The brain of a praying mantis, one of the most dexterous of insects, possesses what is perhaps the most exquisitely structured central complex, revealing 9 distinct modules when visualized under a microscope (right).

The Strikingly Similar Brains of Flies and Men

Decision-making centers in the brains of insects and mammals share too many similarities to have evolved independently, according to comparative studies led by UA neuroscientist Nick Strausfeld. The findings may help better understand the mechanisms underlying diseases such as Parkinson's.

A fruit fly on a pencil tip.
Brain of a fruit fly in which a substructure of the central complex is visualized in green. Similar to the basal ganglia in vertebrates, the central complex mediates the selection and maintenance of behavioral actions. Abnormal function of these structures causes behavioral defects ranging from motor abnormalities to impaired memory formation, attention deficits, affective disorders and sleep disturbances.

Despite their differences in size and appearance, the brains of flies, mice and men rely on similar structures regulating comparable behaviors in a similar manner.

Video tracking allows researchers to follow fruit flies as they walk across agar plates in the lab. Here, a healthy fly was tracked as it walked all over the plate over the course of 3 minutes. A fly with a defective central complex, shown in photo c, exhibits Parkinsonism: It struggles to initiate and maintain movement.

A new study by scientists at the University of Arizona and King's College London published in Science reveals the deep similarities in how the brain regulates behavior in arthropods (such as flies and crabs) and vertebrates (such as fish, mice and humans).

The findings shed new light on the evolution of the brain and behavior, and may aid understanding of disease mechanisms underlying mental health problems.

Based on their own findings and available literature, Nicholas Strausfeld, a Regents’ Professor of Neuroscience at the UA and Frank Hirth of the Institute of Psychiatry at King’s College London...
compared the development and function of the central brain regions – the "central complex" in arthropods and the "basal ganglia" in vertebrates.

Research suggests that both brain structures derive from embryonic cells at the base of the developing forebrain and that, despite the major differences between species, their respective constitutions and specifications derive from similar genetic programs.

"When you compare the two structures, you find that they are very similar in terms of how they're organized," said Strausfeld. "Their development is orchestrated by a whole suite of genes that are homologous between flies and mice, and the behavioral deficits resulting from disturbances in the two systems are remarkably similar as well."

The authors describe that nerve cells in the central complex and the basal ganglia become interconnected and communicate with each other in similar ways, facilitating the regulation of adaptive behaviors. In other words, the response of a fly or a mouse to internal stimuli such as hunger or sleep, and external stimuli such as light/dark or temperature, are regulated by similar neural mechanisms.

"Flies, crabs, mice, humans: all experience hunger, need sleep and have a preference for a comfortable temperature, so we speculated there must be a similar mechanism regulating these behaviors," said Hirth. "We were amazed to find just how deep the similarities go, despite the differences in size and appearance of these species and their brains."

In humans, dysfunction of the basal ganglia can cause severe mental health problems ranging from autism, schizophrenia and psychosis, to neurodegeneration – as seen in Parkinson's disease, motor neuron disease and dementia – as well as sleep disturbances, attention deficits and memory impairment. When parts of the central complex are affected in fruit flies, they display similar impairments.

"We know of many mutations in the central complex of insects that give rise to disruption in behavior," Strausfeld explained. "In one such mutation, the insects can walk in straight lines, but when they turn, they fall over their own feet. Taken together, these manifestations are very reminiscent of what happens in Parkinson's."

The findings suggest that arthropod and vertebrate brain circuitries derive from a common ancestor already possessing a complex neural structure mediating the selection and maintenance of behavioral actions.

Hirth added: "The deep similarities we see between how our brains and those of insects regulate behavior suggest a common evolutionary origin. It means that prototype brain circuits, essential for behavioral choice, originated very early and have been maintained across animal species throughout evolutionary time. As surprising as it may seem, from insects' dysfunctional brains, we can learn a great deal about how human brain disorders come about."

The findings add to an emerging picture of a common ancestor of invertebrates and vertebrates of deep in evolutionary time whose brain may have already been much more complex than many scientists are ready to admit. Other brain structures have revealed their common origins in previous research, such as the hippocampus in vertebrates and the mushroom bodies in arthropods.

Unfortunately, no fossil remains of such a creature have been found.
Strausfeld said it is likely that those earliest common ancestors were so small or decayed so rapidly that they left nothing of their body for fossilization.

There are, however other clues: tracks left behind by unknown creatures crawling across the seafloor hundreds of millions of years ago. These "trace fossils" reveal purposeful changes in direction, with some even leading back to where the animal had gone before.

"If you compare these tracks to the tracks left behind by a foraging fly larva on an agar plate or the tunnels made by a leaf-mining insect, they're very similar," Strausfeld said. "They all suggest that the animal chose to perform various different actions; action selection is precisely what the central complex and the basal ganglia do."

To Strausfeld, the trace fossils support the idea of brains already complex enough to allow for action selection and a shared ancestry of neural structures between invertebrates and vertebrates.

"If these basic circuits appeared early and provided the organism with a very efficient way of forging and decision-making about where it was going to do that, then these circuits should have been evolutionarily stable. Nature doesn't fix what isn't broken."

"It has often been suggested that the common ancestor of us and flies should have been very simple, but it may not have been so simple," he pointed out. "Even those earliest brain structures had millions of years to evolve – enough time to become quite elaborate."

Strausfeld added: "Our study then begs the question whether other parts of an insect's brain – parts that we suspect bring together information from many higher centers – may be functioning in ways comparable to integrative properties ascribed to the frontal cortex or parietal cortex of the mammalian brain."

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