3–12

PLASTICITY OF THE DEVELOPING AND AGING NERVOUS SYSTEM

The data illustrated in this plate suggests a capacity of the nervous system for responsiveness to the environment throughout the lifetime of the individual. Considering the changes we go through in our life, learning and remembering, collecting experiences with each additional day of life, the neurons of our brain must undergo some very significant adaptations.

Start with the upper section. Color the heading Neuron Loss in Development and titles A and B. The numbers of neurons and neuroglia (B) in the lumbar region of the developing spinal cord (A) are compared between chick embryos 12 days and 5 days before hatching. Color structures A and B in the chick embryo first, then the chick. Color the graph last.

Proliferation of neurons and neuroglia is incredibly rapid during the early stages of nervous system development (recall Plates 3-3 and 3-4). However, the death rate of these cells during the latter stages of development is equally incredible, as the graphs portray. The experimental animal here is the chick, a representative of advanced organisms. Note the tremendous loss of *neurons and glia* (B) in the *spinal cord* (A) of the embryonic chick over a period of just 7 days during the total 21-day developmental (gestational) span. The cause or significance of this loss is not known. The survival or death of cells in the brain and spinal cord is influenced by many variables such as availability of oxygen and nutrients, growth factors, hormones, and cell density.

Color the heading of the middle section: Neuron Loss with Aging, and titles C, C^1, and B^1. The numbers of neurons and neuroglia (B^1) in the occipital cortex (C^1) of the brain (C) are compared between 26-day-old and about 2-year-old rats. Color structures C, C^1, and B^1 in the younger rat and then the older. Color the graph (B^1) last.

Studies with rats, a common experimental animal, have shown that the most significant loss of neurons and glia occurs early in life and not after the attainment of adulthood. In this set of experiments, neuron counts were obtained in the *occipital cortices* (C^1) of 11 to 15 young (26-day-old), young adult (108-day-old), elderly (650-day-old), and very old (900-day-old) rats. As the graph shows, the most significant loss of *neurons and glia* (B^1) occurs before 100 days of age. The loss between 108 days and 900 days is considered insignificant by standard statistical methods. How do these data relate to the generality that millions of our neurons die each day of our lives? That aging is associated with slowed reflexes and loss of memory? Are these changes chemical ones and not related to neuronal death? The answers to these questions have yet to come in. We do know that neurons require healthy support systems to survive—good nutrition, a continuous supply of oxygen, and freedom from stresses that can translate into chemical harm. In this environment, neurons will function well for a lifetime.

Color the heading of the lowest section: Cortex Thickens with Training, and titles D and E. The effect of environmental enrichment on the thickness of the cerebral cortex (E) is compared with the thickness of the cerebral cortex of nonenriched animals (D). Color structures D at left, then the arrow (D and E) and the title Enrichment. Then color structures E at right. Color the graph (D and E) last.

It has been shown in studies (not shown here) that neuronal size and complexity and numbers of glia increase in the cerebral cortices of animals exposed to enriched environments (characterized by large cages and exposure to objects that arouse curiosity and stimulate exploratory activity). Presumably, such increases in neuronal complexity and neuroglial numbers imply a greater adaptability of the organism to its environment, possibly a greater capacity for storage of memory, and enhancement and modification of reflexes (in substance, "smarter animals").

The data illustrated here corroborate such theories. "Enriched" rats housed in large cages and exposed to toys and stimulus objects were compared with nonenriched (control) rats of the same age. After varying periods of enrichment (6–26, 60–90, 600–630, and 766–900 days), the cerebral *cortices of enriched animals* (E) were seen to be significantly thicker than the *cortices of control animals* (D), presumably reflecting increases in neuronal complexity and numbers of neuroglia of the trained rats.

From such data we may infer that experience, whether formal education or adventure, is to some degree reflected in the structure of our brains. The evolutionary implications of such a phenomenon are staggering, both in history and in the future.