

threatened by a welter of problems that destroy corals, ruin reef ecosystems and imperil fishing success. Protecting reefs from overfishing or from coral destruction has been a successful way of restoring ecosystem health and increasing fish populations [6]. Broad-scale implementation of such protected reserves, however, demands that we understand a key feature of reef populations: the movement potential of adults and larvae [7]. Adult neighborhoods, that is, the way adult fish and invertebrates use habitat space, and larval neighborhoods, the distance larvae disperse, are key elements in setting the size of marine reserves and their spacing [6]. Adult neighborhoods can be understood by physically tagging fish or invertebrates. But the movement of larvae is exceedingly difficult to measure, previously requiring indirect methods such as genetic discovery of population movement patterns or matching of the trace elements in fish bones to a chemical atlas from coastal waters [8].

The results of this small study [2] show that a surprisingly large number of juvenile clown fish stayed home during their planktonic period. This simple result suggests that local protection of reef fish is likely to pay strong local dividends by enhancing the settlement and subsequent population size of resident species of fish and invertebrates. At the smallest geographic level it shows that overzealous collecting of clown fish from a patch of anemones will probably reduce the settlement of new fish onto those anemones by limiting larval supply. At a larger spatial scale, the results provide a strong hint that the most powerful ecosystem-based tool in the marine management toolbox – marine reserves – has a chance to provide benefits to the local communities that protect them.

The Jones study [2] also confirms another important aspect of reef fish life styles. Although many fish came from local sources, many did not. The non-local fish made up 60–80% of the juveniles and must have come from 10 km away or more. This

strong result shows that for fish with moderate planktonic periods, there is a chance for healthy reef areas to reseed damaged ones over scales of at least tens of kilometers. Because the artificial restoration of reefs by replanting or restocking is expensive, time consuming and limited in spatial scope [9], this is good news for efforts to restore reefs with natural seed supplies. Showing the scale over which healthy coral gardens should be maintained as natural seed sources may provide a better recovery road map to help the hundreds of kilometers of ruined reefs around the world.

The tiny drama of an ocean life can drive a powerful narrative. It can put the dangers of ocean species into human perspective and paint a picture of precious life in the struggling seascape. A cartoon glimpse of the life of an anemone fish does not do this narrative justice. But with drug tests and paternity analyses, Jones *et al.* [2] provide a 21st century tracer for really finding Nemo.

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Primate Cognition: Putting Two and Two Together

The human mind has the capacity for abstract numerical representations that cut across different sensory modalities. New research with monkeys shows that this mathematical achievement is not unique to our species.

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Imagine that you are a young male chimpanzee. You are sitting on a comfortable branch, minding your own business, when all of a sudden you hear a panthoot vocalization from a rival chimpanzee in the distance. As your fight-or-flight mechanisms kick in, you realize you have two choices: you could fight or take flight. Should you stay or should you go? What information do you use to decide?

Actual chimpanzees faced with this problem do something quite

crafty. Like well-trained military strategists [1], chimpanzees solve the problem by calculating whether they are outnumbered [2]. Chimpanzees sitting alone tend to slink away from the voice in the distance: a one-on-one fight with an unknown chimpanzee is not a safe bet, so it is best not to approach. In contrast, chimpanzees in groups of three or more choose to advance on the unknown bigmouth. With a three-to-one numerical advantage, victory is relatively assured. Remarkably, for chimpanzees facing potential

combat, the calculator may be mightier than the sword.

The above example highlights just one instance in which an organism's future survival and reproductive success seems to hinge on its capacity for numerical assessment. From a bee optimizing its flower visits to a mother duck looking after her ducklings, animals face a variety of problems that could be solved by keeping track of different numbers of items. For the human species, this task of numerical assessment is easily solved. Our linguistic counting system offers us a powerful and precise way to reason about number in a variety of contexts. For animals that lack language, however, the problem of numerical assessment is far more difficult. How do bees and ducks — and other organisms that lack language — come to reason about numerical information?

Interest in this question of non-linguistic numerical representations has led to a wealth of comparative research suggesting that both human and non-human animals have the capacity to represent some numerical information non-linguistically [3–6]. Prelinguistic human infants, for instance, can enumerate small numbers of objects placed into a box [7] and can discriminate different numbers of dots presented on a screen [8]. Similarly, trained rats can press a lever a specific number of times to obtain a food reward [9].

Animals also exhibit an understanding of number without training; naturally living rhesus monkeys spontaneously assess the number of food pieces placed into a box [10]. And there is recent evidence that infants and non-human animals spontaneously represent numerical information in other modalities; both monkeys [11] and infants [12] spontaneously discriminate sound sequences containing different numbers of elements.

Unfortunately, much of the empirical work on non-linguistic number representations in infants and animals bears a considerable limitation. To date, most tests of these representations have employed only a single stimulus

modality (usually vision). The numerical representations observed in these modality-specific tasks could, therefore, be intimately tied to the modality in which they were tested, or to some modality-specific stimulus attribute that happens to be correlated with number. In contrast, true abstract numerical representations, like those of linguistically sophisticated adult humans, would necessarily be independent of stimulus attributes and modality.

A study reported recently in *Current Biology* by Jordan *et al.* [13] presents the first evidence to date that a non-linguistic animal, the rhesus monkey, shares the human capacity for *modality-independent* number representations. The authors investigated whether monkeys spontaneously represent numerical information simultaneously presented across two separate sensory modalities: vision and audition. To do so, they developed a simple preferential looking methodology, much like the ones typically used to test cross-modal processing in human infants. The logic of the methodology is that subjects should prefer to look at a visual stimulus that matches a synchronously presented auditory stimulus.

Using this logic, Jordan *et al.* [13] developed dynamic video displays of a number of different monkey faces vocalizing. Having matched these videos across a number of stimulus parameters, the researchers then split the video and audio portions of these dynamic videos, such that they could vary the number of each played simultaneously. During testing, they placed rhesus monkey subjects in front of two different LCD screens, one playing a video component of two monkey faces vocalizing, the other playing a video component of three monkey faces vocalizing.

The monkey subjects then heard an auditory stimulus of either two or three vocalizations. If subjects spontaneously detect both the number of vocalizations *and* the number of faces, then looking at three faces while hearing only two voices should

feel like the monkey-equivalent of watching a badly dubbed foreign movie — the audio and visual signals won't match. So, if monkeys detect and match the number of voices and faces, they would be expected to look preferentially towards the number of faces that correspond to the number of simultaneously presented voices. Jordan *et al.* [13] found that monkeys do just this. Subjects demonstrate a consistent preference for the matching over non-matching number of faces, suggesting that they spontaneously assess and match numerical information in both the visual and auditory modalities.

This result provides the first compelling evidence that monkeys can represent and connect numerical information across two sensory modalities. In doing so, this study [13] raises a number of unanswered questions and thus some important objectives for future research. The first concerns the nature of the representations underlying monkeys' capacity to match number information across different modalities. It is widely agreed that at least two different non-linguistic representational systems support numerical judgments: an approximate system, which noisily computes the quantity of a set using analogue magnitude estimates; and an object tracking system, which computes numerical information by keeping track of a small number of discrete objects [3]. It is unclear which of these two systems underlie the cross-modal numerical assessments observed by Jordan *et al.* [13]. Future work would therefore profit from testing the limits on monkeys' cross-modal numerical processing, and examining more specifically which of these two representational models best accounts for these limits.

Another question for the future concerns the neural mechanisms underlying the monkeys' cross-modal number capacity [5]. Neurophysiologists have observed that areas of the macaque prefrontal and posterior parietal cortex encode quantity

information at the level of single neurons (see [5] for an elegant review of this work). These quantity-sensitive neurons tend to have a 'preferred numerosity', firing most strongly when presented with a specific number of visual objects. Unfortunately, the level at which these cells represent numerical information is at present unclear. While it is possible that number-sensitive cells reflect abstract numerical processing, it is also possible that such cells process only visual numerical content, and thus may be tied to a single sensory modality.

The findings of Jordan *et al.* [13], however, suggest that the macaque brain is capable of integrating multi-sensory information about quantity, and thus raise the possibility that previously identified prefrontal number-sensitive cells may underlie this processing. Future work could therefore profit from developing cross-modal tasks that can be used in conjunction with neurophysiological

recordings. In this way, the results of Jordan *et al.* [13] pave the way for a broader comparative investigation of modality-independent number representations; their approach will undoubtedly lead to new insight into both the nature of and mechanisms underlying numerical representations.

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Evolution: Revenge of the Clones!

Recent work on ants shows both extraordinary patterns of reproduction and a new type of sexual conflict, leading to the remarkable scenario where females have no father and males have no mother.

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Why do we have sex, and why so often, when many species do without it? This question still poses a major problem for biologists [1,2] and is raised once again with the recent discovery [3,4] that two species of ant produce workers sexually but queens and sons (reproductives) asexually.

If the main aim of reproduction is to create copies of our genes, then why don't we simply produce clones of ourselves, as asexual organisms do? Our gene combinations have been selected over time as successful, yet we pass on only half of them and mix these up with our partner's during meiosis — twisting fully working

gene combinations into ones that may not function as well; this is the so-called 'recombination load'. This cost alone may seem bad enough, but in species such as humans with separate sexes, there is the added cost of producing males to fertilise the females, effectively cutting the number of reproducing individuals by half. This is known as the two-fold cost of sex. A variety of theories have been put forward to explain why, despite these costs, sexual reproduction is widespread in animals and plants [1,2].

The two most favored hypotheses explaining sex and recombination are, first, that they provide an advantage in coevolutionary arms races, especially with parasites; and

second, that they facilitate the purging of deleterious mutations [1,2]. The parasite hypothesis relies on the idea that parasites will evolve to infect common genotypes in a population, providing an advantage to the production of rare genotypes by sex [5]. This explanation has been termed the Red Queen theory, because it suggests that, just like Alice, one has to run just to stay in the same place — mixing the successful genes from the last generation to stop the parasites infecting the offspring in the next. The mutation hypothesis relies on the idea that sex allows you to lose deleterious mutations in a few low quality offspring. This can make up for a two-fold cost of sex, as long as there are at least one or two mutations per genome per generation, and the fitness cost of each additional deleterious mutation is greater than the last, a phenomenon termed synergistic epistasis [6].

A common theme with most theories that provide an advantage