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 non-magnetic 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.

References

Evolution of the Social Brain
Robin Dunbar

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 who raise 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
Forging social bonds. The relationship between the number of core grooming partners and the number of adult female gelada baboons in a reproductive group. Data points represent the average number of grooming partners per female for different group sizes. The mean number of grooming partners declines rapidly once there are more than five females in the group (even though time devoted to grooming remains constant) because of the need to reinforce critical social relationships that are essential for social and reproductive success. [Source (17)]

constraints on the correlation between time invested in social interactions and the quality of the relationships produced (5) (especially as measured in terms of their value as alliances). And third, there are also constraints on the size of the social networks formed (see the figure) (6).

Another question raised by these data concerns the mechanisms that bring about the intricate sociality of baboon communities. Current evidence points to two quite separate processes. The first is cognitive and involves the ability to understand the social intentions of others. The second is psychopharmacological and is most likely a consequence of the fact that social grooming (the principal behavioral process used in primate social bonding) is a very effective releaser of endorphins (7). Among other effects, endorphins create a sense of euphoria and relaxation, both of which are probably conducive to building a sense of trust (and perhaps obligation) between grooming partners.

The cognitive aspects of sociality in primates have attracted particular interest (8, 9). In their work carried out at another long-term field-study site in Botswana’s Okavango Delta, Bergman et al. (2) investigated whether adult female baboons are capable of evaluating the status of another individual in terms of both rank and kinship. They examined whether their baboon subjects could classify these attributes hierarchically, giving precedence to one over the other—a capability that underpins many aspects of human cognition, including the grammatical parsing of sentences.

Bergman et al. recorded threat vocalizations and submission screams from different female baboons. They then played back the recordings from hidden speakers to 19 female baboon subjects. First, the subjects listened to a combination of calls: threats from a subordinate and screams from a dominant individual (reversed rank relationship) that belonged to either the same or different groups of closely related adult females (matrilines). The subjects then listened to a control set of vocalizations: threats by a dominant and screams by a subordinate (normal rank relationship) from within or outside their matriline. The technique relies on the well-established fact that both human and animal subjects are more attentive to stimuli that are “surprising” (in conflict with their current knowledge of the world) than they are to familiar stimuli (10).

As predicted, Bergman et al. found that their baboon subjects stared in the direction of the hidden loudspeakers for significantly longer when played a pair of calls signaling reversed dominance involving members of different matrilines. They stared at the hidden loudspeakers for shorter times when played calls signaling reversed dominance among members of the same matriline or normal dominance between members of the same or different matrilines. Bergman and colleagues interpret this as evidence that baboons can categorize the world in a hierarchically embedded fashion.

Elusive Supernova Progenitors

Schuyler D. Van Dyk

Super novae—the complete disruption of stars at the end of their lives—are among the most energetic events in the universe. But which sorts of stars give rise to supernovae?

To answer this question, astronomers should ideally identify a supernova progenitor on pre-supernova images. Unfortunately, no supernova has been definitely discovered by eye in our Galaxy since 1604 A.D. Progenitors have been identified for 6 of the ~2900 known extragalactic supernovae, but 5 of these 6 supernovae are somewhat peculiar; 2 may not be supernovae at all.

Searches to isolate more supernova progenitors have been taking advantage of the superior angular resolution afforded by the Hubble Space Telescope (1). Yet, for the vast majority of supernovae, the progenitor’s nature can only be inferred indirectly from observed characteristics of individual supernovae, global properties of supernovae, or their relationship to their environment in the host galaxy.

Supernovae have historically been divided into two main categories, based on whether their optical spectra show hydrogen spectral lines (Type II) or not (Type I). Type I supernovae have been further subdivided into those that have a characteristic absorption line attributed to doubly ionized silicon (Type Ia), those that lack the silicon line and show strong helium lines (Type Ib), and those that lack the silicon line but exhibit virtually no helium (Type Ic) (2).

Astronomers are confident that Type II supernovae occur when all the nuclear fuel in the core of a massive (>8 to 10 solar masses) supergiant star has been burned. The supernova arises when the iron-rich core within the hydrogen-rich envelope of such a star (3) collapses to form a neutron star. The released energy is carried away primarily by neutrinos. A fraction is carried by a shock wave of kinetic energy, which rips apart the envelope. Type Ib and Ic supernovae are probably also core-collapse events (4).

Type Ia supernovae are believed to arise from the destruction of a white dwarf. White dwarfs, with typical masses of ~1 solar mass, are the bare cores of dead stars that were originally less massive than 8 solar masses. When a white dwarf reaches ~1.4 solar masses—the maximum that nature allows for these stars (the Chandrasekhar limit)—a