ological support for the molecular findings (*10, 11*). These earliest corn cobs don't look much like those of modern corn, but they look even less like teosinte cobs (see the figure). They are tough and have several rows of tightly attached kernels, implying that the plants wouldn't have survived without people to detach and plant the seeds. By contrast, teosinte's reproductive structure, the rachis, falls apart when mature to release its hard seeds. Thus, even 6000 years ago, ancient maize cobs were already corn-like.

The GM corn spread far—and fast. Maize appears in the archaeological record of the southwestern United States more than 3000 years ago (*12*), and it is evident that cob size had already increased under selection. The Jaenicke-Després *et al.* study (*1*) examines the selection of traits that can't be observed in fossilized cobs. Taking tiny samples of fossil cobs from the Ocampo Caves in northeastern Mexico (2300 to 4400 years old) and the Tularosa Cave in the Mogollon highlands in New Mexico (650 to 1900 years old), the authors extracted DNA and amplified, cloned, and sequenced small DNA fragments of the *tb1* gene, the *pbf* gene that controls the amount of storage protein, and the *su1* gene encoding a starch-debranching enzyme whose activity affects the texture of corn tortillas. They compared their ancient DNA sequences with those of 66 maize landraces (the corn grown by indigenous farmers) from South, Central, and North America and 23 lines of teosinte parviglumis.

They report that alleles of these genes typical of modern corn were already present more than 4000 years ago, implying that plant architecture and kernel nutritive properties were selected early, long before corn reached North America. All 11 ancient cobs carried the *tb1* allele present in modern corn, but fewer than half of the 23 teosinte varieties carried this allele. Similarly, all ancient samples contained a *pbf* allele that is common in corn but rare in teosinte. The predominant modern *su1* allele was found in all of the older Mexican cobs, but the younger New Mexican cobs had several different alleles, suggesting that this gene was still undergoing selection when maize reached North America.

The authors conclude that "... by 4400 years ago, early farmers had already had a substantial homogenizing effect on allelic diversity at three genes associated with maize morphology and biochemical properties of the corn cob." This suggests that once this special combination of GMs was assembled, the plants proved so superior as a food crop that they were carefully propagated and widely adopted, perhaps causing something of a prehistoric Green Revolution. It also implies that the apparent loss of genetic diversity following the introduction of high-yielding Green Revolution wheat and rice varieties in the 1960s and 1970s, and attending the rapid adoption of superior GM crops today, is far from a new phenomenon.

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PHYSICS

Flux Quanta on the Move

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Most superconductors are penetrated by flux vortices when exposed to magnetic fields. The dissipative motion of these "Abrikosov vortices"—first predicted by Alexei Abrikosov, one of the recipients of this year's Nobel prize in physics—can be good or bad for practical applications. In applications involving large superconducting currents, vortex motion is best avoided altogether, whereas controlled vortex motion can be useful in superconducting electronic devices.

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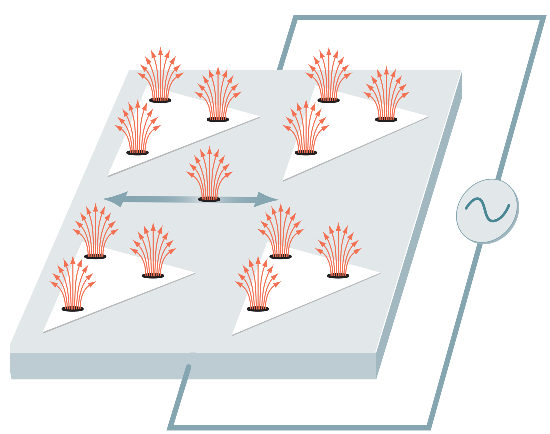
On page 1188 of this issue, Villegas *et al.* show how vortex motion may be controlled in superconducting electronic devices (*1*). They have realized a rectifier that converts a zero-averaged ac supercurrent into a dc voltage. In the device, the vortex motion in superconductors is guided with asymmetric vortex-pinning sites. For certain values of applied current and magnetic field, an inversion in the direction of the vortex flow, and thus in the sign of the dc voltage signal, occurs.

The Abrikosov vortices in superconductors are kept in place by a pinning force. However, under the influence of electrical currents they also experience a Lorentz force. When the Lorentz force exceeds the pinning force, the vortices start to move. This motion produces a voltage over the superconductor. The resulting energy dissipation is unwanted for large-current applications, such as magnets, and hence many groups have tried to create strong pinning sites.

Because the core of an Abrikosov vortex is in a normal conducting state, it is energetically favorable for the vortex to be located in regions of reduced superconductivity. Furthermore, the vortex can be "pinned" by magnetic dots within, or on top of, the superconductor. This pinning is further enhanced by the local suppression of superconductivity near magnetic dots. For strong magnetic fields, the vortex density becomes so large that the vortices start to feel each other. The repulsive interaction between them gives rise to an ordered vor-



Directed vortex motion. For large applied magnetic fields, the triangular pinning sites are completely saturated with three pinned vortices each. Due to the interaction with these pinned vortices, the interstitial sites experience a ratchet potential, resulting in net motion to the left when an ac-bias current is applied. For smaller magnetic fields, the vortex motion is in the opposite direction, from triangle to triangle. In that case the asymmetric shape of the triangles forms the basis for the ratchet behavior.

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tex lattice. Ordered arrays of pinning sites, with a periodicity matching that of the vortex lattice, are very effective for pinning the vortex lattice as a whole.

Individual pinning sites are usually symmetric in shape. However, when they are asymmetric, the flux quanta experience a ratchet-like pinning potential. Under the influence of an alternating bias current, the net motion of the vortices will be in a direction set by this ratchet potential. Lee *et al.* (*2*) have proposed that vortex ratchets may be used to "sweep" trapped flux—an important source of noise—out of superconducting quantum interference devices (SQUIDs) before their operation. Zhu *et al.* have studied the vortex dynamics for triangular pinning sites numerically (*3*, *4*). Recently, Kwok *et al.* realized asymmetric pinning sites experimentally with heavy-ion lithography (*5*).

Inspired by these studies, Villegas *et al.* have patterned triangular magnetic dots, with side lengths of several 100 nm, beneath a superconducting niobium film. They demonstrate the ratchet behavior for operating temperatures just below the critical temperature of the film. When the applied magnetic field is small, all vortices can find a place at one of the triangular pinning sites. Under the influence of an ac bias current, they move from triangle to triangle in a net directed motion (from left to right in the figure). In this case, the ratchet behavior arises from the asymmetrical, triangular shape of the pinning sites.

When the applied magnetic fields exceed the fields for which all pinning sites are saturated with vortices, additional flux accumulates at interstitial positions. Being pinned more weakly, these interstitial vortices are the first to move under the influence of a driving current (*6*). In the configuration used by Villegas *et al.* (*1*), this motion is in the opposite direction from that for smaller magnetic fields, and thus from right to left in the figure. In this case, the ratchet behavior is determined by the repulsive interaction of the interstitial vortices with the pinned vortices at the triangles. The change in direction is a striking example of current inversion by particle interactions in a ratchet system (*7*). It is accompanied by a change in the sign of the dc voltage over the structure.

The incorporation of magnetic material can lead to substantial additional noise in SQUIDs. Nevertheless, the work of Villegas *et al.* provides useful insights for the possible application of future ratchets using nonmagnetic asymmetric pinning sites.

Aside from flux removal, the controlled motion of flux quanta forms the basis for various superconducting electronic device concepts. For example, in rapid single flux quanta circuits (*8*), flux quanta are used as information carriers between connected superconducting ring structures. The inherent speed of these devices far exceeds the fundamental limitations for semiconductor circuitry. And in vortex flow transistors (*9*), flux quanta are set in motion in a superconducting drain-source channel under the influence of an external parameter acting as the gate.

The structure investigated by Villegas *et al*. (*1*) functions as a reversible rectifier, in which a variation in the ac bias current or in the magnetic field gives rise to a change in the sign of the output voltage. This rectifier could form a basis for novel sensors or switching devices, depending on the attainable sensitivity, speed, magnitude of the ac background voltage, and temperature range over which the functionality persists.

Furthermore, the structure (*1*) can be used to steer the direction of the vortex flow, and can thus function as a reversible vortex pump. This ability to modify the vortex density controllably at chosen positions may be a useful tool for basic studies of the properties of vortex matter. Altogether, the work is a nice example of how vortex motion can be tailored through the use of nanometer-scale artificial pinning sites.

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PSYCHOLOGY

Evolution of the Social Brain

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We share with our monkey and ape cousins a particularly intense form of social life that, so far as we can tell, is not found in any other group of animals. For primatologists that raises two leading questions: Why are we so social (in simple evolutionary terms, does sociality confer fitness benefits?), and are unique cognitive capacities needed to service the formation of such tight social bonds? Two papers in this issue by Silk *et al.* on page 1231 (*1*) and Bergman *et al.* on page 1234 (*2*) report field studies of baboons that go some way toward answering these two questions.

In many respects, baboons mark a high point in monkey sociality. They live in some of the largest social groups observed for any primate, and they boast a brain that has the largest neocortex of any Old World monkey (the neocortex is the brain region with which sociality has the strongest correlate) (*3*). That makes them a particularly suitable species to use for exploring these kinds of questions. But they have another advantage that places them in a quite different league for these purposes: Several wild baboon populations have been studied intensively for many decades. With known life histories from a large sample of individual animals, it is possible to test hypotheses that simply cannot be studied in any of the more conventional war-horse animal models of evolutionary ecology. Like humans, baboon social groups have a history: Over the course of whole lifetimes, animals build relationships that may be based as much on kinship ties as they are on expediency.

In their study, Silk and her coauthors test the hypothesis that sociality among baboon females has a direct impact on their reproductive fitness. These investigators exploited 16 years worth of data from a long-term study of the Amboseli baboon population in Kenya. They describe how females who are significantly more social (indexed principally by the amount of time that others spend grooming them) have more than the average number of infants surviving to 12 months of age. (A 12-month old baboon is roughly equivalent to a 5-year old human, and has a good chance of surviving into adulthood and breeding.) The sociality of adult female baboons is positively associated with infant survival and thus with overall fitness. In evolutionary terms, sociality is good for you.

These findings raise intriguing questions about how such an effect is produced. One puzzling feature is that the relationship between sociality and fitness appears to be asymptotic: After a certain point, continuing to invest precious time in additional social relationships does not yield significant benefits. There are a number of possible reasons for this. First, time devoted to sociality is time taken away from other fitness-enhancing activities—such as feeding or watching over one's fragile offspring (*4*)—and there may be a limit to how much social time can be afforded. Second, there are intrinsic cognitive

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