Cutler, is that giants are exposed to growth hormones for much longer times and at times that may be crucial for it to be effective. Most giants are born making too much growth hormone, whereas most doctors do not diagnose a child as destined to be short until age 2 at the earliest, and some children are not diagnosed until they are 9 or 10. Yet, says Cutler, that first couple of years of life with huge amounts of growth hormone may be absolutely essential for the hormone to work.

There are some hints that children treated with growth hormone may actually reach puberty earlier than untreated children and so stop growing earlier. It is possible that growth hormone–treated short children will end up even shorter than they would otherwise have been. Giants do not go through puberty, says Cutler, which is one reason why they grow so tall.

A placebo-treated group, rather than simply an untreated control group, is necessary in a clinical trial because it may well be that the extra attention a child gets when he is injected three times a week influences growth. Or it may be that the implication that something is wrong with the child will affect his growth. The fact is, says Cutler, that "the brain controls growth." Virtually every known neurotransmitter has some effect on controlling the release of growth hormone. Emotions affect growth—abused children, for example, may not grow. "Who's to say there aren't placebo effects?" Cutler asks. "How can you possibly be sure that if you stick a needle in a child's skin three times a week that you won't affect growth?" The data from the current studies, says Cutler, "will never convince me."

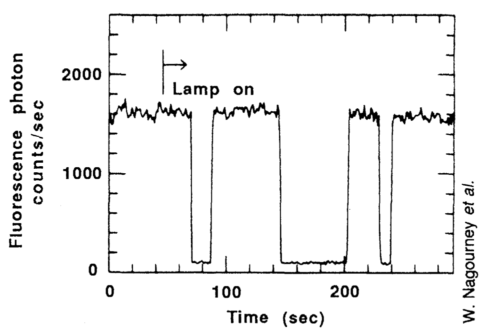
In answer to those who say a placebo-controlled trial would never get past an institutional review board and, even if it did, you would never get volunteers, Cutler responds that his group had permission from the National Institutes of Health ethics review board for just such a study and had enrolled 30 families, all of which understood that they could get growth hormone outside the study and all of which decided to participate, largely for altruistic reasons. But the study was never begun because, just when it was about to start, the Creutzfeld-Jakob cases were discovered and growth hormone was pulled from distribution. Cutler would very much like to start his study again.

Other studies, such as obesity and aging studies, are even less advanced. And, chances are, growth hormone, like so much else in medicine, will be used without a truly scientific evaluation. Yet, says Tanner, "all of us, in our hearts, believe it will work. But, in many ways, I rather think it would be better if it did not." ■ GINA KOLATA

Quantum Jumps Seen In a Single Ion

Researchers can monitor an infrequently occurring quantum transition in a single ion as it happens by measuring the fluorescence due to a frequently occurring transition

ALTHOUGH the optical properties of matter are well described in terms of transitions between the quantum states of atoms, molecules, and solids, observation of individual quantum jumps have only recently been reported. The sightings, which were made by groups at the University of Washington and at the National Bureau of Standards (NBS), Boulder, Colorado, on single ions confined in an electromagnetic trap, resolve the theoretical question of whether quantum jumps can actually be seen. Moreover, they open the way to a new kind of high-resolution optical spectroscopy and allow tests of the quantum statistical behavior of atoms and the like.



Quantum jumps. *A typical trace of the bright fluorescence showing the quantum jumps after the lamp excites the weak transition.*

Interest in the possibility of observing quantum jumps grew after a publication in March 1985 by Richard Cook of the Air Force Institute of Technology, Dayton, Ohio, and H. Jeffrey Kimble of the University of Texas at Austin. Cook and Kimble presented a simple theory outlining the statistics of quantum jumps in a model atomic system comprising a ground state and two excited states that differ in energy and by many orders of magnitude in lifetime.

The transition between the ground and one excited state is a so-called strong transition. "Strong" means that the probability for absorption of a photon when light of the appropriate wavelength irradiates the atom is high and that the atom quickly relaxes back to the low-energy state by radiating a photon. The fluorescence from even a single atom is easily visible because of the large number of transitions per second. The transition between the ground and the second excited state is weak or forbidden, so that a photon of the appropriate wavelength is infrequently absorbed and that, once excited to this quantum state, the atom waits a long time before relaxing to the ground state. The question is, what happens when light sources with the proper wavelengths for exciting both transitions are present?

In sum, most of the time the strong transition is excited, and a continuous bright fluorescence signal is observed. On those rare occasions when the weak transition is excited, the fluorescence disappears until the atom returns to the low-energy quantum state. Consequently, the disappearance and subsequent reappearance of the bright fluorescence signal transitions to and from the long-lived excited state; that is, the fluorescence monitors quantum jumps as they occur.

Actually, the notion of using the bright fluorescence from a strong transition to monitor a weak transition predates Cook and Kimble's analysis by 10 years. Hans Dehmelt of the University of Washington earlier proposed the idea as a means of obtaining spectroscopic information on weak optical transitions in single atoms. Such transitions are of interest because their spectral lines are intrinsically very narrow, which makes them candidates for optical frequency standards and possibly for atomic clocks. In principle, one could study the fluorescence that is emitted when the long-lived quantum state relaxes. But the long lifetime, which is responsible for the narrowness of the spectral line, makes this approach impractical.

Consider an excited state with a lifetime of 1 second and neglect background radiation. Photons are emitted throughout the full 4π solid angle around the atom, whereas photodetectors intercept only a small fraction of it. Moreover, photodetectors are inefficient and do not record every photon that comes their way. Between these two effects, if only one photon is registered for every 1000 emitted, a photon would be counted on the average only once every 17 minutes.

Even with these detector inefficiencies, however, the disappearance of the bright fluorescence due to the strong transition at intervals when weak transitions are excited allows every weak transition to be seen. In effect, the fluorescence acts like an amplifier that provides the highest possible signal-to-noise ratio. Dehmelt coined the term "shelved optical electron amplifier" to describe the operative mechanism. In 1981 David Wineland and Wayne Itano of NBS applied this idea to the measurement of an optical transition in a single ion and obtained an amplification of 10^6.

Although the argument for quantum jumps seems intuitively obvious, theorists have had to go to some effort to show that such jumps should, in fact, be observed because the quantum theory cannot predict a specific sequence of transitions; it deals with probabilities and statistics. An alternative possibility for what happens when two lasers are used to excite the strong and weak transitions is that they would drive the atom into what is called a coherent superposition of states. In this case, the bright fluorescence signal would drop in intensity as compared to that when only the strong transition is excited, but would otherwise remain constant in time. Both quantum jumps and coherent superposition of states give the same average fluorescence intensity. Several theoretical treatments that support quantum jumps have appeared or soon will appear.

The actual observation of quantum jumps, as reported last June at the International Quantum Electronics Conference in San Francisco by Warren Nagourney, Jon Sandberg, and Dehmelt of the University of Washington and by James Bergquist, Randall Hulet, Itano, and Wineland of NBS puts any doubts to rest. The Washington researchers studied a single barium ion that was confined in a trap with a potential energy well generated by a radio-frequency electric field in a special geometry. The technique of laser cooling lowered the ion's kinetic energy, so that the ion was well down in the well where it was confined to a space with a characteristic dimension of 1 micrometer. An ultrahigh vacuum of 8×10^{-11} torr greatly reduced collisions with other species that could cause transitions within the ion.

In operation, the experiment generated a fluorescence signal of constant intensity that intermittently shut off, as in a telegraph signal. Nagourney told *Science* that the blinking was clearly visible to the eye. Because of the statistical nature of the excitation processes, the on and off times were not fixed in duration. For example, the off times followed an exponentially decaying distribution. After allowing for the effects of collisions, the Washington investigators deduced from the time constant a lifetime for the shelf state of 32 ± 5 seconds. The lifetime had previously been measured by another technique to be 47 ± 16 seconds. The result has been confirmed by a group at the University of Hamburg, West Germany, consisting of Thomas Sauter, Werner Neuhauser, Rainer Blatt, and Peter Toschek.

The NBS group made a similar study of quantum jumps in a single, trapped and laser-cooled mercury ion. As compared to barium, mercury has both advantages and disadvantages. One feature that makes the experiment more difficult is that both of the relevant transitions in mercury are at ultraviolet wavelengths. The NBS researchers used nonlinear optics techniques to convert visible laser light to the appropriate wavelengths of the two transitions.

The shorter lifetime of the shelf state in mercury, about 0.1 second, also made it practical to study the quantum statistics of the fluorescence emitted when the shelf state relaxes. The quantum theory of electromagnetic radiation almost always predicts the same statistical properties as the classical theory, so it is important to verify the few instances where the two theories differ. One is a property called photon antibunching, which the NBS researchers also observed.

To understand antibunching, consider the probability for the arrival of a second photon at various intervals after the first is registered. Incoherent light exhibits bunching; that is, the probability is highest at the shortest intervals. For coherent light, such as that from an ideal laser, the probability is the same for all intervals. Antibunching refers to those instances when the probability is lowest for short intervals and is not allowed in the classical theory. One intuitively expects antibunching in the fluorescence from a single atom because, after the emission of a photon, it takes a certain time for the atom to be reexcited so that it can emit another photon. In the past, antibunching has been observed in atomic beams of sodium so dilute that only one atom at a time passed through the exciting laser beam, but a low signal-to-noise ratio made the experiment difficult. ■ **ARTHUR L. ROBINSON**

ADDITIONAL READING

W. Nagourney, J. Sandberg, H. Dehmelt, "Shelved optical electron amplifier: observation of quantum jumps," *Phys. Rev. Lett.* 56, 2797 (1986).

J. C. Bergquist, R. G. Hulet, W. M. Itano, D. J. Wineland, "Observation of quantum jumps in a single atom," *ibid.*, in press.

Supply-Side Ecology

Existing models of population structure and dynamics of ecological communities have tended to ignore the effect of the influx of new members into the communities

ONE of the most complex issues that ecologists are attempting to address is the assembly and structure of communities. "The overall issue," says Jonathan Roughgarden of Stanford University, "is to account for the variety, abundance, and distribution of the members of the community." Availability of resources, competition, various forms of perturbation, including predation and environmental hazard, and a certain degree of stochasticity have been identified as influential factors in shaping communities. But, until recently, one factor that has been more or less overlooked in the major formulations of the problem is the supply of new individuals to the community. "Yes," says Roughgarden, "you can call the new approach 'supply-side ecology'."

You can, of course, learn a great deal about the internal dynamics of an ecological community by recording the nature and extent of biotic and abiotic influences on the individuals within it, whether this is by direct field observation or experimental manipulation. In fact, these kinds of studies are essential in the formulation and testing of general models of ecological communities, an approach that has been particularly successful for intertidal communities.

What supply-side ecology adds to this is to identify those elements of the internal dynamics whose importance depends on the abundance of new individuals entering the community.

Supply-side ecology clearly does not apply to "closed" communities, which by definition are completely self-sustaining in terms of new members. But, argue Roughgarden and his colleagues Steven Gaines and Stephen Pacala, "at some scale most ecological systems are open systems." In which case, they suggest, "the control exerted by physical transport processes on population and community dynamics matches the effect of local processes, such as predation and competition among residents of the site." Supply-side ecology can apply to larvae settling on rocks in an intertidal community, seeds entering a terrestrial habitat, and, on a grand