ing those experiments. But what is in dispute—and it is a recurring issue when it comes to awarding scientific prizes—is who should get the primary credit: the principal investigators who guided the laboratory's research or the more junior scientists who did the experiments?

Both Bishop and Varmus pointed out that other researchers in their laboratories had also contributed to the work that won the Nobel Prize. "Dominique played a major role in one piece of the story, but it was not the whole story, which developed over the course of years," Varmus says. Ramareddy Guntaka, for example, had begun the work on the probe needed to detect the cellular *src* gene before the project was assigned to Stehelin. And Deborah Spector, now at the University of California in San Diego, performed the experiments showing that the *src* gene is also present in mammalian cells.

But French officials evidently think Stehelin's claims have merit. According to the Reuters news agency, Hubert Curien, the minister for research and technology, has joined a chorus in France protesting that Stehelin should have won the award too.

Will any of this change the prize committee's mind? Definitely not. "It is our opinion that [Bishop and Varmus] are the key persons in the discovery," says Jan Lindsten, secretary of the Nobel medicine committee. ■ J.L.M.

were detecting in cells was not of viral origin at all, but was instead a cellular gene. That was a surprise. "There were a lot of people around who were telling us we were looking at an artifact," Bishop says.

But the San Francisco group had made no mistake. Subsequently, many investigators, including Bishop and Varmus, established that the oncogenes found in other cancer-causing retroviruses are also of cellular origin. And those genes have since been cloned and sequenced and their identities established beyond doubt.

In their normal state, the cellular genes, which are called proto-oncogenes, control cell growth and development. But the sequencing also revealed that when the proto-oncogenes were picked up by the retroviruses, they underwent changes that allowed them to go awry, causing the uncontrolled growth and other abnormalities of cancer cells. More recently, researchers have evidence that chemical carcinogens can also convert proto-oncogenes to active oncogenes. In fact, Bishop describes the proto-oncogenes as "the keyboard on which carcinogens play." ■ JEAN L. MARX

Basic Measurements Lead to Physics Nobel

Their work on atomic properties led to atomic clocks, magnetic resonance imaging, and verifications of quantum mechanics

WHEN THE NOBEL PRIZE COMMITTEE divided the 1989 physics prize into two halves last week, it may have had two very different motives. On the surface the committee provided a single rationale: to honor pioneering work over the past 30 years that vastly improved the measurements of fundamental atomic properties.

But the accomplishments being saluted were of two very different kinds. One was seminal, Nobel-quality work in a single field, the other more of a lifetime achievement award.

Half of the $469,000 prize went to Norman Ramsey of Harvard University, who invented the "separated oscillatory fields method" for measuring the differences between atomic energy levels. This method, the Nobel committee noted, was essential to developing today's superaccurate atomic clocks, which allow time measurements of an accuracy of about 1 part in 10 trillion. Ramsey was also cited for his work on the hydrogen maser, the microwave analogue of the laser.

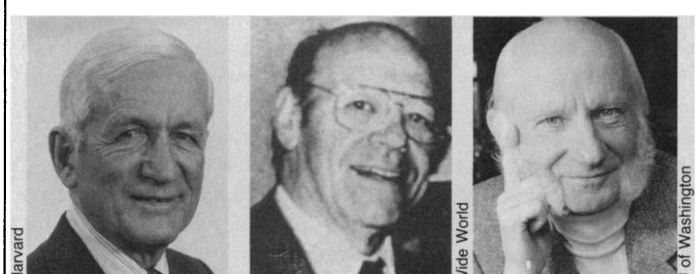
The other half of the award was divided between Hans Dehmelt of the University of Washington and Wolfgang Paul of the University of Bonn in West Germany for their development of ion trap techniques. Their work has allowed researchers to isolate individual atoms and particles and perform exacting measurements on them.

Comparing the two halves of this year's award, Paul and Dehmelt's development of ion traps is undoubtedly "Nobel quality" work in and of itself, while Ramsey's half of the prize may have been more a recogniion of an outstanding physics career.

Paul, 76, performed the first experiments on trapping atoms and ions in the 1950s. He showed that it is possible to use a hexapole magnetic field to focus a beam of atoms and later developed a way to separate ions of different masses that ultimately evolved into the now widely used a quadrupole mass spectrometer. Paul also invented a way to hold ions in a small area using only radio-frequency radiation. This "Paul trap" or "radio-frequency trap" was the first ion trap and is still one of the most commonly used.

Where as Paul made his reputation in developing various machines for studying atomic properties, Dehmelt is better known for pushing the machines to their limit in measuring those properties. Robert Van Dyck, who went to the University of Washington in 1973 to work with Dehmelt, characterizes his mentor's career as devoted to creating an ideal system in which to perform atomic measurements. Each improvement in the ion traps was aimed at achieving "a single particle without unwanted interactions, suspended in an environment we could control," Van Dyck said.

Dehmelt, 67, lived in Germany until 1952, when he moved to the United States. In 1955, he developed the "Penning trap," which uses a strong magnetic field and a weak electric field to hold ions. He used the Penning trap to study electrons with the goal of measuring the electron "*g*-factor"—essentially the ratio of the magnetic and angular momenta of the electron.



Physics laureates. *From left, Norman Ramsey, Harvard; Wolfgang Paul, University of Bonn; Hans Dehmelt, University of Washington.*

In 1973, working with Van Dyck, Dehmelt finally succeeded in isolating a single electron in the Penning trap, and 2 years later he invented a way to cool the electron so as to improve the accuracy of measurements on it. This, Van Dyck said, "allowed us to make measurements that were never dreamed of."

Dehmelt's group in Washington has now measured the electron g-factor to an accuracy of four parts in a trillion. This provides a test of the theoretical predictions of quantum electrodynamics that is more sensitive than any other test of a physical theory.

Ramsey, 74, has done work in several areas. At Harvard in the late 1940s, he developed the technique cited by the Nobel prize committee: the separated oscillating fields method. Until that time, atomic energy spectra were measured by passing a beam of atoms through a magnetic field and exposing them to an electromagnetic field that was tuned to an energy equal to the difference between two energy levels of the atom. The accuracy of this technique was limited by the necessity of keeping the magnetic field constant over a large area.

Ramsey discovered that if the atoms were exposed to two separate electromagnetic fields, once as they entered the magnet and again as they left, the accuracy of the measurement could be greatly improved without the need to make the magnetic field more homogeneous. That idea found application in a number of areas, including today's atomic clocks.

Ramsey also studied the chemical shifts seen in nuclear magnetic resonance experiments. "His work was seminal in the theory of chemical shifts, which underlies the use of the magnetic resonance imaging units in hospitals," say Daniel Kleppner of the Massachusetts Institute of Technology.

And Ramsey has been "a statesman of science," Kleppner adds. He has been president of the American Physical Society and is now chairman of the board of the American Institute of Physics. "He's done so many things that he's a monumental figure in contemporary physics," Kleppner says.

■ ROBERT POOL

Building on Nobel Research

David Pritchard knows what it is like to stand on the shoulders of giants and see farther than anyone else.

In the 16 October issue of *Physical Review Letters*, Pritchard describes a technique for determining the ratio of the mass of CO^+ to the mass of N_2^+ to within an accuracy of 4 parts in 10 billion, or nearly a factor of 10 better than had been reported before for a mass measurement. Speaking to *Science* on the day the 1989 Nobel Prize in Physics was announced, he said his work would not have been possible without the prior accomplishments of physics laureates Wolfgang Paul, Hans Dehmelt, and Norman Ramsey.

Pritchard, a physicist at the Massachusetts Institute of Technology, used a device called a Penning trap to hold single CO^+ and N_2^+ ions in isolation in order to get accurate information on their masses. The Penning trap was invented and developed by Dehmelt and further improved by one of Dehmelt's students, Robert Van Dyck of the University of Washington.

To calculate the masses, Pritchard used the fact that a charged particle in a magnetic field will move in circles with a "cyclotron frequency" that is inversely proportional to its mass. By putting first one type of ion in the magnetic field of the trap and then the other, he compared their cyclotron frequencies and got an extremely accurate measure of the ratio of their masses. The technique for measuring the cyclotron frequencies owes a lot to Ramsey's separated oscillating fields method, Pritchard says.

Pritchard says he hopes to improve the accuracy of measurement by a factor of 10 or more, which could allow some interesting applications, such as calculating the rest mass of the neutrino. Tritium decays into helium-3, an electron, and a neutrino. Since the rest mass of the electron is already well known, an accurate comparison of the masses of tritium and helium-3 should make it possible to calculate the rest mass of the neutrino, long been assumed to be zero. Pritchard's method may reveal whether that assumption is correct.

■ R.P.

Early Work Rewarded

The Nobel Prize for Economics is a relatively recent innovation—the first one was awarded in 1969—so there seems to be a feeling among economists that there is a lot of catching up to do. That may well be the case with this year's award to Trygve Haavelmo, a professor at the University of Oslo in Norway. Haavelmo is honored for his "fundamental contributions to econometrics," which were mostly made in the 1940s.

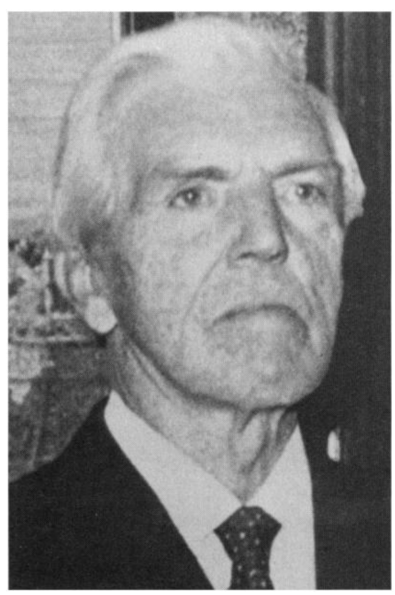
Haavelmo was a pioneer in applying the methods of mathematical statistics to the problems of modeling economies. "His contributions have been path breaking, but unappreciated by many professional economists, let alone the public at large," said Mary Morgan, a lecturer in economic history at the London School of Economics. His central achievement was to develop statistical tools to cope with the fact that an economy is the product of millions of individual decisions bound together in a complex web of interdependencies.

Haavelmo's influence on the subject has been profound. He influenced Lawrence Klein of the Wharton Business School and Arthur Goldberger of the University of Wisconsin at Madison to create the first major model of the U.S. economy, an "algebraic gymnasium," but one that worked quite well. And his methods are still extensively used by econometricians.

The prize comes late in Haavelmo's career. He is almost 78 and has not been very active in the field recently. He is not known as a traveler or conference attendee. Indeed, some economists were surprised to learn that Haavelmo was still alive.

Informed of the news at his home in a suburb of Oslo, Haavelmo was irritated. "I do not like this type of prize," he told reporters in Oslo before unplugging his telephone, getting into his car, and vanishing into the Norwegian countryside. The prize is worth about $470,000.

■ JEREMY CHERFAS



Influential econometrician. *Trygve Haavelmo of the University of Oslo in Norway.*