statistical fluctuations could be applied to the frequency distribution of random noise in such structures as semi-conductor devices.

In the 1980's, Machlup would join colleague T. Hoshiko of the CWRU School of Medicine's Department of Physiology and Biophysics in a research collaboration which wedded the statistical mechanics approach to the analysis of a biological systems. One such paper reports a study of ionic transport in frog skin cells. (*Biochimica et Biophysica Acta* **942** 186 1988)

In a somewhat related area, Machlup investigated the impact of low-frequency electromagnetic fields on biological systems. Reports by researchers that various physical disorders in humans and animals appear to result from exposure to low-field electromagnetic radiations from devices ranging from kitchen appliances to cell phones to power transmission lines have encouraged extensive measurements and analysis.

Machlup and his collaborator, Carl Blackman of the Environmental Protection Agency facility at Research Triangle in North Carolina, have conducted studies in this area. They approach the problem at a very elemental level. They tracked the growth of rat liver cells as a function of the intensity, frequency and angle of application of quite low magnetic fields. The cells were arranged in a flattened mono-layer on a culture dish, and the communication between neighboring cells was measured by observing the transfer from cell to cell of a dye. Machlup had proposed a model for this process in 2000, and the results presented in 2003, specifically the dependence on the angle of the applied fields, were in agreement with his predictions

Stefan Machlup taught at CWRU for four decades. He published an introductory text, "Physics" (Wiley, 1988), which was based on his long class-room experience and which emphasized biological examples of special interest to health-science students. He was a frequent contributor to conferences of the AAPT. Complementary to Machlup's long career in teaching and research has been his lifelong passion for music. He is an accomplished cellist who has enjoyed performing with chamber groups since his college days. He assumed emeritus status in 2000 and continues his work on the biological effects of magnetic fields.

Weinberg: gravity and MRI

Joseph Woodrow Weinberg was born in New York City in 1917, completed his BS at CCNY in 1936 and his PhD with J. Robert Oppenheimer at UC Berkeley in 1943. He worked at the UC Radiation Lab until 1947, when he was appointed associate professor at the University of Minnesota. During this period, Weinberg began working with graduate student Gerald Tauber (see above), on the gravitational stability of white dwarf stars.

In 1949, the young Weinberg fell victim to Senator Joseph McCarthy and the House Un-American Activities Committee. He was accused of being the mysterious "Scientist X", who was purported to have given nuclear secrets to the Soviets while at the Radiation Lab. Though he denied being a spy, he was dismissed by the University of Minnesota Board of Regents in 1951. Weinberg was completely exonerated two years later after a long series of humiliating hearings and trials, but he was *not* reinstated at UM. Subsequently, Weinberg worked for the American Institute of Physics, then as a research engineer for an optical manufacturer, and later for the Pioneer Scientific Company before resuming his academic career by accepting a position at WRU in 1959. His appointment at Reserve was made possible through the efforts of President John S. Millis who was himself a PhD physicist. Weinberg's photo is shown in **Fig. 11-5**.

Fig. 11-5.
Joseph Weinberg.

Soon after taking up his post at WRU, Weinberg and Tauber published the paper on the gravity of collapsing stars which was described above. Of Weinberg's four doctoral students, one wrote on relativity, two on particle theory, and the fourth, Clyde Bratton, on "Nuclear Magnetic Resonance Studies of Living Muscle". This work, unusual in 1964, was done in collaboration with Amos L. Hopkins of the WRU Department of Anatomy. Samples of "living" (though excised) frog muscles were studied. Magnetic resonance techniques were used to determine the disposition of water molecules in the tissues as the muscles were electrically stimulated to contract and relax. (*Science* **147** 738 1965) Thirty years later, magnetic resonance imaging would become a major area of research in the CWRU department. In 1970, Weinberg left CWRU to join the faculty at Syracuse University.

Paul Zilsel: superfluidity theory

In 1958, John Major invited **Paul R. Zilsel** to join the WRU department as a visiting lecturer. Thirty-five year-old Zilsel had received his PhD ten years earlier, and already had a reputation as a significant contributor to the theory of superfluid helium. Zilsel was born in Vienna in 1923 and had come to the United States with his family in 1939, a refugee from Nazism. He did his undergraduate degree at the College of Charleston (South Carolina) and a master's at Wisconsin. He accompanied his professor, Gregory Breit, when Breit moved from Wisconsin to Yale. Zilsel published three papers at Yale: two on the scattering of slow neutrons by bound protons (as in water molecules), and one on proposed corrections to the potential for low energy proton-proton scattering. He completed his doctorate in 1948.

As a post-doc with Fritz London at Duke, Zilsel would change fields from particle theory to the theory of helium at low temperatures. He and London wrote an important paper on heat flow in superfluid liquid helium in which they compared experimental measurements with the predictions of the widely accepted two-fluid model. "Heat transfer in liquid helium II by internal convection" *Phys. Rev.* **74** 1148 1948. In 1950, Zilsel took a faculty position at the University of Connecticut where he continued this work, publishing several papers on the two-fluid model. Zilsel then spent two years at the Israel Institute of Technology and two at McMaster before coming to WRU. His photo is shown in **Fig. 11-6.**

Zilsel's most important contribution to the theory of superfluidity followed from work done at WRU with graduate student, Richard Whitlock. The question of how helium atoms interact at very low temperatures and how they collapse into a single quantum mechanical ground state had been studied by many of the world's leading theorists (e.g. Lee, Yang, Dyson, Bogoliubov, Bloch). Zilsel and Whitlock proposed a new approach for the hard-core plus weakly attractive interaction. It is based on a mathematical analogy with the two-valued quantum number for spin. The authors end their paper with the hopeful comment: "….the fact that the model.…is able to describe rather well at least *some* features of the λ transition in liquid helium, give(s) rise to the hope that refinement of the approach.…may lead to a feasible method of treating the liquid He^4 problem." "Pseudospin model for hard-core bosons with attractive interaction. Zero temperature" *Phys. Rev.* **131** 2409 1963. Chairman Major sought the opinion of CIT's Foldy on this paper when Zilsel was up for promotion to professor. From Foldy's letter: "I believe that this is a paper of which anyone in this field would be happy and proud to be the author."

Fig. 11-6. Paul Zilsel.

In October, 1965, Zilsel was awarded a Science Faculty Fellowship from the NSF and he was granted a 15-month leave of absence to allow him to work at Stanford and at Princeton. He extended his work on the "pseudospin model", this time using it to calculate such features as the liquid-vapor phase curve, the λ temperature, the degree of superfluidity, and the low energy excitations. "Pseudospin model of liquid He^4" *Phys. Rev. Lett.* **15** 476 1965. Returning to WRU in 1966, Zilsel found his department very much caught up in working out the federation with the Case department. He took on a new PhD student, Ranendra Roy, with whom he advanced the work on superfluidity. In a variation on the Bose condensation topic, Zilsel and post-doc Michael Schick investigated the problem of a superfluid in an annular container. In analogy to work done by Felix Bloch on persistent electrical currents in superconducting rings, they considered what will happen to the angular momentum of the superfluid when a torque is applied to the container. They predicted that the torque will produce an angular acceleration, but that there would be regularly spaced jumps in the acceleration. This occurs because the total moment of inertia of the fluid and container has a non-classical piece which steps upward as the angular velocity is increased. The extra term results from the creation of quantum vortices in the superfluid. "New manifestations of the Josephson effect in helium" *J. Low Temp. Phys.* **1** 385 1969. Zilsel's final paper at CWRU was written with Mike Schick. "Order Parameter, mean-field theory, and the ideal Bose gas" *Phys. Rev.* **188** 522 1969.

In the summer of 1968 there were serious anti-war riots in Cleveland, as in other American cities. During the following year a CWRU professor of political science, Louis Masotti, would become head of the CWRU Civil Violence Research Center. He was responsible for the preparation of a report on the disturbances for a federal commission on violence. In May of 1969, a participant in the riots, Ahmed Evans, was sentenced to death for murder. The supporters of Evans called for the immediate release of the Masotti report and disrupted a seminar which Professor Masotti was conducting on campus. Among the more vociferous protesters was Paul Zilsel. The affair escalated over the following days, including occupation of various university offices. A few weeks later a related demonstration which took place at the Cleveland Criminal Court Building culminated in the arrest of several protesters, including Zilsel. Although supported in court by five members of the CWRU physics department, he was fined, sentenced to ten days in jail, and required to seek psychiatric help. In 1971, Zilsel spent several months at the University of Washington in Seattle, working with his friend and collaborator, Mike Schick. He left the CWRU department in 1974, resettling in Seattle, where, as one of the founders of the Left Bank Books Collective, he would continue his lifelong campaign for peace and social justice.

Goswami - nuclei

In 1963, the department added a second nuclear theorist. **Amit Goswami** arrived with a fresh doctorate from Calcutta. He and Kisslinger soon collaborated on the calculation of nuclear energy levels. Their first paper looked at the effect of "isospin pairing". The quantum number, isospin, was invented to join the neutron and proton in a family of two. Because they each react similarly to the force which holds nuclei together, it is reasonable to lump them together and invent a new quantum number for them – isospin. A family of two would have T = ½, because that has two substates: T_z = +1/2 or -1/2. Therefore, any *pair* of nucleons can have a net T=0 or T=1. It turned out that the energies of nuclear excited states depend on how they pair up. "Particle correlation arising from isopin pairing in light nuclei" *Phys. Rev.* **140** B26 1965.

Goswami continued similar fundamental studies of nuclear states until his departure from the newly merged department in 1969. He took a faculty position at the University of Oregon where he has taught physics for over thirty years. His interests would eventually turn from nuclear theory to studies not found among traditional physics topics. He has become well known as a writer and lecturer on the intersection of science with the study of human consciousness.

Chew - particles

One more particle theorist would spend a rather short time in the WRU department: Chinese-born **Herman W. Chew**. He had done his doctorate in 1961 at the University of Chicago under R. H. Dalitz and spent one year each at the University of Pennsylvania, Columbia, and Princeton before his appointment as assistant professor at WRU in 1964. His doctoral work was on the effects of $\pi\pi$ scattering in the rare radiative kaon decay: $K \rightarrow \pi\pi\gamma$. “Structure of radiative decay amplitudes” *Phys. Rev*. **123** 377 1961. Chew contributed to a wide variety of problems in particle theory. His first paper at WRU was largely mathematical, “Analytic expression for a class of Green’s functions”, *Phys. Lett*. **23** 85 1966. A second work examined the electromagnetic mass difference in the Ξ strangeness-minus-two baryon doublet (another family of two), building upon published works on the neutron-proton mass difference. *(This work predated the development of quantum chromodynamics in which particle properties follow from their quark content.)* “$\Xi^- - \Xi^o$ mass difference” *Phys. Rev*. **150** 1249 1966. Chew spent the 66-67 academic year on leave at Clarkson College of Technology, and deciding to remain there, resigned from WRU in August 1967.