In pursuit of the mystery and complexity of brain development

Unveiling the mechanisms underlying the creation of the “control tower” of the organism

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Division of Organogenesis
Brain Morphogenesis

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Seem-Like for the mechanisms determining the properties and destination of neurons and the architectures of each brain tissue according to the map of the brain

The nervous system by which our brains, highly functioning “control towers” that determine our every activity, are formed remains deeply mysterious and has yet to be understood. Yet this puzzle is exactly what Dr. Kenji Shimamura has focused his research on, in particular how and where neurons are formed, as well as how the various areas of the brain come to develop according to the map setting out the map of the brain.

The neural plate appears at a very early stage in embryogenesis, and it is made up of epithelial cells, the stem cells of the central nervous system. It is, in short, out of cells, that the map of the brain has been imprinted. “The behavior of neutrons is determined by the instructions found in this map; first, the areas of the brain such as the cerebrum and cerebellum are formed. Research has already revealed the basic principles by which the brain map is imprinted onto this brain primordium, the neural plate, and the mechanisms by which different neurons with distinct characteristics are generated according to the position in the brain,” says Dr. Shimamura. There is still much that we do not know. Yet, for example, how each area goes about forming the structure required of it by the brain map.

The cerebral neocortex, which contains a number of significant regions including the motor, language, visual, and auditory cortices, is made up of neurons. We already know that these layers differ in structure and thickness throughout the various species, and although we know how the cortices are determined, we don’t yet know why different structures are formed. Sensory information is transmitted to the neocortex via the neural fibers derived from glial cells. What we think is that, at the beginning, some of the neural fibers may control the formation of layer structure of the target cortical areas.

Neural stem cells divide rapidly, and the outcome of division varies in some cases. Both daughter cells arising from division will have the same characteristics as the parent cell (proliferation); in other cases, one cell will be identical to the parent cell (self-replication) while the other cell becomes a neuron (differentiation). In still others, both daughter cells will be neurons. This principle applies to every area of the brain, but the number of neurons created, the ratio between neuron and glial cell production according to position and developmental stage, are Dr. Shimamura. One possible mechanism, he suggests, is based on the contact between parent and daughter cells; daughter cells that have become neurons release the contact quickly away from the parent cell, allowing that cell to continue to differentiate rapidly, while those daughter cells that retain the contact with the parent prevent the parent cell from differentiating, prompting it instead to proliferate. His research seeks to verify this hypothesis, in which daughter cells regulate the differentiation and proliferation of parent cells.

Next, neurons move away from their birthplace and move toward their destination, building brain tissue in the process. Dr. Shimamura speculates that the pace of neuron production must be linked in some way to differences in the internal structures formed after the neurons have moved position. “The neurons start to build the wall of the brain, but in some areas neurons will stack up in layers, in others the neurons form opaque clusters. The basic mechanism of neuron production remains the same, yet differences emerge in the tissue they form; we believe that quantities and temporal changes in the basic mechanism are behind these differences.” This would suggest, for example, in one position in the brain, the formation of a large volume of neurons in a short time results in cluster-like tissue, while in another position, the pace of production is slow, allowing the neurons to gradually form sheets over time. Dr. Shimamura continues to press forward with his examination of the assumed mechanisms.

Towards the mysteries of evolution: the mechanism of cerebral neocortex formation

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This cerebral neocortex is only observed in mammals, including humans; it does not appear to be present in other vertebrates, including birds and reptiles. By investigating the mechanisms that cause tissue morphology to change according to brain region, Dr. Shimamura hopes to be able to clarify the mechanisms by which different brain structures among the various species. “I would like to further our understanding of brain morphogenesis, in the hope of advancing our understanding of the evolution of human brains.”

References

