News Release

Diversity of Oligodendrocytes Supports Sound Localization in the Brain

Key Points

- The research team discovered that oligodendrocytes distributed along axons in the brainstem auditory circuit, which integrates sound information from both ears with microsecond precision, differ in their morphology and density across regions.
- These regional differences in oligodendrocytes enable precise control of signal conduction velocity along axons, thereby supporting sound localization—the ability to detect the direction of sound sources.
- Although the diversity of oligodendrocytes distributed throughout the brain has been known, this study revealed that such diversity can contribute to information processing in local neural circuits and suggested the existence of an unknown mechanism that allocates diverse oligodendrocytes to appropriate locations.

Summary

A research group led by Assistant Professor Ryo Egawa and Professor Hiroshi Kuba of the Department of Cell Physiology, Nagoya University Graduate School of Medicine, in collaboration with Professor Dai Watanabe of Kyoto University, has discovered that the diversity of oligodendrocytes supports precise sound localization in the brain.

Oligodendrocytes are glial cells that wrap their processes around neuronal axons to form myelin sheaths, which enable saltatory conduction—a mode of electrical signal propagation that can increase conduction velocity up to 100-fold. The conduction velocity depends on the spacing of Ranvier nodes, the small unmyelinated gaps between myelin sheaths. However, it has remained unclear why the spacing between nodes varies not only among brain regions but also along individual axons.

Using the chick brainstem auditory circuit, which detects tiny time differences in sound arrival between the two ears, the team visualized the entire three-dimensional structure of the circuit by optical tissue clearing. They found that differences in node spacing were not determined by axonal geometry, such as diameter or branching, but reflected regional variations in oligodendrocyte morphology and density. Furthermore, when neuronal activity was artificially suppressed, the overall spacing pattern remained unchanged, but the generation of new oligodendrocytes near synaptic regions decreased,

producing unmyelinated segments along the axons. These results indicate that intrinsic differences in myelin-forming capacity between regional oligodendrocytes primarily determine node spacing, while neuronal activity indirectly contributes by regulating oligodendrocyte density.

This study demonstrates that the diversity of oligodendrocytes—long known to exist in the brain—plays a critical role in local circuit computation, supporting precise auditory signal processing for sound localization.

Research Background

Sound localization allows animals, including humans, to identify where a sound originates. This ability relies on detecting microsecond-level differences in the arrival times of sounds at the left and right ears (known as interaural time differences, ITDs). The underlying neural mechanism resides in the brainstem auditory circuit, where signals from both ears converge and are integrated with remarkable temporal precision.

In birds such as chickens, the auditory nerve transmits sound information to the nucleus magnocellularis (NM), whose axons project bilaterally to the nucleus laminaris (NL) (**Figure 1**). Within this circuit, the spacing of Ranvier nodes along NM axons differs across regions, producing regional variations in conduction velocity that are essential for detecting ITDs (**Figure 2**). While this spatial bias has been recognized, the cellular mechanisms shaping it have remained unexplored.

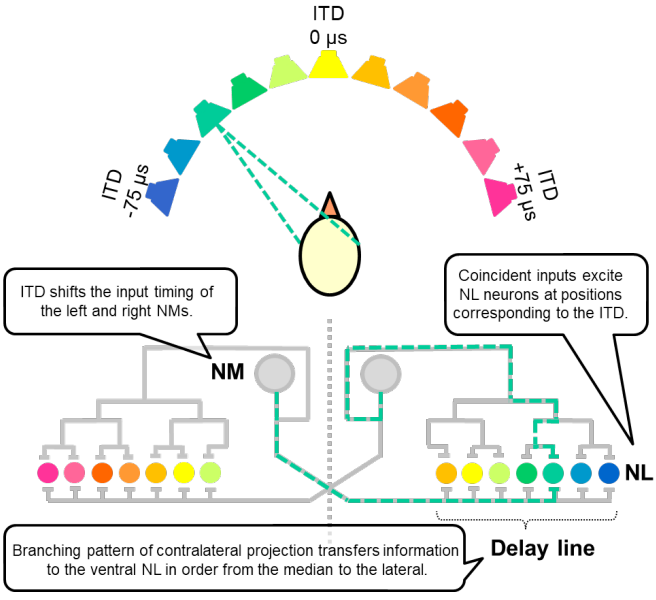

Figure 1. Avian brainstem auditory circuit detecting interaural time difference.

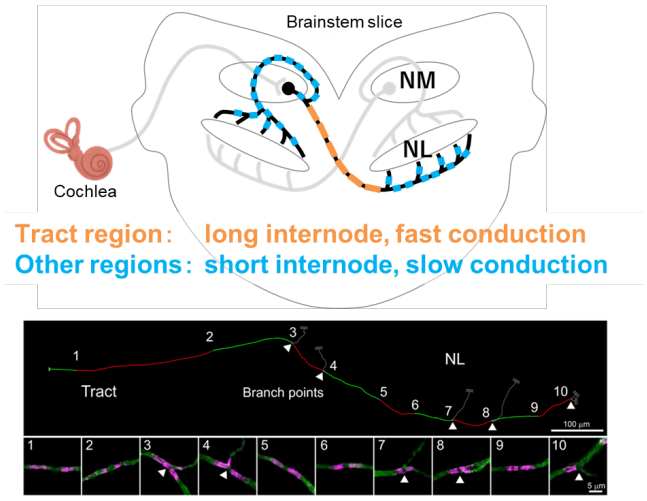

Figure 2. Regional differences in Ranvier node spacing along the NM axon.

Research Results

By expressing fluorescent proteins in both axons and oligodendrocytes in chick embryos and using tissue clearing, the researchers revealed their three-dimensional structures (**Figure 3**). The number and length of myelin sheaths, cell body size, and density of oligodendrocytes differed significantly between regions of the same axons (**Figure 4**). In contrast, axonal structure, including branching points and diameter, did not account for the observed differences in node spacing. When synaptic activity was suppressed using a genetic silencing tool, the morphology of individual oligodendrocytes and the node spacing pattern remained unchanged. However, oligodendrogenesis, the generation of new oligodendrocytes from progenitor cells, was reduced near synaptic regions, resulting in unmyelinated segments along the axons (**Figure 5**). These findings show that regional differences in the intrinsic properties of oligodendrocytes shape the biased node spacing pattern, while neuronal activity ensures full myelination through local enhancement of oligodendrogenesis.

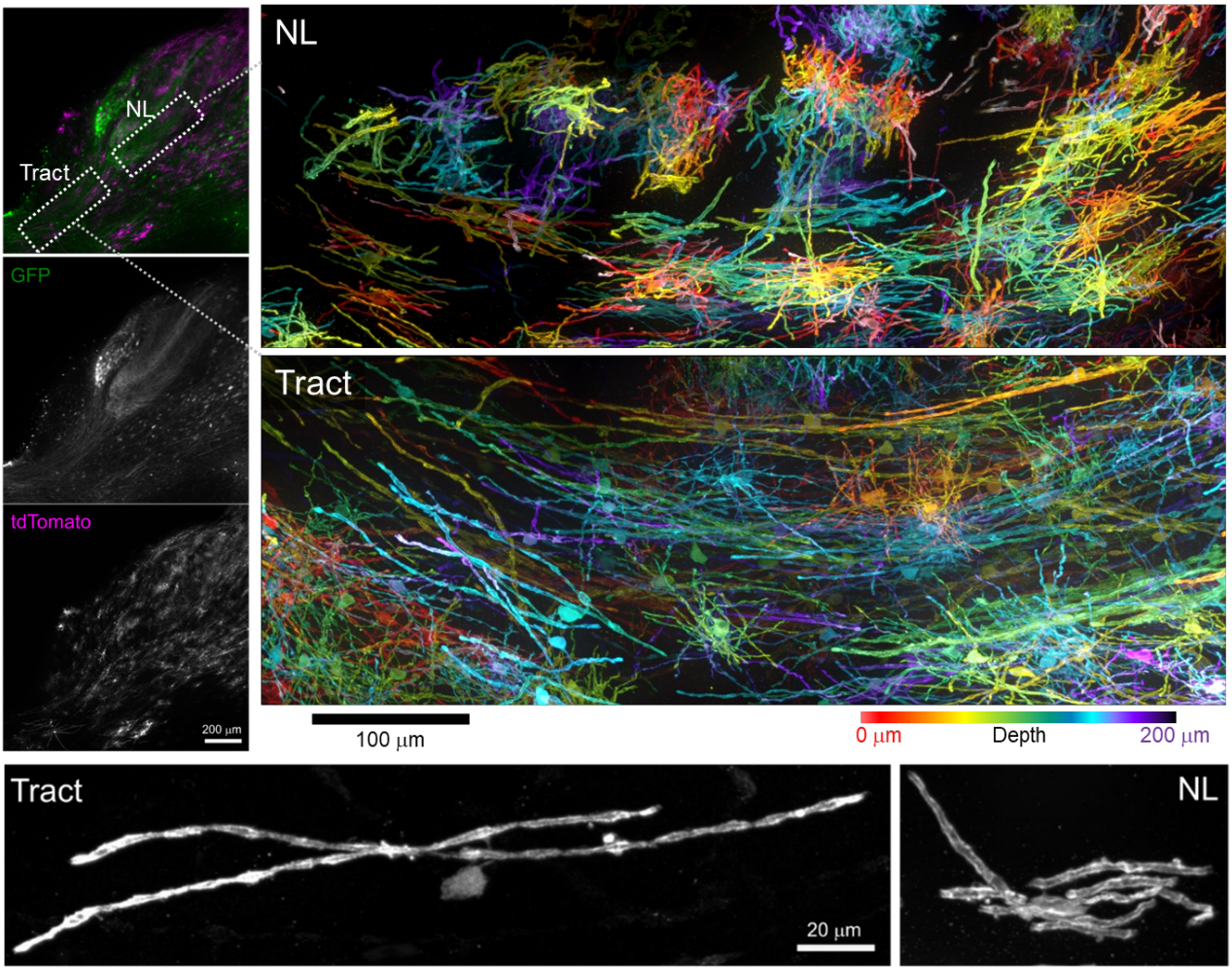

Figure 3. Sparsely labeled oligodendrocytes.

Research Summary and Future Perspective

Oligodendrocytes were once thought to form a uniform population, but recent research has revealed extensive heterogeneity in their morphology and gene expression. This study provides the evidence that such cellular diversity contributes functionally to local information processing within the brain. Understanding how diverse oligodendrocyte types are generated and positioned in appropriate regions will be key to uncovering the mechanisms governing neural circuit precision. Moreover, elucidating how oligodendrocytes contribute to circuit function will advance our understanding of demyelinating diseases such as multiple sclerosis, which cause sensory and cognitive impairments. Further investigation into when, how, and by what signals these region-specific differences in oligodendrocytes are established may reveal the unknown mechanisms that allocate distinct oligodendrocyte types to specific neural circuits.

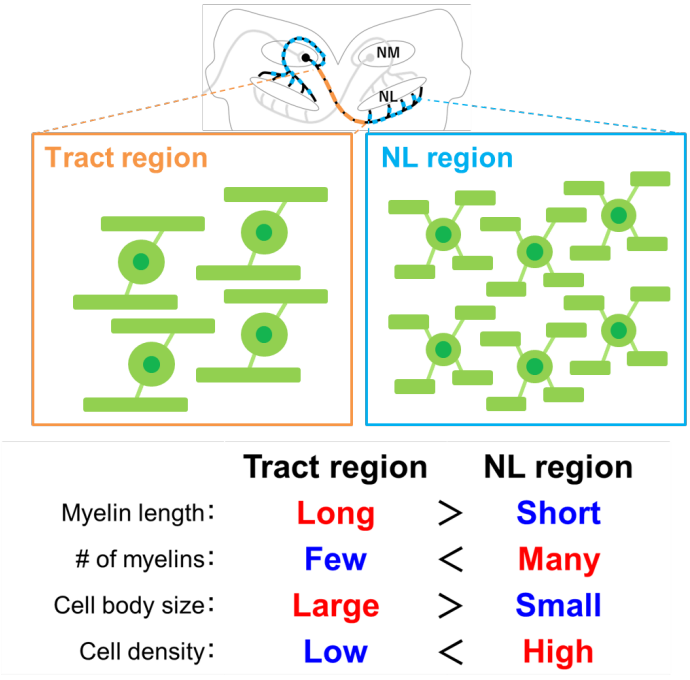

Figure 4. Regional differences in oligodendrocytes within the brainstem auditory circuit.

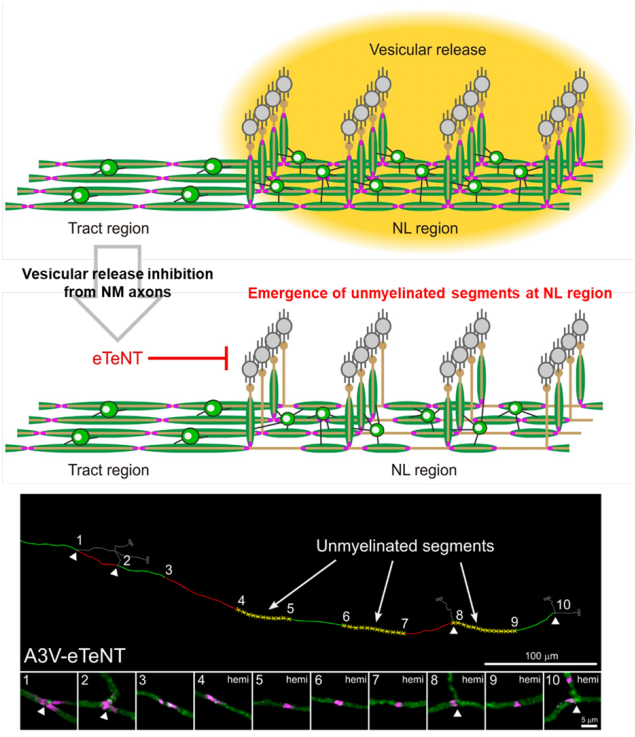

Figure 5. Suppression of neural activity reduced oligodendrocyte density.

Publication

Journal: eLife
Title: Regional heterogeneities of oligodendrocytes underlie biased Ranvier node spacing along single axons in sound localization circuit
Authors: Ryo Egawa, Kota Hiraga, Ryosuke Matsui, Dai Watanabe, and Hiroshi Kuba

DOI: 10.7554/eLife.106415

Japanese ver.
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