sub-served by theta-band oscillations. For adults, equivalent category signals emerge quickly in already established semantic networks, which communicate through alpha-to-beta frequency channels and incorporate explicit top-down knowledge about our world[12]. In this way, adult brains can reach category decisions very quickly and efficiently, because they make use of already established neural pathways, which is beneficial for rapid object identification and navigation in a complex and constantly changing visual environment. But these ultra-rapid categorization skills based on predefined semantic networks come with costs. Always engaging the same brain pathways in similar ways each time we encounter a new object may trap us in repetitive thinking and stereotypical behavior. Also, we may make overhasty decisions and judgments that we may regret later. From this perspective, the rapid category signals in the alpha-to-beta band seen in adults may reflect our own idiosyncratic goal-driven, top-down projections on the visual world around us, which are the result of previous extensive learning processes. By contrast, the slower theta-based category signals seen in infants may be our innate rhythm for learning new associations, including category decisions, and thus more in-tune with the natural way we explore our visual reality and make sense of it[13,14]. The new study by Xie *et al.*[2] also reminds us that sometimes it could be useful to take a step back and break away from ever-existing structures and 'the way it has always been', to be able to look at our surroundings in novel ways. Or in other words, sometimes it's better to view the world through infants' eyes.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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Microbial biofilms: An ecological tale of Jekyll and Hyde

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The molecules of life can be double-edged, performing both beneficial and detrimental roles depending on the environmental context. New work reveals how the Jekyll and Hyde nature of nitric oxide shapes complexity in microbial biofilms, from ecological interactions to spatial structure.

We come to terms with the world around us through narratives. Stories contain and explain the complexity in our lives, allowing us to grapple with tragedy and uncertainty. In science, stories play an often-underappreciated role[1], enabling us to understand our oftentimes confusing observations and communicate challenging ideas to the next generation[2].

From religious texts to folk tales to superhero movies, few narratives garner more attention than the struggle between good and evil. This duality can be particularly complex, and in some ways

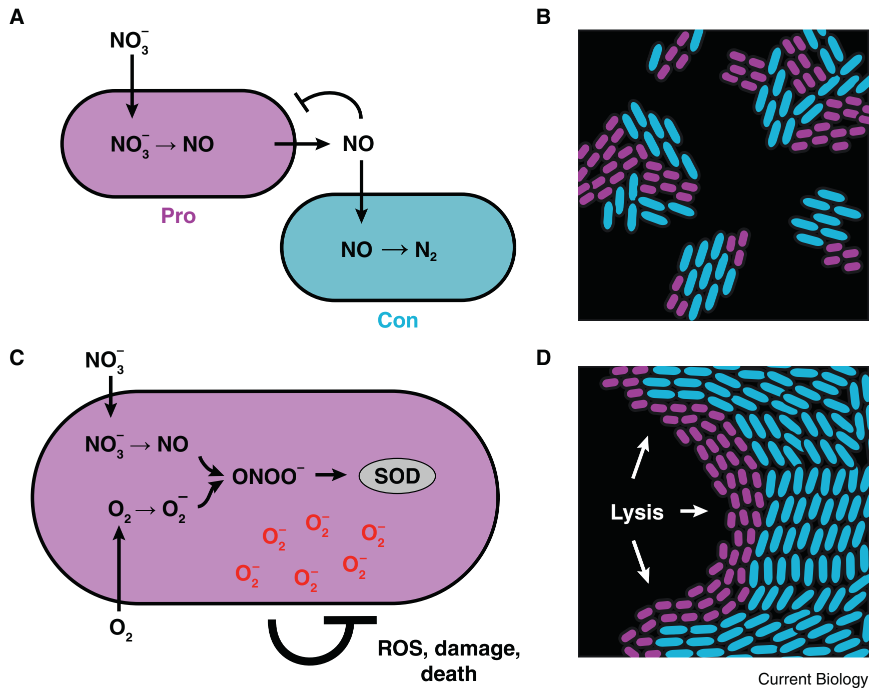

Figure 1. Nitric oxide (*NO*), a Jekyll and Hyde metabolite.
(A) Wilbert and Newman[3] engineered mutants of the denitrifier *Pseudomonas aeruginosa*: Pro, which converts NO_3^- to *NO*, and Con, which converts *NO* to N_2 under anaerobic conditions. (B) Because Pro is harmed by high concentrations of *NO*, and Con requires *NO* to grow, Pro and Con have a mutualistic relationship in anaerobic environments. (C) When Pro performs denitrification in a hypoxic environment, the combination of *NO* and superoxide (O_2^-) forms peroxynitrite ($ONOO^-$), which saturates the enzyme superoxide dismutase (SOD), resulting in damage due to reactive oxygen species (ROS) and cell death. (D) In hypoxic conditions, Con grows primarily by respiring O_2, while Pro requires Con to alleviate toxicity induced by the combination of *NO* and O_2. Thus, the relationship between Pro and Con is commensal, and Pro can survive only in the vicinity of Con.

truer to life, when it concerns the conflict that can exist within a single individual. Stevenson's Jekyll and Hyde, a respectable gentleman and a murderous psychopath both inhabiting the same body, illustrated this vividly, highlighting the complexities of being human through a powerful, if extreme, storytelling device.

An important new study by Wilbert and Newman[3] published in this issue of *Current Biology* invokes this narrative to open a window into understanding the staggering diversity and spatiotemporal complexity of microbial ecosystems. Microbes routinely and reproducibly self-organize into spatially structured communities comprising many species[4–6], and much prior work has focused on how positive ecological interactions, corresponding to the creation of redox-mediated metabolic niches, underly these structures. Wilbert and Newman instead provide an example of how some redox compounds have a distinctly Jekyll and Hyde quality, characterized by both positive and negative ecological interactions, and how this double-edged behavior provides at least a partial explanation for the complexity of microbial ecosystems.

In particular, Wilbert and Newman[3] shed new light on the *agathokakological* (from the Greek for "composed of both good and evil") nature of the compound nitric oxide (*NO*), and how it can give rise to spatial complexity in microbial biofilms. While it is well known that *NO* is an electron-accepting intermediate in the ubiquitous microbial process of denitrification[7], and therefore can play an important role in cellular energy generation in anaerobic conditions (the good), it is also the case that *NO* can be toxic[8], with the presence of oxygen amplifying that toxicity (the evil). The authors ask of this double-edged molecule: what, at the level of ecological interactions and reproducible spatial structures, comes out of the struggle between good and evil?

The authors began by creating a model system in which these primal forces could face off. This entailed genetically manipulating *Pseudomonas aeruginosa*, a tractable model organism capable of performing all the reactions of the denitrification cascade: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$. By knocking out genes, the authors generated two mutant *P. aeruginosa* strains, one that produces *NO* ('Pro', performing $NO_3^- \rightarrow NO_2^- \rightarrow NO$), and another that consumes it ('Con', $NO \rightarrow N_2O \rightarrow N_2$) (Figure 1A). The authors then demonstrated how this two-strain system brings out the Jekyll and Hyde in *NO*: when performing denitrification under anaerobic conditions, Pro generates *NO* as a toxic product that Con can use to grow, meaning that a mutualism between these two strains is necessary for the whole population to flourish (Figure 1B). In short, under anaerobic conditions, a dynamic duo of mutants defeats evil through a partnership that benefits both.

The relationship between these mutants hits a rough patch, though, when oxygen (O_2) enters the story. *P. aeruginosa* can respire O_2, and in fact prefers to do so over respiring *NO* via denitrification. However, in spatial gradients that form when a population locally depletes O_2 and begins denitrification, the combination of O_2 and *NO* can lead to far more toxicity than under purely anaerobic conditions. The authors demonstrated that the Pro strain takes the brunt of the punishment in this scenario, since it switches to denitrification from aerobic respiration quickly after O_2 levels decline, and therefore experiences a deadly intracellular mix of O_2 and *NO*. Using dyes that sense *NO* and superoxide (O_2^-), Wilbert and Newman[3] provided strong evidence that excess toxicity is due to the spontaneous conversion of *NO* into peroxynitrite ($ONOO^-$), which saturates the enzyme superoxide dismutase, preventing it from fulfilling its critical role in detoxifying reactive oxygen species (Figure 1C).

Thus, the relationship between Pro and Con becomes fairly one sided when both O_2 and *NO* are involved. Because Con can generate energy through aerobic respiration, it has no need for Pro. However, the opposite is not true, since Pro, though also capable of aerobic respiration, quickly begins to kill itself after generating toxic *NO* and requires Con to intervene. This much-diminished partnership predicts that, in a spatially extended context, Pro can only survive if it is in close proximity with Con. Indeed, by imaging fluorescently labeled Pro and Con strains in oxic biofilms, Wilbert and Newman[3] observed that the only Pro cells saved from lysis are those found within a few cell lengths of Con (Figure 1D).

Work remains to demonstrate the relevance of the authors' observations to microbial communities in nature. While truncated denitrification pathways are highly prevalent in the wild[9,10], and it is no doubt true that gradients of aerobic respiration and denitrification occur often, it is still not known whether, or in what environmental context, Pro- and Con-like strains form spatial structures driven by the double-edged effects of *NO*. Despite this, Wilbert and Newman's work represents a crisp experimental demonstration of *NO*'s potential as a force for sculpting spatial complexity.

The story of Pro, Con and *NO* adds to a growing list of agathokakological compounds in microbial ecology. For example, at low concentrations, antibiotics can have physiological impacts far different than their presumed inhibitory functions, even serving to facilitate communication between cells[11]. Similarly, phenazines and other redox-active metabolites can function either as deadly antifungals or as molecules that promote growth by facilitating nutrient acquisition and redox balance, depending on the context[12]. Other molecules important to primary microbial metabolism can also play Jekyll and Hyde, for example with the oxidation of sulfide supporting phototrophic growth at low concentrations but causing toxicity at high concentrations[13], and similarly the reduction of nitrite supporting anaerobic respiration but causing toxicity at low pH[14]. In the former case, the dual roles of sulfide can spatially structure populations, and, in the latter, the toxicity of nitrite promotes the division of labor over multiple populations.

Wilbert and Newman's work reveals that the dual nature of metabolites can create complexity and nuance. Just as narratives help us to understand our own experiences, a story of good and evil helps us to make sense of the complexities of the natural world.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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Pollinator conservation: Where will bees go in the Anthropocene future?

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For pollinator conservation in human-transformed landscapes, it is crucial to know whether species can overcome gaps between fragments of natural habitat. A new study reveals why colony size, recruitment communication, and flower constancy increase the foraging ranges in social bees.

The bees, a group comprising more than 20,000 known species[1], are the most important pollinators of both native plants and crops[2]. The worldwide decline of bee populations over the past decades has been associated with a deadly cocktail of interacting anthropogenic stressors, including the destruction of natural habitat, climate change, increasing exposure to agrochemicals, and, concomitantly, a reduced disease resistance[2,3]. The