Check for updates

NEUROSCIENCE

Encoding identity in the marmoset

Hippocampal cells integrate multisensory input to represent the identity of others

By **Sylvia Wirth**

Humans identify other individuals using traits including their face, voice, or gait. By combining these perceptual cues with semantic information, such as the person's name and memories of previous encounters with that person, humans form a conceptual representation of the other's identity. Neurons in the hippocampus—a brain region involved in memory—can bind this multimodal information into a distinct conceptual representation of another's identity by responding equally to different views of a person's face and reading or hearing their name (*1*). On page 417 of this issue, Tyree *et al.* (*2*) report that such multisensory integration is not specific to humans. In the marmoset (*Callithrix jacchus*), they identified single neurons and distributed population-based codes that represented the identity of another marmoset upon viewing their face or hearing their vocalization. By revealing similarities and differences across species, the findings prompt questions about the universality of hippocampal computational principles.

Primates, including humans, have specialized cortical networks that are dedicated to processing facial features. However, individuals with prosopagnosia, a neurological condition that impairs face recognition, can identify familiar individuals on the basis of their voice or clothing (*3*). This suggests that the brain integrates various sensory elements across the anatomically localized systems that primarily process unimodal features. How does the brain accomplish such a meta-representation? Previous work established that the hippocampus fosters binding of multimodal information in humans (*4*).

A hallmark of information binding are concept cells, which respond to different pictures of the same person (for example, front or profile views of the person in different clothing and with a different facial expression) and to their spoken name, thereby encoding the concept of their identity rather than the individual perceptual features (*1*). However, although the hippocampus is an evolutionarily conserved structure, only unimodal representation of others (as in, separate populations of cells responding to either faces or voices of other individuals) had been described in nonhuman animals (*5*). This has hindered investigation of whether common neuronal mechanisms underlie the recognition of identity across species, which is important given the use of animal models in clinical research.

Tyree *et al.* found cells in the marmoset hippocampus that respond to the face and the vocalizations of familiar marmoset individuals, much as human concept cells respond to the face and the name of other humans. The presence of these cells in the marmoset, which diverged from the evolutionary path of humans nearly 40 million years ago, suggests that there is an evolutionarily rooted ability of the hippocampus to create abstract neural representations of another's identity. Ecologically relevant stimuli may be necessary for experiments to reveal such neuronal properties, which might explain previous failed attempts to detect multimodal identity representation in other nonhuman species. Indeed, marmosets, which live in close family groups, exhibit a rich acoustic communication that they use to maintain contact when foraging in forests (*6*).

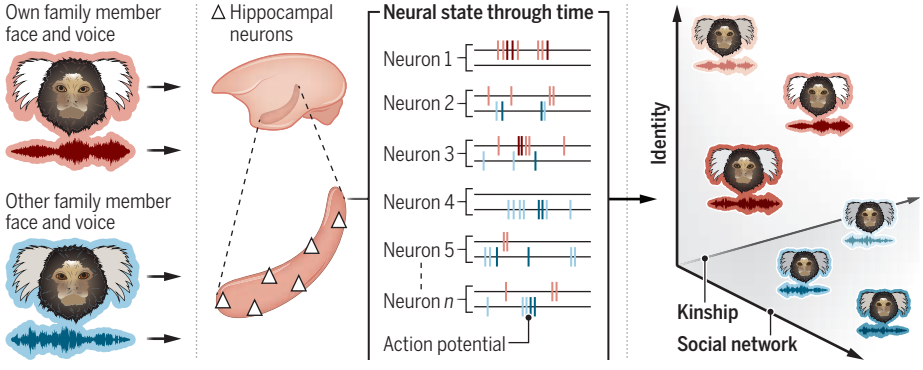
The observation of concept-like cells in a species lacking symbolic language builds on previous examples of abstraction in the macaque hippocampus (*7*, *8*). These examples include the observation that neurons encode the logical organization of recurring elements across different spaces (*7*) and form an abstract map of the relative value between different rewards (*8*). This reinforces the view that the hippocampus builds higher-level representations of elements that make up the animal's environment. Whether the concept-like cells in the marmoset could reach a semantic level of acoustic communication is an intriguing question because some primate species have adapted existing calls to signal the presence of categorically related (air or ground) but previously unseen types of predators (*9*).

In addition, Tyree *et al.* found that hippocampal cells in the marmoset encode sets of associated identities, which accounts for social networks, such as family groups. Similarly, concept cells in the human respond to conceptually related items (for example, characters from the same movie), thereby representing the learned relationship among elements (*10*). This capacity of concept cells implies that elements of an experience can be represented by combinatorics (akin to the assemblage of letters into words) by adjusting neuronal selectivity to nest individuals within larger groups.

A similar fine-grained representation of social identity was recently observed in the hippocampus of bats (*11*), whose evolutionary lineage diverged from that of humans about 95 million years ago. Wireless recordings during bat flights identified hippocam-

Encoding multimodal identity

Following an acoustic (vocalization) or a visual (face) stimulation, hippocampal neurons in the marmoset encode an abstract representation of identity. In addition, variations in the moment to moment state of the neural population encode identity, kinship and position within the social network.



GRAPHIC: A. MASTIN/*SCIENCE*

Institut des Sciences Cognitives Marc Jeannerod, Centre National de la Recherche Scientifique, Bron, France. Email: sylvia.wirth@isc.cnrs.fr

Downloaded from https://www.science.org at University of California San Diego on October 04, 2026

pal cells that encoded the presence of specific individuals at landing sites, depending on their proximity in the social network (socially close bats were represented more often compared with socially distant bats). Activity of hippocampal cells in stationary bats was also slightly modulated by the echolocation calls of other bats, suggesting some degree of multimodal representation. In both bats and marmosets, the socially modulated neurons were anatomically dispersed in the hippocampus, confirming previous findings in humans (*1*). Thus, in phylogenetically distant species, fine-grained social signals are represented at all stages of information processing within the hippocampal circuitry, which likely facilitates the incorporation of social information in new memories.

In addition to selective concept-like cells, Tyree *et al.* identified distributed population codes for the representation of multimodal identity, which challenges the current understanding of hippocampal computational principles. These distributed codes, which have not yet been observed in the human hippocampus, enable the extraction of identity from differences in the moment-to-moment state of the neuronal population in response to multiple stimuli over time, rather than from the selectivity of single neurons for a specific stimulus (see the figure). This observation in the marmoset is supported by data from bats and rats (*12*, *13*), whose hippocampal place cells—once thought to represent a single position within a space—have been found to represent multiple positions when animals move within large spaces. Such findings suggest that the representation of place emerges from distinct states of the broader population of place cells. Overall, these observations have implications for understanding computational efficiency across different contexts and species. These findings also reveal what could be important species-specific idiosyncrasies, suggesting that in nonhuman animals, representation of information in the hippocampus may depend less on the selectivity of individual neurons than it does in humans (*14*). Whether this reflects differences in cognitive ability is not yet clear. ■

REFERENCES AND NOTES

1. R. Q. Quiroga *et al.*, *Nature* **435**, 1102 (2005).
2. T. J. Tyree *et al.*, *Science* **382**, 417 (2023).
3. B. Rossion, *Neuropsychologia* **173**, 108278 (2022).
4. B. Mišić *et al.*, *PLOS Comput. Biol.* **10**, e1003982 (2014).
5. J. Sliwa *et al.*, *Cereb. Cortex* **26**, 950 (2016).
6. C. T. Miller *et al.*, *Am. J. Primatol.* **72**, 974 (2010).
7. P. Baraduc *et al.*, *Science* **363**, 635 (2019).
8. E. B. Knudsen, J. D. Wallis, *Cell* **184**, 4640 (2021).
9. F. Wegdell *et al.*, *Nat. Ecol. Evol.* **3**, 1039 (2019).
10. E. De Falco *et al.*, *Nat. Commun.* **7**, 13408 (2016).
11. A. Forli, M. M. Yartsev, *Nature* **621**, 796 (2023).
12. T. Eliav *et al.*, *Science* **372**, eabg4020 (2021).
13. H. Zhang *et al.*, *Nat. Neurosci.* **26**, 131 (2023).
14. R. Q. Quiroga, *Hippocampus* **33**, 616 (2023).

10.1126/science.adk8413

GRAPHIC: N. CARY/*SCIENCE*

CHEMISTRY

Interconverting mirror-image molecules

A light-driven multitasking catalyst enhances chirality in molecular mixtures

By **Sojung F. Kim** *and* **Richmond Sarpong**

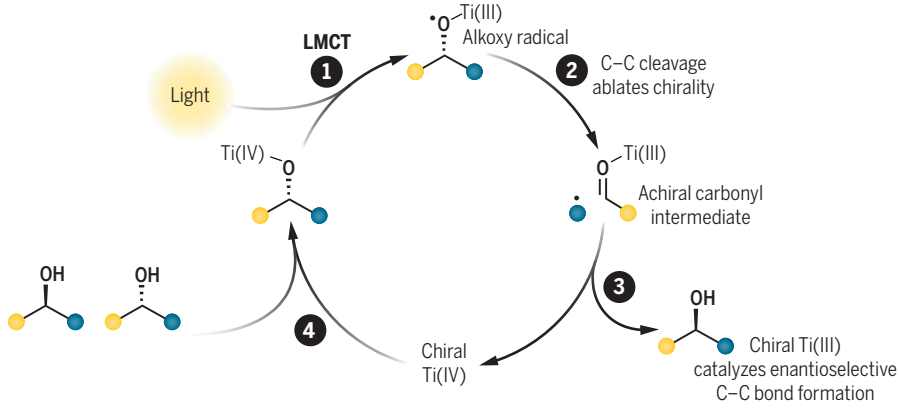
Enantiomers, though simply mirror-image molecules, can cause considerably different biological effects. Therefore, pharmacological and bioactive compounds may require separation (resolution) of one enantiomer from a racemic or scalemic mixture (equal or unequal mixtures of enantiomers, respectively). Most resolutions achieve enantiomeric enrichment by sacrificing 50% of, or chemically modifying, the material (*1*). Direct deracemization (the 100% conversion of a mixture to a single enantiomer) would be conceptually ideal. However, there are substantial barriers to realizing such a strategy, and highly selective deracemizations remain rare. On page 458 of this issue, Wen *et al.* (*2*) present a light-driven deracemization of alcohols using a single chiral titanium (Ti) catalyst that breaks and remakes carbon–carbon (C–C) bonds to achieve high levels of enantiomeric excess across a broad range of substrates by combining two enantioselective processes into one reaction. Such deracemizations could enable precise control of chirality in complex molecules.

Deracemizations face two main challenges. They increase order in the system (decrease entropy) without releasing energy (no change in enthalpy) because enantiomers are equal in energy. The result is that deracemizations are endergonic processes—energy is required to drive the reaction in the desired direction (*1*). Moreover, the principles of microscopic reversibility and detailed balance dictate that at equilibrium, forward and reverse processes occur at the same rate and by microscopically identical chemical steps in opposite directions (*3*). Any equilibrium process that converts one enantiomer to the other just as easily converts the desired enantiomer back to the undesired one, resulting in a racemic mixture. Thus, deracemizations require distinct mechanisms for the removal and formation of stereocenters (where a chiral carbon is bonded to four distinct groups in the molecule).

These thermodynamic and kinetic requirements can be met by designing redox-driven deracemizations, for example, to deracemize mixtures of indolines or tetrahydroisoquinolines (*4*, *5*), which are specific nitrogen-containing molecules with pharmacological importance. However, redox deracemizations require the consumption of a larger amount of reagents than is desirable. Photochemistry provides a nonequilibrium alternative be-

A multifunctional catalyst converts alcohols into their mirror image

A chiral titanium (Ti) catalyst selectively enriches a mixture of enantiomers. A light-mediated ligand-to-metal charge transfer (LMCT) process excites the Ti(IV)-alcohol complex and generates Ti(III) and an alkoxy radical (**1**). The C–C bond in the alkoxy radical is broken, which results in an achiral carbonyl intermediate (**2**). The generated Ti(III) complex enantioselectively catalyzes C–C bond formation to yield the desired alcohol enantiomer (**3**). The Ti(IV) catalyst is regenerated to restart the process and preferentially binds the undesired enantiomer (**4**).



Downloaded from https://www.science.org at University of California San Diego on October 04, 2026

Science
AAAS

Encoding identity in the marmoset

Sylvia Wirth

Science **382** (6669), . DOI: 10.1126/science.adk8413

View the article online
https://www.science.org/doi/10.1126/science.adk8413
Permissions
https://www.science.org/help/reprints-and-permissions

Downloaded from https://www.science.org at University of California San Diego on October 04, 2026

Use of this article is subject to the Terms of service

Science (ISSN 1095-9203) is published by the American Association for the Advancement of Science. 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.

Copyright © 2023 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works