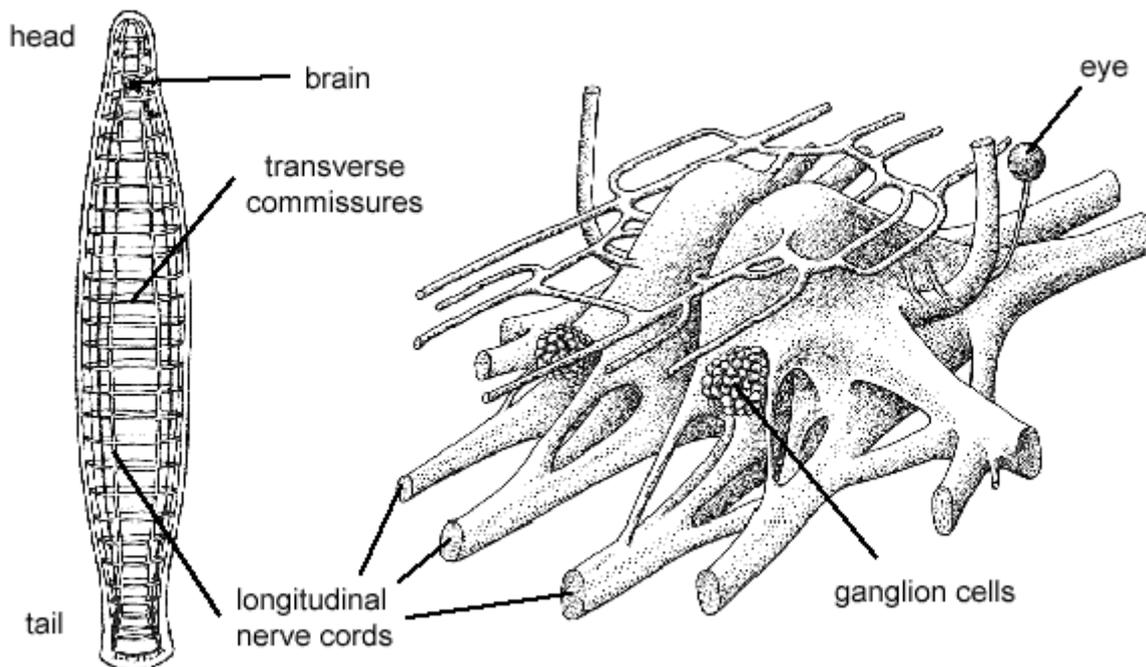


---

## Polyclads in Neurobiology

The brain and peripheral nerve network of free-living polyclad flatworms such as *Notoplana acticola* represent the most primitive nervous systems currently under investigation. It consists of a small but well-defined brain (right panel) and numerous peripheral motoneurons connected by **longitudinal nerve cords** and **transverse commissures** (left panel). This nervous system enables flatworms to perceive environmental changes and to respond to internal and external stimuli.



Superficially, the brain of *Notoplana acticola* resembles those of other invertebrates, but its cells also possess many vertebrate features. There is a surprising diversity of cell types with complicated branching patterns. Multipolar neurones appear to be the most common type, but a few monopolar cells, typical for invertebrates, and bipolar cells are detectable as well. Small multipolar cells that could either be glial or interneurons were found scattered through the brain (Keenan et al., 1981). As depicted in the schematic drawing above, all brain cells except some ganglion cells are surrounded by proteinaceous sheaths. Longitudinal nerve cords and neurones connecting peripheral sensory cells (e.g. photosensitive cells of the ocelli) arise directly from the brain. The ventral nerve cords are stronger developed than the dorsal nerve cords.

Flatworms can serve as an excellent model system for neurobiological investigations and brain research, because they are quite thin and their brain, a few millimeters in size and consisting of a few 100 to 1000 cells only, can easily be prepared for experimental studies. Currently, several topics of neurobiological and electrophysiological interest are addressed.

**Analysis of cytoarchitecture and neural connections:** For examination of the three-dimensional architecture of polyclad flatworm brains nerve cells can be stained specifically. This is performed by a (modified) method according to [Camillo Golgi](#) (1843 - 1926), one of the best known histologists of the 20th century. Neurone configuration within the brain is

investigated by intracellular iontophoresis using fluorescent dyes. In this experimental approach, described by Koopowitz and his coworkers (1996), specimen of *Notoplana acticola* were anesthetized with equal parts of sea water and isotonic MgCl<sub>2</sub>. Consecutively, the nervous system was exposed using minute pins and tools. Brain sheaths were removed by protease digestion resulting in direct accessibility of brain and ganglion cells. Using ultrafine glass microelectrode techniques single nerve cells were then filled with fluorescent dyes, such as *Lucifer yellow*. The injected dye migrates within the cell right to the very ends of axon and dendrites and can be traced by fluorescence microscopy. Using confocal laser-scanning fluorescence microscopy the reconstruction of three-dimensional images from digital data of a series of two-dimensional pictures is possible and any details of the three-dimensional neuronal cytoarchitecture in polyclad brains can be mapped.

**Investigation of nerve repair and neuronal plasticity:** Just as all invertebrate and vertebrate species so far investigated, *Notoplana acticola* cannot regenerate brain tissue. However, neuronal repair is rapid and highly efficient. When polyclad brains were transplanted into decerebrated flatworms new neural connections between the transplanted brain and the peripheral nerve network of the recipient flatworm are established within 24 hours after surgery. Such transplantation experiments were described by Davies and coworkers (1985). In their experiments four brain transplant orientations were used: *normal*, *reversed*, *inverted* and *reversed inverted*. The functionality of the transplanted brains was tested and measured using both behavioral and electrophysiological criteria. Within 23 days, 56% of the transplants that survived and retained the transplants recovered the four behaviors tested: *righting behavior*, *avoidance turning*, *ditaxic locomotion*, and *feeding*. Nerves exiting the brain tended to join with the peripheral nerves closest to them. Some normal behavior was seen within the first 36 hours after surgery. Control decerebrated worms without transplant did not recover behavior. Intracellular recordings from several brain sensory interneurons revealed normal electrophysiological properties implicating that the appropriate connections with peripheral sensory cells had been reestablished. Intracellular dye-marking of these neurons in reverse-oriented brains revealed that, although individual nerve processes apparently leave the brain and associate with inappropriate nerve cords, some of the processes turn 180 degrees to reinnervate nerve cords, which they normally occupy in unoperated worms (Davies et al., 1985).

It will be very interesting to find out about the molecular basis and regulatory mechanisms of specific neuronal reconnection. Such knowledge is of high importance for treatment of patients with paraplegia or serious injuries of the nerve system after accidents.

---

| [main](#) | [back](#) | [photo galleries!](#) |