the nucleus, both in cultured cells and in animals. The exciting conclusion is that *WTX* is a tumor-suppressor gene in Wilms tumors because its normal function is to control β-catenin activity.

These findings are revealing for a number of reasons. Apart from Wilms tumor, footprints of β-catenin activity have been detected in other human cancers, mostly by virtue of the nuclear presence of the β-catenin protein. In many of those cases, there has been no evidence that the known components of the WNT signaling pathway are mutated, suggesting that β-catenin becomes activated without any genetic alterations. But the new knowledge provided by Major *et al.* invites speculation that *WTX* is in fact mutated in these cancers.

In the absence of data on the possible involvement of *WTX* in other cancers, we may also speculate about the tissue specificity of tumor-suppressor genes. Clearly, Wilms tumors can be caused by activating mutations in the gene encoding β-catenin or by loss-of-function mutations in *WTX*. Other cancers, particularly colon cancer, may result from similar activating mutations in the β-catenin–encoding gene, but the major tumor-suppressor gene mutated in colon cancer is *APC*. Why this specificity? Are *WTX* and *APC* functionally redundant, meaning that loss of one will not lead to β-catenin activation, unless the other gene is not expressed? This possibility invites careful examination of the expression of *WTX* and *APC* in normal cells before they become cancerous. An X-linked tumor-suppressor gene is a time bomb waiting to go off, so there must be mechanisms to protect cells against loss of *WTX*. Such mechanisms could include *WTX* homologs on autosomes, perhaps expressed in cells other than kidney cells.

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PHYSICS

Condensates Made of Light

At low temperature, atom wave functions can lock together. Such a state has now been seen in trapped photons and electron-hole pairs.

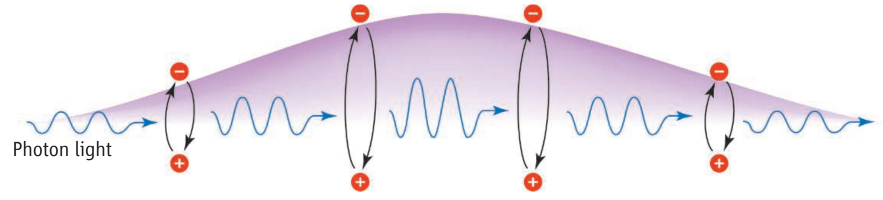
Peter Littlewood

A Bose-Einstein condensate (BEC) is the remarkable state of matter obtained when the collective quantum mechanical desire of atom waves to synchronize defeats their random motion in a normal liquid. Predicted by Einstein in 1924 and first observed with the discovery of superfluid helium in 1937, BEC has been subjected to intense study in the past decade, facilitated by the development of experimental methods of trapping and cooling of atomic gases at microkelvin temperatures. On page 1007 of this issue, Balili *et al.* (*1*) demonstrate trapping of a different kind of "atom" that can condense in the relative warmth of tens of kelvin, or perhaps even higher. By creating these warmer condensates, the researchers have now greatly expanded the variety of systems in which quantum coherence can be studied. Apart from the substantial fundamental interest in quantum coherence, such systems might become the building blocks of future quantum information processing systems.

BEC is a quantum phenomenon that depends on the overlap of atomic wave functions. An atom has a wave function whose size depends inversely on the atomic mass; hence, to reach BEC for massive atoms in a dilute gas, the temperature must be reduced below 1 μK, and even for dense liquid ^{4}He the transition temperature is only 2 K. But if it were possible to make a high-density gas of "atoms" whose mass is small, then quantum coherence might be expected to occur at much higher temperatures. Using a special kind of very light atom called a polariton—whose mass is as small as 0.0001 of the mass of an electron—several groups have been making progress toward this goal.

The trick to making a very light atom begins with the observation that the absorption of a photon by a semiconductor creates an electron in an excited state while leaving behind a positively charged "hole" (see the figure). This electron-hole pair can be bound into an atomic state, just like the proton and electron of the hydrogen atom, but the mass of the new particle—called an exciton—is much smaller. Of course such an "atom" is transient—it will vanish by reradiating a photon—but now one can play a second trick by placing mirrors on the sample. Then the photon bounces back and forth. If treated classically, it would be reabsorbed (by forming excitons) and re-emitted many times (by recombining excitons) before eventually escaping. In a quantum system, the superposition of the exciton and photon leads to the formation of yet another particle, which is known as a polariton. Because the photon is massless, polaritons are extremely light relative to the atoms typically found in BEC, and hence they offer the basis for exciting new quantum physics.

High-quality mirrors are difficult to make, but trapped "microcavity" polaritons were first made by semiconductor engineering in the early 1990s (*2*, *3*). Progress in making dense polariton gases inside these microcavities has been rapid in recent years but has usually occurred under nonequilibrium conditions. The challenges include cooling particles whose lifetime (from leaking through the mirrors) is measured in picoseconds, and making traps in which the particles can



Lightweight "atom." Photons from a laser (blue arrows) excite electron-hole pairs called excitons (black arrows). The excitons and photons form a quantum state called a polariton with a mass much less than that of an electron. Balili *et al.* have now trapped a quantum condensate of polaritons.

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equilibrate before the polaritons escape from the cavity as a puff of photons.

Last year, Kasprzak *et al*. (*4*) produced good evidence for an equilibrated BEC of polaritons, although in an open system without a trap to confine them. The energy level of an exciton can be shifted a little by squeezing the sample, which allows the exciton and photon to be tuned in or out of resonance, thereby weakening or strengthening polariton binding. Balili *et al*. have cleverly used a sharp pin to make an inhomogeneous strain, producing a system close in spirit to that of trapped atomic gases. Moreover, their host system is the widely used III-V semiconductor alloy GaAs rather than the less tractable and more disordered CdTe used by Kasprzak *et al*. This will open the field to a wider community.

Aside from the higher temperatures for the onset of coherence, there are a number of special differences from the atomic systems that give additional richness [see (*5*) for a review]. The current systems are inherently two-dimensional, so that the BEC phase transition in equilibrium should be of a special variety known as a Berezhinskii-Kosterlitz-Thouless transition, where spatial correlations of the coherence have a finite range giving a predicted experimental signature of the emitted photons. The polaritonic atoms are large—roughly the scale of the wavelength of light, about 1 μm—and thus overlap at very low density, quite unlike the dilute atomic gases whose interactions are short-range. And because the mirrors are not perfect, the polaritons escape (to be emitted as photons) and the trap must be continuously repopulated, which adds a continuous perturbation to the macroscopic coherence.

The light emitted from the condensate is, of course, as nearly coherent as a two-dimensional system can be—this being one of the tests of condensation—which makes the whole device behave like a special kind of (low-threshold) laser. And the output coupling to coherent light was already demonstrated some time ago by experiments that showed that resonant laser coupling could drive condensate formation through nonlinear scattering (*6*). There is thus a lot to explore.

Current experiments, although warm with respect to ultracold atoms, are still at cryogenic temperatures. The ultimate transition temperature is set by the exciton-photon coupling, measured by an energy scale known as the Rabi splitting. This is limited by fundamental properties of the material and device structure; its value is 13 meV (~150 K) in the GaAs system and about twice that in CdTe. In microcavities containing some organic molecules, Rabi splittings as large as 80 meV have been seen (*7*)—which is tantalizing for a room-temperature device. These objects are, on the one hand, a new kind of low-threshold laser, but the fact that they consist of coherent quantum objects (unlike a regular laser) puts them potentially in the class of quantum devices. A rash speculation is that a small polariton condensate could become the basis for an elementary quantum computer, but the easy coupling to light might simplify the wiring issues that many quantum information technologies find challenging.

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DEVELOPMENTAL BIOLOGY

A Decade of Cloning Mystique

Was Dolly a fluke or one of the biggest breakthroughs in modern science? Probably both.

Jose Cibelli

Ten years ago, Ian Wilmut, Keith Campbell, and their colleagues from the Roslin Institute in Scotland announced the first cloned adult mammal—a sheep named Dolly—using a technique called somatic cell nuclear transfer (*1*). Since then, the experiment has been independently replicated in 16 other mammalian species. Laboratories around the world launched efforts to identify the mechanism responsible for this phenomenon. Hundreds of peer-reviewed manuscripts later, we are left with many unanswered questions about the technique and are still unable to substantially increase its efficiency. For all species cloned by this method, less than 10% of embryos transferred into the uterus will produce a healthy clone. Why?

Wilmut and Campbell's curiosity radically changed our views on the plasticity of the genome. The technique, in which the nucleus of an animal's somatic cell is inserted into an enucleated, unfertilized egg cell (called an oocyte) of the same species, essentially takes a differentiated cell and "turns it back," in a developmental sense, to a zygote, poised to develop into a fetus and mature adult that is genetically identical to the animal that provided the somatic cell nucleus. The old dogma that a differentiated cell can never turn back in development has been replaced by a new one stating that somatic cell nuclear transfer is possible and that our failures are attributable to insufficient understanding of the mechanisms that govern how a somatic cell nucleus is reprogrammed by the cytoplasm of an oocyte.

When performing somatic cell nuclear transfer, we are asking a somatic cell to turn into a gamete in a matter of hours, a process that normally takes months (*2*). Shortly thereafter, we expect such a pseudo-gamete to "turn into a fertilized egg," or zygote (coaxed by electrical or chemical stimulation in vitro), ready to divide and form an embryo. This is a tremendous undertaking for a genome that the day before was governing the identity and physiology of a completely different cell type. Now we are faced with trying to improve a technique that supports a process that is clearly unnatural. Should we? We cannot afford not to. Beyond the obvious practical benefits we might expect from achieving success—such as agricultural cloning (livestock production) and therapeutic cloning (generating stem cell–derived cell lines for understanding devastating diseases)—it poses a scientific challenge that goes to the heart of developmental biology.

Ten years have not been enough time, though; the long list of unanswered questions about animal cloning reflects how our understanding is stalled at a fundamental level. For instance, is somatic cell dedifferentiation or embryonic differentiation the step at which

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