To Fence or Not to Fence

Rosie Woodroffe *et al.*

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the right circumstances, be broken without a penalty. Unraveling this fundamental puzzle has several practical implications.

Through the formation of cyanoformate, CO_2 can "cloak" cyanide and escort it away from its potential targets. This process may shed light on the mystery surrounding ethylene production from 1-aminocyclopropane-1-carboxylic acid (ACC) by ACC oxidase (also known as ethylene-forming enzyme, EFE) (*8*). Ethylene is a plant hormone that plays an important role in processes such as fruit ripening and seed germination. Along with ethylene, this enzymatic pathway forms the putative cyanoformate intermediate, (*9*) in close vicinity to the iron center of the enzyme active site. If cyanoformate were to decompose immediately, the iron-containing active site could be deactivated by the CN^-. For example, CN^- halts cellular respiration by inhibiting cytochrome c oxidase. Sacrificial metal ions, such as Fe(III) and Co(II), are used in antidotes for cyanide poisoning because of their ability to intercept CN^-.

Murphy *et al*. suggest that nature may use a more economical solution by employing CO_2 as a masking Lewis acid and that the transient stability of cyanoformate allows sufficient time for CN^- to be shuttled away under the cloak provided by coordination with CO_2. The calculated energies for release of CN^- suggest that cyanoformate should be unstable in water but persist in the less polar enzyme active sites.

There is one more important implication of the fleeting stability of cyanoformate. Capture of CO_2 from the atmosphere or combustion streams is a crucial technological challenge for mitigating its effects as a greenhouse gas. A common approach uses the Lewis acidity of CO_2 in reactions with a suitable base, i.e., by scrubbing with amines (*10*) or by catalytically reducing CO_2 into formates, either enzymatically (*11*) or with metals (*12*, *13*) (see the figure, panels C and D). The range of Lewis base–CO_2 interactions changes from covalent bonds to weak noncovalent interactions in amine-functionalized nanoporous solids (*14*). Reversibility of such processes is important because it allows regeneration of the sorbent. The work of Murphy *et al*. illustrates how CO_2 complexes with a Lewis base can be formed and broken on demand, depending on external conditions.

The story of cyanoformate illustrates that even simple molecules can unlock chemical and biochemical mysteries. What lessons can we learn from this small ion on the brink of fragmentation? If plants need CO_2 to detoxify from cyanide, can we rely on cyanide to detoxify the atmosphere from CO_2? With the blanket of greenhouse gases around the world thickening year by year, now is the time to investigate.

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ECOLOGY

To Fence or Not to Fence

Fences must be used with care in biodiversity conservation to avoid unintended consequences.

Rosie Woodroffe,[1] Simon Hedges,[2] Sarah M. Durant[1,2]

Habitat fragmentation undermines the functioning of ecosystems, and so biodiversity conservation often entails maintaining or restoring landscape connections. However, conservationists also destroy connectivity by constructing wildlife fences. A recent debate about the use of fences to protect African lions (*1*–*3*) highlights a more general need to evaluate the role of fencing in conservation.

People and wildlife can be uneasy neighbors. Many wild species damage valuable livestock, crops, or infrastructure; some carry livestock diseases; and a few threaten human lives. At the same time, people kill wild animals for food, trade, or to defend lives or property, and human activities degrade wildlife habitat. Separating people and wildlife by fencing can appear a mutually beneficial way to avoid such detrimental effects.

While some fences may be last-ditch attempts to preserve wildlife areas already isolated by human development, others are constructed within relatively contiguous wildlife habitat. For example, in parts of southern Africa, fencing of individual land parcels secures wild animals as privately owned commodities in a wildlife economy centered on sport hunting. In North America, roads may be fenced to minimize collisions that can kill people and wildlife. Fences have been constructed in Australia to protect native marsupials from invasive species, and in Kenya to separate critically endangered hirola antelope from natural predators. Botswana is traversed by veterinary cordon fences intended to prevent disease transmission from wildlife to livestock, and fencing has also been considered as a way to halt the spread of infectious cancer among Tasmanian devils. In Africa, containing rhinos in small fenced areas makes them easier to protect from poachers.

Although fencing can have conservation benefits, it also has costs. When contiguous habitats are converted into islands, the resulting small and isolated populations are prone to extinction, and the ensuing loss of predators and other larger-bodied species alters interactions between other species in ways that cause further local extinctions, a process that has been termed ecological meltdown (*4*). Areas isolated by fencing are likely to experience similar consequences unless the wildlife populations they contain are intensively managed.

Fencing can lower not only the number but also the density of organisms that can be supported in a landscape. In highly variable environments, both wild herbivores and pastoral people move widely to track resources such as food and water. Constraining these movements by fencing lowers the carrying capacity of such environments. Just as settlement of formerly nomadic pastoralist people can lead to overgrazing and land degradation (*5*), so construction of fences

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Pros and cons of fencing. Fences may allow some species, such as lions, to reach high densities, but they also profoundly alter ecosystems. For example, for species like the African wild dog (**A**) and many of its ungulate prey, fencing may increase the risk of extinction and reduce their resilience in the face of climate change. Furthermore, in some cases fences may fail to prevent passage of wildlife, such as these elephants in Kenya (**B**).

(DOGS) ROGER DE LA HARPE/WWW.AFRICAIMAGERY.COM; (ELEPHANTS) LAUREN EVANS/WWW.GEOG.CAM.AC.UK/PEOPLE/LEVANS AND WWW.SPACEFORGIANTS.ORG

has been linked to vegetation changes (*6*) and marked declines in wild herbivores, even where fences were constructed for conservation purposes (*7*). Such impacts are likely to be especially severe where climate change increases the frequency and severity of extreme weather events (*5*, *8*).

Fencing structures themselves can exacerbate pressures on wildlife. They offer a ready supply of wire, which can be used to fashion snares for poaching. Furthermore, predators such as wolves and African wild dogs (see the figure, panel A) can learn to improve their hunting success by chasing prey into fences (*9*). These impacts and the resulting fence damage in turn prompt hostility from managers, which can lead to deliberate predator removal. Less tangibly, fencing alters people's relationship with nature. Where policy changes have constrained the movements of formerly nomadic people, fences can be perceived as symbols of the policy, generating local hostility to wildlife conservation efforts (*10*).

In principle, these harmful effects of fencing on ecosystems might be countered by improved protection from human activities, as well as the societal benefits of protecting people from wildlife. However, the challenges of appropriate fence design, location, construction, and maintenance mean that fences often fail to deliver the anticipated benefits (see the figure, panel B). In Africa, fences are a negligible barrier to determined poachers, who need little more than a pair of pliers to gain access to valuable wildlife. For example, fencing has not prevented substantial illegal killing of rhinos in recent years. Although many fences provide effective barriers to wildlife, failures are commonplace. For example, a study of 37 fences in South India found that 49% failed to prevent passage of elephants, mainly because of poor maintenance and deliberate breaches by local people seeking access to the fenced areas (*11*).

The balance between beneficial and detrimental effects of fencing wildlife was recently debated after a call to fence African parks to conserve lions, which reach higher densities (relative to estimated carrying capacity) inside fenced reserves than in unfenced areas (*1*). If fencing is effective in resolving human-wildlife conflict, it should reduce lion mortality from human predation (a top-down effect). However, herbivores may not benefit in the same way, because fencing constrains their ability to escape lions and other natural predators. At the same time, restricting herbivores' ability to exploit ephemeral food sources increases the likelihood of their populations being food-limited (bottom-up effects), and fencing has been repeatedly associated with herbivore declines (*7*). Changes in herbivory prompt cascading effects on vegetation (*6*) and are likely to influence many other ecosystem components. Although relatively high lion densities inside fenced areas have been portrayed as successful conservation of a key ecosystem process (*3*), they might indicate food webs profoundly altered by fencing.

Despite these concerns, fences are a powerful tool for conserving and restoring wildlife in landscapes that are highly modified by human activity. In New Zealand, where invasive species extirpated mainland populations of species such as the hihi, fencing of Maungatatauri and other sites has facilitated the creation of "mainland islands" free of invasive species, allowing restoration of native fauna (*12*). Likewise, in South Africa more-or-less intact (albeit highly managed) assemblages of large mammals have been restored in fenced areas of former farmland at reserves such as Ithala and Pilanesberg, and these areas are increasingly viewed as nuclei for more extensive restoration efforts entailing progressive removal of fencing.

Where wildlife habitat remains extensive, however, alternative approaches will usually be more appropriate than large-scale fencing. A variety of approaches—including traditional farming practices such as herding, planned grazing, and crop guarding, as well as wildlife-sensitive land-use planning—can help to mitigate conflicts between people and wildlife without the need for fencing (*13*). Likewise, a combination of testing, vaccination, and meat preparation can prevent transmission of foot-and-mouth disease without the need to separate cattle from wildlife by fencing (*14*). Rather than enclosing wildlife, fences may be used to enclose small areas of intense conflict such as settlements, wells, or grain stores. Where rhinos need to be contained for their own protection, special fences that allow passage of other species have proven effective. Likewise, in North America, livestock fences have been constructed that allow passage of pronghorn. Even virtual fences have been developed for particular species; for example, scent marks have been used to constrain African wild dogs in an otherwise unfenced reserve (*15*). The wider applicability of such costly and labor-intensive approaches is uncertain.

Reconciling the needs of people and wildlife is a perpetual challenge, and separating the two may be appealing. Too often, however, fences are constructed without a realistic assessment of the costs and benefits. In the United States, growing populations of large carnivores and megaherbivores are conserved in unfenced reserves, showing that fencing is not a necessary condition for conservation of such species. As climate change increases the importance of wildlife mobility and landscape connectivity, fence removal may become an important form of climate change preparedness, and fencing of wildlife should become an action of last resort.

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NEUROSCIENCE

The Michael Jackson Fly

A pair of neurons in the CNS of flies controls and coordinates their ability to walk backward.

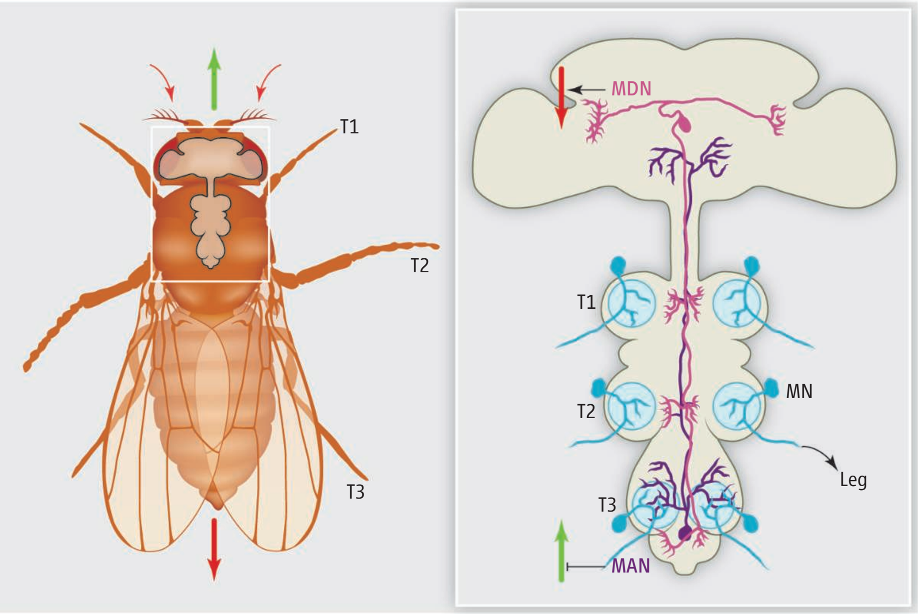
Richard S. Mann

Although most of us are more comfortable walking forward, in part because we can see where we are going, people also have the capacity to walk, and even run, in a backward direction. This skill comes in handy when we get stuck in tight dead-end spaces and is even a trendy exercise routine for some (*1*). Perhaps most famously, Michael Jackson immortalized the move in his iconic moonwalker dance. Not surprisingly, the capacity for backward locomotion is not limited to humans and now, thanks to elegant experiments carried out in the fruit fly by Bidaye *et al.* and reported on page 97 of this issue (*2*), we have some understanding of how animals choose between forward and backward locomotion.

Experimental systems as diverse as mice, locusts, stick insects, and flies have taught us a lot about the kinematics and underlying neural control of forward walking (*3*–*7*). Each leg joint is controlled by motor neurons triggering contractions of opposing flexor and extensor muscles. The challenge for the nervous system, and perhaps more so for a six-legged fly compared to the two-legged Mr. Jackson, is to coordinate each of these joint bends, both within a leg (e.g., hip and knee) and between legs (e.g., left and right). Interneurons acting locally within the central nervous system (CNS), where the motor neuron cell bodies reside, somehow coordinate all of these limb movements, assisted by sensory neurons in the legs that report load and joint angle back to the CNS (*7*, *8*).

Walking backward is not a simple reversal of walking forward: For example, when we walk forward or backward, our knees bend the same way with each step, but the muscles in our hips that move our thighs work oppositely, depending on the direction (*9*). Such reversals in the movement of a proximal leg joint relative to more distal leg joints are also observed in backward-walking stick insects (*10*, *11*). In other words, when our brains tell our motor systems to change direction, they selectively modulate parts of the locomotor circuit. How do nervous systems manage to accomplish this?

To begin to answer this question, Bidaye *et al.* turned to the fruit fly to exploit its powerful genetic toolkit. They began by watching what happened to the locomotor behavior of flies in which different combinations of neurons were artificially activated. To execute this screen, the authors used the yeast transcription factor Gal4 and its cognate UAS binding site to drive the expression of the thermally activated cation channel TrpA1 in subsets of neurons. From about 3500 Gal4/UAS-TrpA1 transformed fly lines, each expressing TrpA1 in a stereotyped set of neurons, they found one line that caused flies to walk backward



A neural circuit for moonwalking. Flies walk forward (green arrow) or backward (red arrow) in response to sensory cues (small red arrows). MDN and MAN are neurons that control walking direction, presumably by indirectly coordinating the activities of motor neurons (MN) via the leg neuropil (blue circles).

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