# Nerve Cell Morphology

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## 1. Introduction

Our body is made up of tissues and organs with highly specialized functions. The nervous system controls connections between tissues and organs and coordinates their functions to maintain life. The central nervous system comprises the brain and spinal cord and is made up of nerve cells and glial cells (non-neuronal cells in brain) glial cells (non-neuronal cells in brain). Nerve functioning is primarily carried out by nerve cells, while glial cells support nerve cells—their main role is to exchange matter between blood vessels and nerve cells. Each cell type can be further divided into a number of categories.

The fundamental function of nerve cells is to react to various chemical and physical stimuli and to transmit the stimulation (signal) triggered by this reaction to other body parts. The morphology of a nerve cell differs greatly from that of other cells because of the specific function of the nervous system. A typical connection between a nerve cell and other cells is illustrated in Fig. 1.

A nerve cell is made up of a cell body, dendrites, and axon protrusions (or simply axons). Dendrites are relatively short projections that receive signals from other nerve cells. A nerve cell is classified as monopolar, bipolar, or multipolar, depending on the number of dendrites; most nerve cells are multipolar. The role of an axon is to transmit stimuli (signals) generated within the cell to other cells; the signal is eventually transmitted to the junction between the cell body or dendrite and another nerve cell. This junction is a small gap that is called a synapse. The cell body and its protrusions constitute the building blocks that form the nervous system and control its functioning. Nerve cells are also called neurons.

## 2. Nerve Cells

With a few exceptions, nerve cells cannot be viewed by the naked eye. Observations can be made by staining finely sliced cell specimens and viewing these with an optical or electron microscope. One must be aware that the whole nerve cell body cannot be clearly observed when only one staining method is used. For example, the cell body structure, in particular the cell nucleus and the surrounding area, can be observed with Nissl staining. On the other hand, the protrusions of the nerve cell and its external form can be observed with Golgi staining.

It took a long time before nerve cells were acknowledged as building blocks of the nervous system because staining nerve cells and observing them under a microscope was difficult. Then, C. Golgi (1843–1926) invented the Golgi silver impregnation method for staining protrusions. This method consists of fixing brain cell specimens with a particular substance (a mordant) and then coating the specimen with silver nitrate.

Countless nerve cells are spread throughout the layers of the brain. Staining dendrites makes the extremely complex network structure visible. R. Cajal (1852–1934) studied the nervous system using the Golgi method and revealed that the nerve cell cytoplasm did not come into direct contact with the cytoplasm of other cells, and that connections were made through the dendrites and axons instead. The study showed that a single nerve cell could be viewed as a functional unit. This concept is now known as the neuron doctrine. At that time, the idea that the brain had a reticular structure (a kind of network structure), where the cytoplasm was connected to the nerve cells (reticular theory) and functioned as a bundle, was prevalent. However, Cajal's neuron theory is the primary concept behind current cerebral nerve research, and his work demonstrates the importance of correctly perceiving the morphology of living organisms. Nerve cells with various shapes are illustrated in Fig. 2. Different morphologies of dendrites are based on the function and location of the nerve cell.

## 3. Dendrite Complexity

Dementia (a kind of intellectual defect) and brain ageing are typical issues at present; in addition to the loss of nerve cells, there is also considerable dendrite loss in many instances. In particular, nerve cell dendrites of the hippocampus, the part of the brain associated with memory, show obvious changes in Alzheimer's dementia. D. A. Sholl proposed a method of measuring such dendrite changes quantitatively. The technique involves drawing concentric circles from the center of each nerve cell body and determining the number of dendrites that intersect each circle of a set radius. The complexity of nerve dendrite is represented by the slope of log-lot plots between the radius of each circle and the number of intersect points.

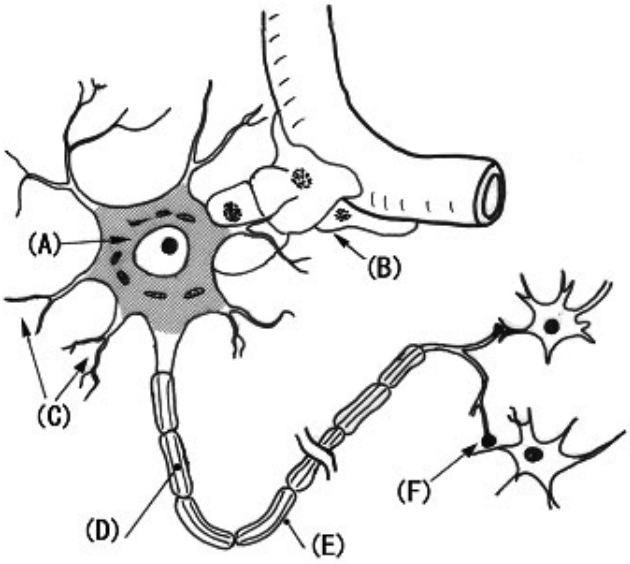


Fig. 1. Schematic nerve cell and glial cells. (A): nerve cell, (B): glial cell, (C): dendrite, (D): axon, (E): myelin sheath and (F): synapse.

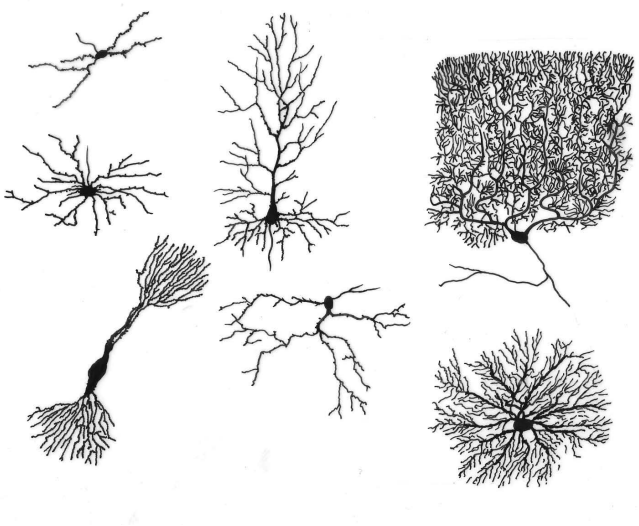

Fig. 2. Schematic diagram of various nerve cell dendrites.

Recently, there have been many reports on the use of fractal analysis to determine the complexity of dendrites and to quantify changes in dendrite morphology. Fractal dimension tests have been used to evaluate the differences in the complexity of dendrites depending on nerve cell type and to observe the change during ontogenetic and phylogenetic growth processes (Takeda *et al.*, 1992). However, some reports have pointed out that dendrites have a more uniform distribution than can be anticipated from the fractal theory (Muray, 1995), and the adaptation of fractal theory for nerve cells remains a problem to be solved.

## References

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