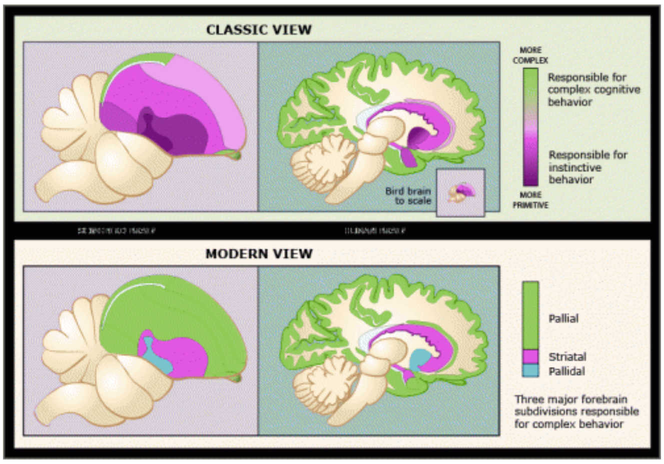
Study finds mammalian and avian brains share corticosensory microcircuit

23 February 2015, by Christopher Packham



Credit: Zina Deretsky,NSF, via http://avianbrain.org

The canonical cortical microcircuit of mammalian brains governs information flow among the brain's layers and gives rise to complex behaviors. Researchers at Columbia University have proposed that this microcircuit also exists in avian brains, despite the fact that avian brain physiology is not characterized by the same layered architecture as mammalian brains. They have published their results in the *Proceedings of the National Academy of Sciences* in a paper titled "Coding principles of the canonical cortical microcircuit in the avian brain."

The cognitive abilities of birds have been documented in numerous experiments. Corvids, such as crows, rooks and jays exhibit many complex behaviors analogous to those of mammals, including:

- Referential gesturing
- Causal reasoning
- Mirror self-recognition
- Planning for future needs based on recent experience

Nonetheless, the anatomical structure of avian brains bears considerable differences from that of mammalian brains. While mammals' brains exhibit a laminar, or many-layered structure, the avian pallium is instead composed of interconnected nuclei with bands of neurons that comprise processing regions.

Comparative neurological study

To compare the functions of these different avian structures to those of mammals, researchers recorded the activity of auditory neurons in the brains of six head-restrained and unanaesthetized male zebra finches. They evoked neural responses in the birds by the presentation of 10 distinct samples of zebra finch songs, recording neural responses in the auditory cortex and in the caudal nidopallium, a secondary auditory cortical region. Each of the 10 samples was presented 30 to 40 times in pseudorandom order.

The researchers recorded spikes of neural activity in response to the sound samples:

- All recorded single units were classified as putative interneurons or putative principal cells based on action potential width.
- Single-cell sparseness was computed as the sound-evoked firing rate of individual cells.
- Population sparseness was computed as the fraction of cells that did not fire in response to stimulus.
- Selectivity was computed as the fraction of different stimuli that did not elicit a significant response from a given neuron.

The researchers also studied characteristics such as spectrotemporal latency fields, the response latency for each neuron, and receptive field separability and linearity. Analysis of the results reveals that population-coding differences in brain regions, neuron classes, and across spatial distances in the avian brain are "strikingly similar to those in the neocortex."

The mammalian neocortex is known to have two major classes of neurons: excitatory principal cells (PCs) and inhibitory interneurons (INs). PCs fire wide action potentials at low rates; INs fire narrow action potentials at higher rates. To determine if the avian auditory cortex was similarly ordered, the researchers used a cluster analysis based on action potential shape and found that both classes of neurons were present in avian brains.

By characterizing the activity in specific sensory regions, the researchers determined that six discrete brain regions in the avian brain correspond to specific cortical layers in mammalian brains. As in the mammalian sensory cortex, thalamic projections to the primary auditory somatosensory cortex of avian brains terminate mainly in the intermediate region and sparsely in the deep region. Using multielectrode arrays, they determined further that hierarchical processing is a main feature of the avian auditory microcircuit, displaying the same information-processing activities observed in mammalian animal models.

They authors summarize their findings with three conclusions:

1. As in mammalian cortices, adjacent and connected regions of the avian auditory cortex form a hierarchy of information processing.
2. The same two classes of neurons are found in both the mammalian and avian cortex.
3. Neurons in the neocortex and in the avian cortex exhibit comparable single-cell and population-coding strategies across regions/layers, between neuron types, and over anatomical distances.

To explain their results, they cite the homology hypothesis of brain evolution. It suggests that the canonical cortical microcircuit evolved in a common ancestor of both mammals and avians, and its functions were preserved even as the architecture of the brain types diverged. "If so," they write, "then the microcircuit evolved in stem amniotes and predates cortical lamination by at least 100 million years."

Alternatively, they suggest that the pallium evolution of birds and mammals both converged on the same neuronal circuit organization as the simplest architecture for somatosensory processing. They write, "Regardless of these alternatives, this study provides a physiological explaination for the evolution of neural processes that give rise to complex behavior in the absence of lamination."

More information: Ana Calabrese and Sarah M. N. Woolley. "Coding principles of the canonical cortical microcircuit in the avian brain." *PNAS* 2015 ; published ahead of print February 17, 2015, DOI: 10.1073/pnas.1408545112