Developing ‘inducible-knockout’ mice, in which the expression of the α6 or δ subunits can be stopped quickly, might avoid the problems of compensatory alterations and may clarify the roles of tonic inhibition in brain function.

The next major advance in this field might not come from studies of genetically altered mice. The development of drugs that specifically block receptors containing the δ subunit, for example, would provide tools for unravelling the precise function of background inhibition, not just in the cerebellum but also in other brain areas where such receptors are expressed extrasynaptically. The task of understanding the function and importance of extrasynaptic GABA receptors is an exciting one, and it is clear that neuroscientists have already lost their inhibition about listening to background noise.

Ivan Soltesz is in the Department of Anatomy and Neurobiology, University of California, Irvine, California 92697–1280, USA. e-mail: ivan@uci.edu

Zoltan Nusser is in the Laboratory of Cellular Neurophysiology, Institute of Experimental Medicine, Hungarian Academy of Sciences, Szégyeny Street 43, 1083 Budapest, Hungary. e-mail: nusser@akl.hu

Quantum engineering

Squeezing entanglement

Nick Bigelow

Quantum entanglement between two particles is a spooky connection that means measuring one has an instant effect on the other. Connecting many atoms in this way would be the first step towards a quantum computer.

If a street magician with two identical coins told you he could predict which way up your coin would land — heads or tails — simply by tossing his coin first, you probably wouldn’t believe him. But what if he told you that, because of the laws of physics, your toss had to turn out the same as his toss? Not convinced, you try it and find that, yes, it is true. And it remains true, time after time, toss after toss. By some mechanism, there is a surprising correlation between the behaviour of the two coins. What’s going on? Well, it could be that these two coins have somehow been prepared in a remarkable quantum state known as an entangled state. On page 63 of this issue Sørensen et al. provide physicists with an exciting new recipe for creating such entangled states from an unusual sample of atoms known as a Bose–Einstein condensate.

The concept of entanglement is one of the most fundamental features of quantum mechanics, yet it is one of the most puzzling, non-intuitive and ‘non-classical’ aspects of the theory. The consequences of entanglement are so disturbing that Albert Einstein called them “spooky action-at-a-distance”. But is entanglement real? Can we actually create entangled states? More importantly, can we observe the effects of entanglement? The answer to all of these questions is yes, at least on the rather remote and microscopic scale of a single pair of photons. More recently, entanglement has also been demonstrated using an ensemble of four carefully prepared atoms. So far, though, entanglement has not been observed in any macroscopic (human-sized) system.

The physics of entangled states is also at the heart of a new generation of futuristic technologies, including recent plans for quantum computers and strategies for quantum teleportation. Making entanglement a tangible, exploitable phenomenon, however, requires the creation of entangled states of many particles — entanglement on a macroscopic scale. Moreover, it is important to achieve this with massive particles that can easily be stored and transported, rather than with photons, which have no mass. One of the exciting aspects of the work of Sørensen et al. is that, by following their guidelines, researchers may soon be able to do just that — entangle the many particles within a Bose–Einstein condensate (BEC). A BEC is a large sample of particles (as many as 10 million ultracold atoms) that share exactly the same quantum state.

For the purposes of entanglement, theorists are especially interested in a type of BEC in which the atoms have multiple internal states. This was first achieved experimentally for a ‘double condensate’ composed of two clouds of rubidium atoms, each cloud having a different internal spin, which can be thought of as a tiny bar magnet. More recently, researchers have been able to transfer a BEC of sodium atoms from a magnetic trap into an optical trap formed from a focused laser beam. Unlike a magnetic trap, this new laser-trapping technique is not sensitive to the spin state of the atoms, so physicists can vary the complex magnetic properties of these ‘spinning’ condensates.

In the quest to create entangled states for large collections of atoms, the ‘squeezed’ state is of particular interest. To appreciate the relationship between squeezing and entanglement, it is important to have a sense for quantum ‘noise’. At the heart of quantum theory is the idea that nature is inherently probabilistic. In classical physics you can predict the outcome of a coin toss if you know the exact starting conditions. But in quantum theory you can speak only of the probability of a certain outcome, no matter how much detail of the problem is known. Inherent in this picture is the idea that the measurable properties of a given state are accompanied by unavoidable fluctuations.

© 2001 Macmillan Magazines Ltd
These fluctuations are an expression of the Heisenberg uncertainty principle, and they set a quantum noise limit on the accuracy of any precision measurement. In a squeezed state, this quantum noise is 'squeezed', or redistributed in the system, so that some measurable properties become 'quieter', whereas other properties become 'noisier'.

The states studied by Sørensen et al. are 'spin squeezed'\textsuperscript{11,12}. In the quantum world we often represent an atomic spin by an arrow (Fig. 1a). For the simplest spins, like those of electrons, these arrows can point either up or down. Now, applying the uncertainty principle, we find that the transverse part of the spin (the part not exactly in the up–down direction) is uncertain by an amount represented by a small disc. In other words, if we try to find out whether the spin is angled left or right, or in or out of the page, we find that the transverse part of the spin, and in turn pass on some of these protective chemicals to their eggs. But questions remain. Do the females use receipt of alkaloids as a measure of a male’s ‘worth’? Females did seem to prefer males that had released filaments, but it is not certain if females could discern whether the filaments were laden with alkaloids. It is also not clear which plants the moths feed on in the wild, because the moths are rare and hard to spot. Amanda Tromans

**Table 1**

<table>
<thead>
<tr>
<th>Monotremes</th>
<th>Did advanced mammals evolve on the southern continents and then move north? Not according to a new study, which concludes that such mammals evolved in both the south and the north.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Monotremes</td>
<td>- Did advanced mammals evolve on the southern continents and then move north? Not according to a new study, which concludes that such mammals evolved in both the south and the north.</td>
</tr>
<tr>
<td>- Marsupials</td>
<td>- Did advanced mammals evolve on the southern continents and then move north? Not according to a new study, which concludes that such mammals evolved in both the south and the north.</td>
</tr>
<tr>
<td>- Placentals</td>
<td>- Did advanced mammals evolve on the southern continents and then move north? Not according to a new study, which concludes that such mammals evolved in both the south and the north.</td>
</tr>
</tbody>
</table>

Did advanced mammals evolve on the southern continents and then move north? Not according to a new study, which concludes that such mammals evolved in both the south and the north.

Anne Weil

There are three groups of living mammals — placentals, marsupials and the monotremes. The first two, along with some mammalian fossil relatives, have so-called 'tribosphenic' teeth, which provide a highly efficient way of chopping and grinding food. Monotreme ancestors are also thought to have possessed such teeth.

On page 53 of this issue, Luo \textit{et al.} argue that mammals with tribosphenic teeth evolved not once but twice, after the supercontinent of Pangaea pulled apart more than 160 million years ago. According to their hypothesis, one lineage radiated across the southern landmass of Gondwana but is represented today by only the platypus and

**References**