wolf differences, and striking dog-human convergences—in this case, in a task with which most dogs have no previous experience.

But there is an interesting difference between dogs and human infants. Topál *et al*. observed that dogs did not make the location error if the person hiding the object in location B was not the same person who hid it in location A. Children made the error whether the person was the same or not. The authors interpret this as showing that human children are sensitive to true pedagogy—they, in essence, take instruction from all adults equally, considering it as general cultural information, whereas dogs are sensitive only to communication from humans about the immediate situation. It is possible that neither dogs nor any other nonhuman species communicate generalized (normative) information in this way.

Dogs' special social-cognitive skills are not "normal" in that they do not gesture for or teach humans reciprocally, and they do not use their comprehension abilities with other dogs. They have evolved specialized skills for dealing with their unique situation in which they benefit by taking orders from humans. Indeed, a recent study has found more sophisticated communicative skills in dogs that have been directly selected by humans for specific tasks such as hunting and herding (*12*). Domestic dogs thus illustrate one way in which specialized cognitive skills may evolve to meet special ecological circumstances.

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NEUROSCIENCE

Erasing Fear Memories

Why are memories of traumatic events nearly impossible to eliminate?

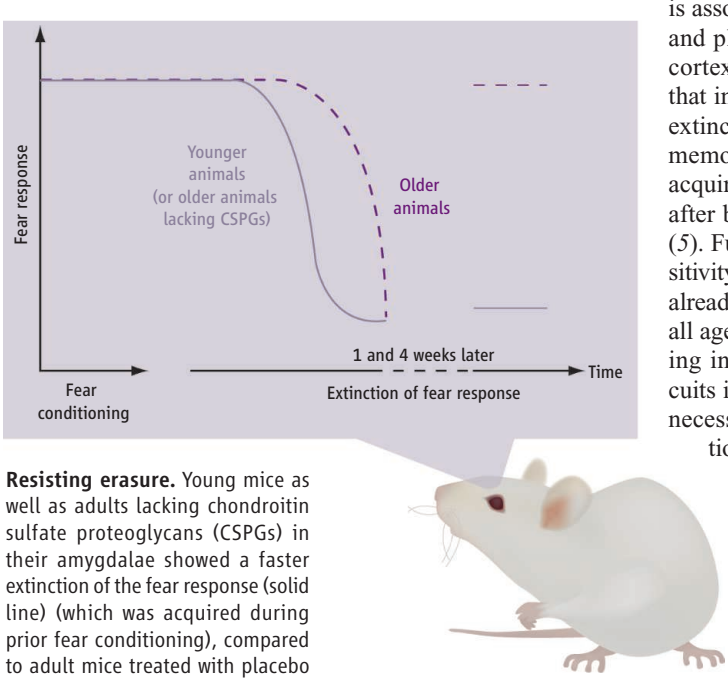
Tommaso Pizzorusso[1,2]

Events that are associated with trauma and fear often leave memories that reoccur spontaneously, leading to excessive fear, anxiety, and, in some cases, posttraumatic stress disorder. Such relapses of fear memories constitute a major clinical problem, and their elimination is a major cornerstone of psychological therapy. Many neurobiological studies are therefore focused on understanding how fear memories are controlled (*1*). On page 1258 of this issue, Gogolla *et al*. (*2*) take an important step in the field by determining that the extracellular environment in a particular region of the brain—the amygdala—is responsible for making fear memories erasure-resistant.

"Extinction" is a popular behavioral technique to block recurring traumatic memories. This form of learning is characterized by a decrease in a fear response when the contingent relationship—between a conditioned stimulus (e.g., a sound) and an unconditioned stimulus (e.g., an electric shock)—is compromised. This situation is most commonly implemented when the conditioned stimulus is repeatedly presented in the absence of the shock (*3*). It is now well accepted that extinction represents new learning and does not erase the preexisting memory (*4*). Indeed, the original memory can spontaneously recover, or it can be renewed, when the conditioned stimulus is presented in contexts different from that in which the extinction protocol was administered. The resilience of traumatic memories to extinction represents a serious obstacle for treating disorders characterized by abnormal fear and anxiety.

Gogolla *et al*. were inspired by previous work originating from fields as diverse as development of fear conditioning (when fear is associated with a neutral stimulus) and plasticity of the visual cerebral cortex. These studies demonstrated that in contrast to the inability of an extinction protocol to erase the fear memory in adult rats, extinction of acquired fear in young rats (17 days after birth) deletes the fear memory (*5*). Further studies showed that sensitivity to erasure of fear memories is already lost at 23 days after birth. At all ages, extinction of fear conditioning in rats implicated neuronal circuits in the amygdala, a brain region necessary for fear memory acquisition and extinction. What changes occur during amygdala development that are responsible for switching off the susceptibility of fear memory to the process of elimination?

Developmental windows during which neural plasticity is different from that of adult animals have been extensively studied in the mammalian visual cortex. Visual



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Resisting erasure. Young mice as well as adults lacking chondroitin sulfate proteoglycans (CSPGs) in their amygdalae showed a faster extinction of the fear response (solid line) (which was acquired during prior fear conditioning), compared to adult mice treated with placebo (dashed line). When fear memory was retested 1 and 4 weeks after the extinction protocol, only the young mice and adults lacking CSPGs had completely eliminated the fear memory, whereas fear response had reoccurred in the placebo group.

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cortical circuits are particularly sensitive to visual deprivations during the so-called critical period. An important determinant of the closure of the critical period is maturation of the extracellular matrix that surrounds visual cortical neurons. Chondroitin sulfate proteoglycans (CSPGs) are the main constituents of the adult extracellular matrix. CSPGs condense into a netlike structure that surrounds a subclass of inhibitory interneurons (those that express the protein parvalbumin). This occurs in parallel with closure of the critical period. Eliminating CSPGs from the adult rat cortex (by injecting the enzyme chondroitinase ABC, which digests lateral chondroitin sulfate chains) can enhance plasticity almost to the level of a juvenile rat (*6*), suggesting that maturation of CSPGs endows the visual cortex with adultlike plasticity.

Like the visual cortex study, Gogolla *et al*. determined that maturation of the extracellular matrix in the amygdala is responsible for closing the developmental period during which fear memories are susceptible to extinction. The authors found that the number of CSPGs-containing perineuronal nets in the mouse amygdala increases sharply between 16 and 23 days after birth, in correlation with the developmental switch of fear memories from erasure-prone to erasure-resistant. Adult mice were injected in the amygdala with chondroitinase ABC to eliminate CSPGs, and then subjected to fear conditioning by pairing a sound with an electric shock. Then, mice were subjected to an extinction protocol consisting of repeated presentation of the sound without the shock. To examine context specificity, the authors administered the extinction protocol in a context different from the one in which the animal had been previously conditioned. During the extinction protocol, the sound elicited progressively less fear response (cessation of body movement, or "freezing") both in mice treated with chondroitinase ABC and in control mice treated with placebo (saline solution). However, the rate at which the fear response decayed was much faster in chondroitinase ABC–treated mice than in control mice (see the figure). Strikingly, when response to the conditioned sound was retested 1 and 4 weeks after the extinction protocol, the fear response was not observed in animals treated with chondroitinase ABC—neither in the same context in which the extinction protocol had been administered, nor in the context in which the animals had originally been conditioned. This indicates complete loss of the fear memory. Thus, treating adult mice with chondroitinase ABC restores fear memory acquisition to the erasure-prone modality that typifies young rodents. By contrast, substantial spontaneous recovery and fear renewal occurred in control adult mice. Interestingly, chondroitinase ABC was effective if injected before fear conditioning, but not if injected before the extinction protocol. Thus, CSPGs are not directly regulating the processes occurring during extinction, but they are important for coding an erasure-resistant memory during memory acquisition.

The results of Gogolla *et al*., together with previous experiments on the visual cortex, suggest that maturation of the extracellular matrix could be a mechanism used by different brain circuits to change from a malleable to a more crystallized state during development. The presence of a high concentration of CSPGs in the perineuronal nets surrounding inhibitory neurons suggests that inhibitory circuits could play an important role in the developmental control of plasticity. Evidence supports this role for parvalbumin-expressing cells in the rodent visual cortex (*7*), but much less is known about other circuits. The mechanistic aspects of how CSPGs control plasticity are also still obscure: Is their organization in perineuronal nets important? What is the function of this structure at the molecular level? Further work is needed to understand how general this mechanism is and whether it applies to the human brain as well.

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ECOLOGY

Threats to Freshwater Fish

Insights into how small, isolated fish populations persist in the wild could aid conservation efforts.

Anne E. Magurran

The sole wild population of the small live-bearing fish known as Picote de Tequila (*Zoogoneticus tequila*, see the figure) lives in a single, 4-m-wide pool in the Ameca Basin in Central Mexico. This pool supports a population of under 500 of these fish, of which fewer than 50 are adults (*1*). Trinidadian guppies (*Poecilia reticulata*) introduced to the area, possibly in an attempt to control mosquito larvae, outnumber them by 6 to 1 (*1*, *2*). Exotic species are a well-known threat to freshwater fish populations, particularly those, like *Z. tequila*, that are vulnerable as a result of their reduced population size and low genetic diversity (*3*). Habitat fragmentation, habitat loss, and overenthusiastic collecting further compound the risk of extinction for this and many other fish species. Biodiversity loss affects all taxa, but freshwater fish are especially susceptible because many fish species are rare. One way to help conserve rare species is to learn how naturally small and fragmented populations manage to persist in the wild.

Picote de Tequila is an exceptionally well-documented example of a fish on the brink of extinction, but the reasons it finds itself in this perilous state are depressingly familiar. Freshwater faunas worldwide are imperiled. Data for many regions are sparse or missing altogether, but the information that is available is chilling. A 2008 assessment found that some 40% of freshwater fish in continental North America are at risk or already lost (*4*). These 761 taxa (of which 230 are vulnerable, 190 threatened, 280 endangered, and 61 extinct or extinct in the wild) represent a 92% increase on the equivalent assessment in 1989 (*4*). Habitat degradation emerges as a substantial threat, as does the presence of nonnative species. The same pattern is repeated in Europe (*5*–*7*).

There is no doubt that human activities have played a major role in the decline of freshwater fish populations, that the situation has deteriorated (*4*, *6*, *8*), and that prospects are poor in light of ever-increasing demands for water and natural resources and the projected impacts of climate change (*9*). The remedies—pollution control, restoration and improved management of freshwater habitats, limits on harvests of vulnerable species, and restrictions on the translocation of fish, par-

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