CHAPTER 19

THE CLINICAL IMPLICATIONS OF NEUROPHYSIOLOGICAL CONCEPTS

Most neurologists find that the most frequent complaint they hear about is headaches. Most headaches are probably due to nervous tension, anxiety, or fatigue and can be treated adequately with aspirin or other drugs. Much less common are headaches that result from tumors, some of which can be treated by surgery. The second most frequent neurological problem is stroke. Usually, for stroke victims, the procedure, after the patient is out of danger, is to treat the patient with physical therapy. The physical therapist's job frequently is to make the person comfortable and to regain, as much as possible, functions lost due to the stroke. In general, the treatment of other maladies of the nervous system is similar.

However, the implicit assumption in the way we treat nervous disorders seems to be that the patient has lost the tissue that performed a particular function and that nothing can restore the tissue or the function. In a way, this attitude is surprising in a scientific age, but, in another way, it is not. If the nervous system is viewed as a set of structures, each with a function that it and it alone can serve, then there is nothing to be done for the patient. For example, if the pyramidal tract is viewed as the only structure that initiates and controls voluntary movements, then its destruction must be assumed to have the inevitable consequence of eliminating voluntary movements. Or, if the spinothalamic tract is viewed as the only pain pathway, then its destruction must eliminate pain sensation from the areas it serves.

This concept, which we will call the "essential component" concept of the nervous system, pervades most neuroanatomy and neurophysiology textbooks and if not stated explicitly, it is at least implied. It seems natural for it to be this way, because the ideas of somatotopic organization and localization of function seem to be so comfortable—that is the way we build our machines.

We have already examined the idea of somatotopic organization in some detail. It might be valuable to examine the idea of localization of function in some detail to see just what we are claiming when we say a function is localized to a particular structure. The term localization appears to be used in several different ways by different people. For some, functions are localizable to an entire hemisphere or to a particular nucleus, but, with the recent increase in interest in neurochemistry, more and more people are talking about localization to particular subcellular organelles. Functions can be localized to a particular circumscribed region of the brain, as motor functions of speech are localized to Broca's area, or they can be localized to systems distributed over large regions of the brain, as the control of emotional behavior is localized to the limbic system.

And, what is a function? Laurence and Stein (Laurence S, Stein DG: Recovery after brain damage and the concept of localization of function. In Finger S [ed]: Recovery from Brain Damage. New York, Plenum Press, 1978) have pointed out that the term function is at times used to specify means and, at times, to specify ends, most authors failing to be explicit about which of these contexts they are using. In the context of ends, functions refer to a goal they accomplish (eating, thinking), the effects they have within a particular context (inhibition), or
the role they have within some larger system (contrast enhancement in vision). In the context of means, functions refer to the way in which a goal is accomplished, describing the actual behavior of an organism (it pulls with upper arm and shoulder muscles). These are not exclusive contexts; they may not even be related. There are usually a number of means to achieve any goal, and the same means may lead to different goals in different situations.

It is difficult to speak of localization when by function we mean a goal. Because goals can usually be achieved by a number of means, they must have numerous localizations, or must they? The more general or complex a goal, the less easily it can be localized. No one has trouble speaking of the localization of language or movements, but it is doubtful that anyone would argue strongly for localization of book writing. However, it was only in the early 1800s that the phrenologists argued for localization of conscientiousness, adhesiveness, and marvelousness. Perhaps future neuroscientists will smile to themselves in a similar way about localization of language. If by function we mean a means, then saying a function is localized indicates nothing more than that a particular biochemical or electrophysiological process exists and can be used. Such localization is not particularly useful to our understanding of brain. Still, the idea of localization of function is pervasive in neuroscience and so is its derivative, the essential component concept.

Yet, there is nothing in our knowledge of the nervous system that requires this essential component concept to be true! The notion that specific behavioral processes are related to specific subregions of the brain is based in part upon the assumption that deficits resulting from removal or damage to a specific structure reflect what the structure normally does. (One cannot help but be reminded of the popular joke about the boy who concluded that grasshoppers hear with their legs on the grounds that his trained grasshopper failed to respond to the command "jump" after its legs were removed.) In fact, this is not necessarily the case; the deficits may reflect what the remaining tissues of the region or even tissues at some distance from the damaged structure do. Care should be taken, for example, in concluding that the hypothalamus plays a role in vision simply because tumors there (over the optic chiasm and tract) commonly produce visual impairments. Great physiologists even in the last century knew that this assumption that deficits reflect normal processes probably was not valid.

There is certainly nothing in the structure of the nervous system that requires the essential component concept. Many colleagues are fond of saying that in the nervous system, "everything is connected to everything." In a way, that is true! If you follow any pathway far enough, you can get from one structure to any other structure of the nervous system, though you may have to go through a mechanical linkage to do it (the exteroceptors are a notable exception). There is certainly nothing in neurophysiology that compels one to think in terms of "essential components." Stimulation of any structure always has more than one consequence, and stimulation in several different places at different levels can have the same consequence. With respect to behavior, ablation of most central nervous system structures above the brain stem does not eliminate behaviors, though it may alter them in profound ways. Cutting the pyramidal tract does influence movements, but it does not eliminate them. Cutting the spinothalamic tract does influence pain sensitivity, but it does not eliminate it.

What then is the alternative to the essential component concept, and what are its implications for clinical practice? Knowledge of the way the nervous system has evolved tells
us that the structures that evolved early are among the only essential components. These are the motoneurons, the receptors, and their reflex connections. Almost everything else added later serves only a modulating function—it only modulates the essential activities of the essential components. It is the pattern of this addition and modulation that makes a monkey, a monkey, and a man, a man. Let us call this the "modulating component" concept. From time to time, new components were added to the system or parts of older components were specialized, allowing new behaviors to develop. In these cases, ablation of these new or specialized components eliminates those new behaviors.

The visual system offers an example for illustration of the implications of the modulating component concept. With damage to the striate cortex, cortical blindness results, the usual interpretation being that the striate cortex "produces" vision and its removal "eliminates" vision. This is the essential component concept. Suppose instead that vision is actually a subcortical event produced by a number of visual structures or pathways, including the superior colliculus and the lateral geniculate nucleus. The visual cortex allows vision to be more flexible or perhaps to achieve some new aspects not present without the cortex. In the process of corticalization, the subcortical visual structures received an input from the cortex and came to depend upon the cortical input to maintain their excitability levels. We have seen time and time again how important summation is to normal neuron discharges. With cortical damage, the visual cortical input to the subcortical structures is eliminated and the neurons in these structures drastically reduce their firing or stop altogether, as spinal motoneurons do during spinal shock. Certainly, this scenario is consistent with what we know of the behavior of neurons. With the essential component concept, there is no treatment for this disorder; vision is permanently, irreparably lost. On the other hand, if the foregoing reasoning, based on the modulating component concept, is sound, then an appropriate prosthesis to restore at least some visual abilities would be any device that increases the excitability in the subcortical structures or pathways, whether or not it excites fibers running out of the visual cortex.

Some interesting results obtained in cats are suggestive that this interpretation is correct and they also suggest a possible treatment. In cats, unilateral removal of the superior colliculus results in homonymous hemianopsia, complete to the vertical meridian, ipsiversive circling movements, and deficits in contralateral movements of the eyes, all of which are somewhat compensated over several weeks time. Unilateral removal of area 17, the primary visual cortex, has only minimal and transient effects or none at all. However, a lesion involving the entire occipitotemporal cortex from the splenial sulcus to the rhinal fissure, including both primary and supplementary visual areas, results in complete contralateral hemianopsia with no compensation occurring within a 1-year period. Thus far, there is nothing new in these observations. However, if this lesion of the cortex is followed by another to the contralateral (with respect to the cortical lesion) superior colliculus, there is a marked return of the visual function that was lost following the cortical lesion, and the deficit that would normally result from the collicular lesion alone is less severe. Table 19-1 gives a qualitative summary of the results one obtains from such an experiment.

One way of understanding these results is as follows: Visually guided behavior is a function of both subcortical and cortical centers. Removal of the visual cortex eliminates a descending (corticotectal) facilitation of the ipsilateral superior colliculus, leaving an inhibition from the
contralateral superior colliculus and possibly elsewhere and resulting in an imbalance

Table 19-1
Summary of Visual Deficits Following Cortical and Cortical + Collicular Lesions*

<table>
<thead>
<tr>
<th>Deficits after right cortical lesion</th>
<th>Deficits after subsequent lesion of the left superior colliculus</th>
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<tbody>
<tr>
<td>Total left hemianopsia</td>
<td>Response to stimuli in left field</td>
</tr>
<tr>
<td>Normal right field</td>
<td>Response to stimuli in right field diminished but improving to near normal</td>
</tr>
<tr>
<td>Follows visual stimuli only on right</td>
<td>Following only on left initially, later also on right with left favored</td>
</tr>
<tr>
<td>Blink to lateral threat on right only</td>
<td>Blink to threat on left only initially, later also on right</td>
</tr>
<tr>
<td>Eye movements and pupils normal</td>
<td>Pupils normal; eye movements to right absent initially, improve</td>
</tr>
</tbody>
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* Sprague JM: Science 153:1544-1547, 1966

in the system. The result is that the discharges of the ipsilateral superior colliculus cease and with them visually guided behavior. Destruction of the contralateral colliculus disinhibits the ipsilateral one, allowing a return of its functioning. The reason for the less severe deficiencies due to the collicular lesion itself is not clear. If this interpretation is correct (there are other possible interpretations), then a possible treatment for hemianopsia resulting from cortical damage would be to stimulate the superior colliculus ipsilateral to the cortical damage. To date this has not been attempted in humans, but 10 to 15 years ago it would not even have been considered. It would have been assumed that there was nothing to be done for the benefit of the patient.

Work with patients suffering from cortical blindness has shown that repeated measurement of visual threshold leads to a reduction in thresholds and increased contrast sensitivity in the damaged visual field and in the contralateral homologous area. Improvements were seen only with specific training; no improvement was seen between sessions. Even though no specific procedures other than visual sensitivity measurements were performed, improvements in flicker-fusion thresholds, acuity, and color vision were also observed. The reasons for these improvements are not clear, but it is possible that systematic stimulation itself leads to increased excitability of the remaining visual pathway.

If the nervous system is viewed in the modulating component way, one will be led to the conclusion that there may be certain modalities of sensation and perhaps certain motor functions
that cannot be replaced once lost, but there are others, perhaps the majority, in which another
structure can take over the same modulating job or a new strategy can be developed to
accomplish the behavior (perhaps using different movements, different muscles, or different
central nervous system structures). To a certain extent this happens naturally. The recovery of
pain sensation following tractotomy and the recovery of motor function following a stroke are
examples of this process at work.

A physician should keep an open mind to this possibility and be alert to recognize cases in
which this kind of "repair" may be possible. There may be some course of action that will speed
up the process or perhaps allow it to happen. At least, bear in mind the extent to which your
view of how the nervous system is put together and how it functions determines what you do for
the patient.

Suggested Reading

1. Laurence S, Stein DG: Recovery after brain damage and the concept of localization of