In addition, these results raise two hypotheses for the biological role of these proteins. First, because they participate in intracellular accommodation in the two symbioses, the role of these LYRIA proteins in plants might be to host microbial partners intracellularly. Secondly, the complementation of the *nfp* and *nfr5* mutants by the tomato and petunia proteins raises the question of the specificity of Nod factor recognition by the legume proteins. We can thus suppose that the Solanaceae proteins are specifically recognizing the general LCO structure, but not the CO molecules, as shown in this work. However, they probably do not participate in the specific recognition of the LCO decoration, which is responsible for the rhizobium strain specificity. Other LysM-RLK like Lyk3 (*M. truncatula*) or NFR1 (*L. japonicus*) or NF hydrolases [16] might be responsible for this specificity.

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Neuroscience: Reevaluating the Role of Orbitofrontal Cortex

Brianna J. Sleezer[1] and Benjamin Yost Hayden[2,*]
[1]Department of Neurobiology and Behavior, Cornell University, Ithaca, NY 14853, USA
[2]Department of Neuroscience, Center for Magnetic Resonance Research, Center for Neuroengineering, University of Minnesota, Minneapolis, MN 55455, USA
*Correspondence: hayde138@umn.edu
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A new optogenetic lesion study shows that the orbitofrontal cortex is essential for integrating information about recent rewards — which may either increase or decrease demand for more — with learned preferences to drive behavior.

To behave effectively, humans and other foragers must constantly incorporate new information about the external world and their internal desires with previously learned information about values, tradeoffs, and structures in the world [1]. For example, one may normally enjoy eating a turkey sandwich for lunch, but after eating turkey leftovers at every meal following Thanksgiving, the thought of eating another turkey sandwich may seem almost unbearable. A study reported in this issue of *Current Biology* by Gardner *et al.* [2] suggests that a brain region known as the orbitofrontal cortex (OFC) may be responsible for this post-Thanksgiving turkey aversion and, more generally, may play a critical role in these sort of revaluation processes in which new information must be incorporated into existing patterns of behavior.

The OFC has been linked to several neuropsychological disorders, including addiction, depression, and obsessive-compulsive disorder, and it is also thought to play an important role in economic choice [3]. But the specific contribution of the OFC to behavior is somewhat contentious. Over the past 20 years, scholars studying this region have focused on two major competing theories. On the one hand, a good deal of evidence supports the idea that OFC plays a simple and direct role: that it is the unique and core site for evaluation and/or comparison of options in economic choice processes [4]. On the other hand, other studies emphasize more complex roles, which include complex representations of possible action–outcome mappings and revaluation in rapidly changing environments [5]. This second view, supported by the new findings of Gardner *et al.* [2], emphasizes the important difference between well-established and well-learned aspects of choice and new, unfamiliar, and rapidly changing aspects, which seem to demand more mental resources. The simpler economic view, on the other hand, does not generally distinguish between these, and focuses instead on the conceptually basic elements of evaluation, comparison, and selection [6].

The study by Gardner *et al.* [2] is the third and capstone of a series of three studies that address this debate (see also [7,8]). In the first two, the authors found that neither of two sub-regions of OFC is essential for economic choice processes. While those results raised the possibility that OFC may play some other role in economic choice, it was unclear exactly what that role was until the present study. To further probe the role of OFC in economic choice, the authors used a technique known as optogenetic inhibition, which, through viral methods, allowed them rapidly, selectively, and temporarily to silence neurons in the lateral OFC in rats (this region is a likely homologue of the primate region generally known as OFC [9]). In these experiments, rats made choices in an implementation of a classic neuroeconomic task. Specifically, on each trial, a rat could choose between two bundles of goods (allocations of pellets that differed in regard to the number of pellets offered and their flavor).

A key innovation in the Gardner *et al.* [2] study was the use of a pre-feeding paradigm. Like the post-Thanksgiving fridge forager, rats will eventually satiate on any food if they have had enough of it. This satiation process is a good tool for distinguishing between hypotheses of OFC function because it requires integrating new information (what food the rat ate recently) with old information (what food the rat likes). The authors then took advantage of a lesser known, but scientifically convenient, fact about pre-feeding in rats: pre-feeding can, for some options, increase preferences, which the authors refer to as an appetizer effect. More specifically, the authors found that pre-feeding a preferred food option enhanced responding toward that option (appetizer effect) and pre-feeding a non-preferred option reduced responding toward that option (satiation or devaluation effect).

Gardner *et al.* [2] were able to demonstrate that inactivation of lateral OFC abolishes the effects of pre-feeding: that is, it reduces the ability of past rewards to appetize or to satiate. In other words, it seems to prevent rats from using recent information to bias their choices, and forces them to rely solely on learned preferences. Because their post-pre-feeding preferences are consistent with baseline preferences following inactivation of lateral OFC, information about previously established choices appears to be retrieved without issue, suggesting that this information is likely stored in a site distal to lateral OFC.

The combination of appetizing and satiating effects is important because it isolates the effects of past outcome from the direction of the effect. That is, OFC is neither a brake nor an accelerator — instead, it facilitates decision making by integrating past information into ongoing choice processes, regardless of the direction in which past information shifts choice preferences. This is an important finding given that previous influential theories of OFC function emphasize the role of OFC in inhibition or the suppression of learned values based on recent information [10]. These results also tie into others highlighting the critical role of OFC in economic choice after revaluation and with previous work demonstrating that neural representations in OFC update to reflect integration of new information (for example [11]).

If OFC does not implement these basic choice processes, then what does? The medial OFC/ventromedial prefrontal cortex seems like an unlikely candidate as well, given the team's null lesion findings in a past study [7]. Indeed, this region appears to be more involved in complex elements of choice, such as integrating past and present information (for example [12,13]). Another likely suspect is the ventral striatum/nucleus accumbens (NAc). However, a recent integrative review [14] concludes that NAc, much like OFC here, does not play a critical role in simple choices, but rather is crucial when the most appropriate course of action is ambiguous, uncertain, laden with distractors, or rapidly changing. That work, in our view, has much in common with the set of studies by Gardner and colleagues [2,7,8], and raises the possibility that no one site houses simple economic choice (an idea also proposed in [7]).

Indeed, it may be a mistake to look for a single brain region that is specialized for economic choice processes. Instead, it is possible that evaluation and comparison are brain-general properties that reflect the integration of multiple sources of information from multiple systems, call upon distributed representations, and, for simple choices, are robust to damage in any one region [15]. That is, attempts to find the single site of choice through individual lesion studies may feel like a game of whack-a-mole because there may be no single site. This is not to say OFC does not participate in choice — its neural signals suggest it does exactly that [5]. Instead, it may simply be non-essential for the simplest cases of economic choice because other brain areas can pick up the slack when OFC activity is impaired. In this case, the unique role of OFC may only be uncovered when the task gets more difficult and specialized processing comes to the fore.

It seems unlikely that OFC's function is now fully solved. Identifying the essential function of OFC, then, requires more experiments like this one. Such work is essential for understanding and integrating other tantalizing findings, such as those indicating that the OFC participates in more complex processes, including prospective simulation of future outcomes [16,17], abstract mapping [18,4], tracking of hypothetical outcomes [19], and maintenance of task-relevant rules [20].

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Mitochondria: A Microcosm of Darwinian Competition

Bryan L. Gitschlag[1] and Maulik R. Patel[1,2,*]
[1]Department of Biological Sciences, Vanderbilt University, Nashville, TN 37232, USA
[2]Department of Cell and Developmental Biology, Vanderbilt University Medical Center, Nashville, TN 37232, USA
*Correspondence: maulik.r.patel@vanderbilt.edu
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Resource limitation underlies competition in the living world, even between intracellular populations of mitochondria. A new study shows that reducing the availability of an essential cellular resource, namely the enzyme that replicates mitochondrial DNA (mtDNA), can alter the selective advantage of one mtDNA type over another.

In his publication *On the Origin of Species*, Charles Darwin remarked that competition over limited resources underlies natural selection. Through a division of labor, collaborating for mutual benefit allows for efficient utilization of resources. Hence, competition for survival and reproduction can select for mutualistic symbiotic relationships. Among the most successful symbiotic relationships in the history of life was the endosymbiosis that led to the formation and evolution of eukaryotic organisms. The success of this relationship is predicated on cooperation for mutual benefit: mitochondria supply energy to the

