V. Flatmap Overviews

Neuroanatomical data can be summarized at various levels of abstraction, each of which can be useful. Photographs of course involve the least interpretation, whereas drawings on atlas cross sections are perhaps the most common. However, it is very difficult to reconstruct in the mind complex 3-D relationships from a series of sections, and artistically clever 3-D renderings derived from them are perhaps the best, though most difficult, way to capture and present the essence of spatial relationships.

As more and more detail is added to 3-D renderings, they become more and more difficult to interpret. This has led to the development of more abstract ways to summarize neuroanatomical information, especially about the organization of CNS circuitry. The most abstract approach involves the refinement of *schematic diagrams* that ignore spatial relationships altogether and instead focus on the organization of connections between various cell groups. This is an engineering approach that has been most commonly used in the network modeling community, and certainly provides the clearest way to understand the basic organizing principles of a particular system. Ultimately, it is based on graph theory.

An intermediate approach involves the development and use of CNS flatmaps, analogous to maps used to represent the surface of the earth on paper (or computer display). The major advantage of a good CNS flatmap is that all functional systems can be represented on the same template, just as earth maps can be used to display political boundaries, transportation systems, census data, and so on (all of which, incidentally, change over time, and thus need constant updating).

The history of CNS flatmap development (Alvarez-Bolado and Swanson 1996), and the methods used to construct our own flatmap, have been described elsewhere (Swanson 1992a, Alvarez-Bolado et al. 1995, Alvarez-Bolado and Swanson 1996). Topologically, the adult CNS is a closed tube that is derived from the embryonic neural plate—a flat, bilaterally symmetrical sheet. In principle, our flatmap is a hypothetical fate map of the neural plate, based on the rather limited experimental data available.

According to basic cartographic principles, distortions are inevitable when transforming a curved surface onto a flat surface. In fact, of the three basic features—distance, area, and shape—only one can be preserved in going from three dimensions to two. We have chosen to preserve "area", although in fact volume must be used because the walls of the "CNS tube" have a substantial thickness, which varies considerably along the longitudinal axis from cerebral hemispheres to spinal cord. This thickness produces inevitable ambiguity in the flatmap because structures are often stacked within the thickness of the wall (the thalamus is a good example, whereas the cerebral and cerebellar cortices can be flattened directly and accurately, disregarding their respective layers). There are various ways to unstack cell groups in the wall of the CNS (involving shifting and nesting), and as the map is refined, the strategy is to produce functionally relevant relationships and the shortest pathways with the least amount of overlap.

Once the basic pattern of cell groups has been established on the flatmap, it is possible to arrange the major pathways in a standardized way (Frontispiece). Using these basic tools, it is then possible to summarize the connections of any cell group, or the organization of any system, or any combination thereof (for examples, see Canteras et al. 1994, Thompson and Swanson 1996, Risold et al. 1997). This approach would hardly be practical without the aid of computer graphics (a layered prototype of the flatmap and pathways is provided on the CD-ROM, files A2—which also contain a flatmap of the human brain, a flatmap of the rat hippocampal formation, and an illustration of how the Atlas Levels map onto the cerebral cortical part of the flatmap).