CYP-generated derivatives of arachidonic acid and dilating cyclooxygenase-generated derivatives. The relative importance of these opposing effects may have differed in the two groups' experiments because of a difference in the age of the animals or the brain area studied: Mulligan and MacVicar looked at the hippocampus of 13–18-day-old rodents; Zonta *et al.* focused on the cerebral cortex at 9–15 days. (Furthermore, outside the brain, whether 20-HETE constricts or dilates depends on both tissue area and age[10].)

The relative importance of the constricting and dilating signals will also depend on the initial baseline level of contraction of the arteriole smooth muscle. Mulligan and MacVicar found that inhibiting NO synthase converted the astrocyte-evoked constriction into a dilation, implying that the dilation observed by Zonta *et al.* might be unphysiological and due to their inhibiting NO synthase. However, a rationale for blocking this enzyme is that, *in vivo*, blood flow generates a baseline level of contraction of arteriole smooth muscle, which is normally absent in brain-slice experiments but can be mimicked by blocking the dilating effects of NO released from neurons and blood vessels. The change from constriction to dilation that Mulligan and MacVicar saw when NO synthase was blocked may reflect a stronger, perhaps more physiological, prior baseline contraction of arteriole smooth muscle in the absence of NO, because from a more constricted baseline it is harder to evoke further constriction and easier to evoke dilation.

Finally, another explanation for the difference between the two groups' results could be that, whereas Mulligan and MacVicar's Ca^{2+}-uncaging experiments elegantly isolate astrocyte-initiated signalling, Zonta and colleagues' use of a glutamate analogue to raise the astrocyte Ca^{2+} concentration could also activate non-astrocyte signalling pathways, for example in the endothelial cells that line blood vessels[11]. These pathways might also be activated by glutamate released *in vivo*.

Excitingly, Mulligan and MacVicar's discovery of an astrocyte-mediated constriction pathway may also give insight into how arterioles are dilated, in both normal and pathological circumstances. Although normal dilation occurs partly through NO increasing the levels of the molecule cyclic GMP in smooth muscle, NO also inhibits the production of 20-HETE[7]. So part of NO's dilating effects may result from a suppression of the astrocyte-initiated signalling discovered by Mulligan and MacVicar. The production of 20-HETE is also inhibited when oxygen levels fall[7], possibly contributing to the dilation produced by low oxygen levels in the brain.

Eventual reconciliation of the results of Zonta *et al.*[5] and Mulligan and MacVicar[3] may require difficult experiments involving perfusing arterioles in brain slices with an artificial extracellular fluid, to generate a physiological level of baseline contraction[12]. Nonetheless, it is clear that astrocytes play a starring role in the control of blood flow in the brain. ■

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Condensed-matter physics

The qubit and the cavity

Yu. Makhlin, G. Schön and A. Shnirman

Coherent coupling of superconducting qubits and electromagnetic modes, analogous to atom–photon coupling, has been demonstrated — a step towards the communication of quantum information.

For some time, the efforts of the quantum-optics community have been dedicated to reaching the so-called strong-coupling regime of cavity quantum electrodynamics (QED)[1]. In cavity QED, atoms are strongly coupled to photons. Usually, photons propagate freely in space over large distances and interact with atoms only briefly as they pass by. The interaction is stronger if photons and atoms are trapped together inside an optical cavity — this consists of a region bounded by two or more mirrors that are aligned to provide multiple reflections of light waves. Suppose that an atom in an excited state enters an empty cavity; it can repeatedly and coherently emit and reabsorb a photon, in a cycle called vacuum Rabi oscillation. In the desired regime, many oscillations occur before the photon or atom escape from the cavity. Starting on page 159 of this issue, Wallraff *et al.*[2] and Chiorescu *et al.*[3] report experiments in which the concept of cavity QED has been realized in a solid-state system, using superconducting Josephson junctions. These experiments constitute a major step towards quantum communication with solid-state systems.

Josephson qubits (quantum bits) are effectively artificial atoms — two-level quantum systems that use either electric charge or magnetic flux as the primary quantum degree of freedom. They are based on Josephson junctions, which are sandwiches of two layers of superconducting material separated by an insulating layer. Progress in experiments with Josephson qubits has included the demonstration of coherent manipulations, as well as free and driven oscillations, in single[4–6] and coupled[7] qubits. Now Wallraff *et al.*[2], inspired by quantum optical cavity QED, have coupled a Josephson qubit (the 'atom'), on a chip, to a harmonic-oscillator mode of a transmission line (the superconducting 'cavity'). In atomic systems, care must be taken to extend the time the atoms spend in a cavity, but here the advantage is that the Josephson qubit is fixed on the chip. The qubit is positioned at a point of maximum amplitude for a standing wave in the cavity, and this induces a strong dipole coupling between the charge of the qubit and the electric field of the wave.

Wallraff *et al.*[2] investigated the strong-coupling regime using spectroscopy. The qubit–wave coupling causes two excited energy states in the system to split; electromagnetic radiation sent into the cavity can probe the structure of the energy states by inducing transitions between the ground state and the two split states (Fig. 1). The energy gap between the split states sets the frequency of the vacuum Rabi oscillations. Walraff *et al.* recorded a splitting energy equivalent to a frequency of about 10 MHz — much higher than the widths of the levels, typically 1 MHz, that characterize the timescale on which the system loses coherence through dissipation. This means that about ten vacuum Rabi oscillations could be observed in a time-resolved experiment.

Chiorescu *et al.*[3] have studied the coupling of a magnetic-flux Josephson qubit to a different kind of oscillation — the plasma oscillations in a SQUID (a superconducting quantum interference device, which comprises two Josephson junctions, on either side of a loop of wire). Chiorescu *et al.* proved that coherent coupling was occurring between the qubit and the oscillator using Rabi oscillations of various kinds. First, they induced Rabi oscillations in the qubit: by shining a resonant microwave signal onto the qubit, a regime can be reached in which the microwave mode periodically transfers the energy of one photon to the qubit and then gains it back. In contrast to the vacuum Rabi oscillations, this process is induced by a classical electromagnetic field involving many photons.

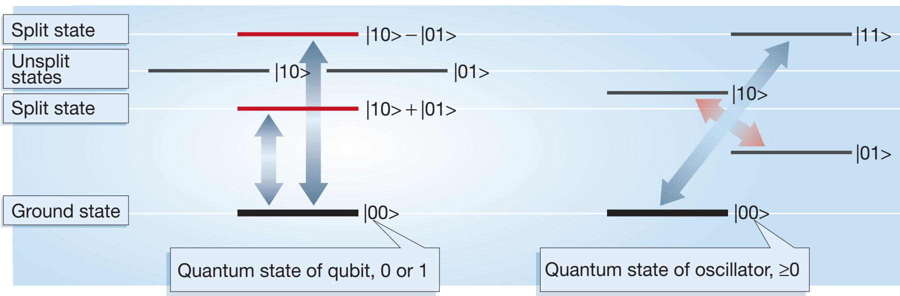

Figure 1 **The structure of the energy levels in a coupled qubit–oscillator system, as studied by Wallraff *et al.*[2] (left) and Chiorescu *et al.*[3] (right).**

As a further test, Chiorescu *et al.* induced and then analysed coherent Rabi oscillations between the energy levels of the coupled qubit–oscillator system; again, their data are in agreement with expectation. When they prepared the qubit in the ground state, only the Rabi processes associated with this state were visible; similarly, when the qubit was prepared in an excited state, only the Rabi oscillations involving that state were observed (Fig. 1). Although the coherence time was, at most, tens of nanoseconds, the demonstration of time-resolved coherent oscillations in this combined system is a remarkable achievement. The measured frequency of these processes, the Rabi frequency, passed the litmus test — it depended linearly on the amplitude of the microwave that induced the oscillations. Moreover, as the microwave power, and hence the Rabi frequency, was varied, the authors saw a resonance between the Rabi oscillations and the SQUID plasma oscillations, at exactly the position expected.

These experiments[2,3] show that a high level of coherence and control is possible in Josephson circuits, such that, on a single chip, qubits could be coupled through the oscillator to create a quantum computer (in the spirit of the coupling in ion-trap quantum registers[8]). This is also a step closer to quantum communication — the transfer of quantum information between relatively distant stationary qubits via propagating waves. In both experiments, there is circumstantial evidence that the qubit and the oscillator were entangled; in future work with electronic qubit–oscillator or multi-qubit[7] circuits, it should be possible to observe the degree of entanglement directly. However, this would require the ability to carry out 'single-shot' measurements of both subsystems: although detectors are available that come close to achieving this[5,6,9], combining all the ingredients into a single circuit and operating it in a coherent regime is a challenge still to be faced. ■

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Animal behaviour

Relative size in the mating game

Malte Andersson and Johan Wallander

A common trend in size differences between males and females is a long-standing puzzle. A study of shorebirds shows that the type and strength of competition for mates may explain much of the pattern.

Five decades ago, the German evolutionary biologist Bernhard Rensch[1] presented an intriguing rule for the differing sizes of male and female animals. He found that in several groups (clades) that each contain related species, male size relative to female size increases with the body size of the species. Rensch's rule has since been verified in animals as diverse as arthropods, reptiles, birds and mammals, including primates[2]. The causes behind the rule, however, have remained unclear[2–5]. Why are males much larger than females in many animals with large body size? And why, in the same clade, are males similar or even smaller than females in species with small body size[1,2]?

As they describe in *Proceedings of the National Academy of Sciences*, Székely *et al.*[6] have carried out a comparative analysis of shorebirds that show such trends, and have come up with some thought-provoking conclusions. They show that the trend in sexual

NATURE

100 YEARS AGO

Are they not methodologically equivalent, the three systems of classification — (*a*) of plants into herbs, shrubs and trees; (*b*) of animals into birds, beasts and fishes; and (*c*) of humans into the sanguine, the lymphatic, the bilious and the melancholy? Why, then, is it that science, having long ago given us a *Systema Naturae* and a *nomenclature botanicus and zoologicus*, still leaves us almost without the rudiments of a *Systema Hominis* and a *nomenclature sociologicus*? It may be asked in reply, What of the anthropologists and their half-century of taxonomic labours in the name of science? But the anthropological classifications belong, in appearance at least, to natural and not human history. They do not rise through psychology into sociology… Of late the anthropologist has shown signs of attaching himself to the psychologist; and this suggests another form of the initial question, Why have anthropologists not endeavoured to formulate even a provisional classification of psychological types? Why have they, with unconscious naïvete, been content to accept implicitly the popular classification that traditionally survives from early Greek thought? To this question the positivist will be ready with his answer, but perhaps it were wiser to leave it as a shameful reminder to the laggard sociologist.
From *Nature* 8 September 1904.

50 YEARS AGO

The passing of Prof. T. F. Dreyer has deprived the study of early man in South Africa of one of its acknowledged leaders, and his place will not be easily filled. Outside South Africa, Prof. Dreyer will be most widely remembered as the discoverer of the Florisbad skull, the most remarkable human fossil to be found in Africa since the Broken Hill skull. This discovery was a well-deserved reward for his intuition in selecting for thorough investigation the Florisbad mineral spring deposits with their wealth of archæological and fossil mammalian remains. But his explorations in the Matjes River Cave and elsewhere also constitute notable contributions to our knowledge of man in South Africa from prehistoric to historic times. With a characteristic scorn for the compartmenting of knowledge, Prof. Dreyer pursued his studies simultaneously in the field of physical anthropology, Quaternary mammalian palæontology, archæology and even Quaternary geology and climatology.
From *Nature* 11 September 1954.