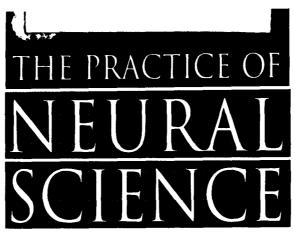
THE PRACTICE OF NEURAL SCIENCE

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From Synapses to Symptoms

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The Practice of Neural Science: From Synapses to Symptoms

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Preface

Students of neurobiology, especially medical students, often experience a wheat-chaff problem: amidst an onrushing deluge of facts and concepts, how does one tell which information has clinical relevance? Do physicians actually encounter symptoms and signs that reflect the difference between ligand-gated and voltage-gated ion channels? Does the proper choice of diagnostic studies ever require awareness that the spinothalamic tract is a crossed ascending system whereas the dorsal column is not? Does it matter that a protein called tau binds to microtubules? It was with such questions in mind that Dr. Eric Kandel invited me to write a companion volume to Kandel, Schwartz, and Jessell's Principles of Neural Science, with the broad aim of demonstrating the applicability of neurobiology to clinical decision making. In addition, it was thought readers might discover that understanding clinical phenomena in neurobiological terms can be good fun.

Although this book is designed especially for students and residents, seasoned clinicians and investigators are welcome. Part I includes a mostly neuroanatomical description of the neurological examination. Part II consists of 79 clinical vignettes, which are discussed neuroanatomically and neurophysiologically. Each case makes a cameo appearance somewhere within the Neurological Examination section, so that the reader can relate that part of the examination to a real world situation. Conversely, the cases are arranged systematically (eg, somatosensory, visual, auditory, olfactory, motor, or autonomic impairment; disorders of consciousness, language, cognition, or behavior), allowing a reader who wishes to start with the vignettes to refer back to the appropriate section of the Neurological Examination.

Students in neurobiology courses can use this book for previews of coming attractions; they will, I hope, be reassured that so much of what they are slogging through really matters. Students in neurobiology clerkships or residents can use the book to refresh their memories—or perhaps, in some instances, to update their fund of information.

This is not a comprehensive textbook. Cases have been selected to cover a broad array of neurological and neurobiological phenomena, but they are, after all, only 79 in number. Some involve patients I have known over the years. Others are from case reports in the literature.

Many thank yous are in order. Manuscript reviews by Eric Kandel, Steven Siegelbaum, Lewis P. Rowland, Timothy A. Pedley, and Robert E. Lovelace nipped a number of gaffes in the bud. John Butler, Harriet Lebowitz, and Eve Siegel of Appleton & Lange were professional, sympathetic, and flexible. Sarah Mack was more than accommodating with some of the artwork. Shirley Myers-Jones created a manuscript, and Arline Keithe polished my prose. As always, Dr. Edward B. Healton and Ellen Giesow of the Columbia University Affiliation at Harlem Hospital provided essential support.

Finally, to return to the original questions posed above, the answers can be found in Part II, Cases 19, 45, and 77.

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I

The Neurological Examination

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- 2. Mental Status: The Components of Thinking Are Not Easily Isolated
- 3. Cranial Nerves: Twelve Is a Misleading Number
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- 7. Examination of the Comatose Patient

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Overview

▶ Strategic Principles

The human brain is the most complicated biological system; Ramón y Cajal referred to it as the "masterpiece of life." Not surprisingly, neurological disease produces very diverse symptoms and signs. (Symptoms are what a patient experiences; signs are what an examiner observes.) To assess a patient's "chief complaint," a clinician elicits a neurological history and performs a neurological examination addressing three basic questions: (1) Do the symptoms and signs signify neurological disease or injury? (2) What part of the nervous system is affected? (3) What is the disease process?

Neurological illness can be direct—from primary disease of the nervous system such as glial tumors or multiple sclerosis—or indirect-secondary to disease outside the nervous system, such as renal failure, which can cause altered mentation, or cardiac disease, which can result in embolic stroke. The terms organic and functional, used to distinguish neurological from psychiatric symptoms, are well entrenched but misleading; psychiatric illness is as organic as neurological illness. Indeed, psychiatry has been described as "neurology without signs." Certain symptomsparticularly headache and dizziness-often have a psychiatric origin, usually anxiety or depression. Psychiatric illness also directly produces neurobehavioral symptoms, for example, schizophrenic hallucinations. Sometimes symptoms turn out to be fabricated by patients for secondary gain (malingering).

Whether direct or indirect, symptomatic

nervous system lesions can be diffuse or focal, can be single or multiple, and can involve the peripheral nervous system (muscle, neuromuscular junction, peripheral or cranial nerve, nerve plexus, and nerve root) or the central nervous system (spinal cord, brain stem, cerebellum, diencephalon, and cerebrum). A competent neurological history and examination thus require a basic understanding of the anatomy and physiology of the nervous system.

Fortunately, such an undertaking is less daunting than might be supposed. For all its complexity, the nervous system is highly organized; different combinations of regions subserve different functions, allowing a clinician to localize lesions with considerable accuracy. Moreover, in the great majority of cases the history and examination not only will define the problem as neurological and localize it accurately within the nervous system but also will generate a reasonable hypothesis as to the underlying disease process (Table 1–1). Laboratory or imaging studies

Table 1-1. Major categories of disease.

Congenital (genetic and nongenetic)
Infectious
Toxic-metabolic
Traumatic
Neoplastic
Vascular
Degenerative
Immunologic
Idiopathic (cryptogenic)
Psychiatric
Malingering

are then selected to confirm or exclude the tentative working diagnosis.

► Neurological History-taking: The Answers Are in the Details

History-taking should allow patients to describe symptoms in their own words. The clinician's questions should not lead the patient, yet should be sufficiently directed to determine precisely what the patient means. Many terms are used differently by different people. For example, dizziness might refer to near-syncope, vertigo, imbalance, or simply a hard-to-describe subjective feeling. Numbness might mean just that or it might refer to paresthesias (spontaneous somatic sensation in the absence of an external stimulus). Weakness might mean loss of power, slowness of movement, or fatigue. Some patients say numb when they mean weak and weak when they mean numb. Similar elaboration is required for terms such as blackout (which might mean syncope, a seizure, an amnestic episode, or loss of vision) and disorientation (which might describe impairment of recent memory, perceptual disturbance, or a psychiatric dissociative state).

Details as to location, duration, quality, and pattern are crucial to neurological diagnosis. Low back pain, described without further detail, could indicate change to any of a number of structures, whereas low back pain that first appears in a young adult during heavy lifting and is subsequently triggered by bending, twisting, or coughing, with radiation down the posterior leg into the heel, suggests compression of the first sacral (S1) nerve root, probably by a herniated intervertebral disk. Similarly, pain in the left side of the face could be of nonneurological origin, such as maxillary sinusitis or a tooth abscess, whereas spontaneous jabs of severe pain lasting only a few seconds, sharply restricted to the region supplied by the second or third division of the trigeminal nerve and triggered by lightly touching the upper lip or gum, describes trigeminal neuralgia.

Even more complex symptoms are often localizable. An episode of confusion or talking out of one's head could signify drug intoxication or a seizure originating in the limbic system of the brain; more detailed descriptions such as "I knew what I wanted to say but I couldn't think of the right words," or "When I tried to say something the wrong words came out," suggests aphasia, in turn implying (at least in a right-handed person) a structural lesion in the left cerebral hemisphere.

A neurological history is of course not obtained in isolation, but is interpreted in the context of a general medical history (including previous illnesses, injuries, hospitalizations, medications, and use of alcohol, tobacco, or recreational drugs), family history, occupational and social background, and review of nonneurological systems (head, eyes, ears, nose, throat, respiratory, cardiovascular, gastrointestinal, renal or urinary, genital, musculoskeletal, skin, endocrine, and hematologic). Sudden hemiplegia is probably of cerebrovascular origin, whether in a 70-year-old person with hypertension and diabetes or in an otherwise healthy 22-yearold person who smokes "crack" cocaine; the underlying causes of their strokes, however, are likely very different.

► The Neurological Examination: Content and Focus

The neurological examination usually follows the medical and neurological history and the general physical examination, by which time a working diagnosis, or at least a differential diagnosis of several possibili-

Table 1–2. The five components of the neurological examination.

Mental status
Cranial nerves
Motor function (including coordination and gait)
Sensory function
Reflexes

ties, has been formulated. The examination consists of five parts (Table 1–2). The thoroughness with which the clinician addresses each part will be influenced by the history as well as by other systemic or neurological signs. For example, olfactory testing would usually be superfluous in someone with a peroneal nerve injury but should be performed in anyone with significant head trauma. Reading and writing do not usually need to be assessed in someone sus-

pected of having myasthenia gravis but should—if possible—be tested in anyone with cognitive or behavioral disturbance. Proprioception obviously cannot be tested in the presence of delirium, and gait may be difficult to assess in someone with postural syncope. Vigorous strength testing should be deferred in a patient whose myocardial infarction occurred the day before. Chapters 2–6 review the five parts of the neurological examination.

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Mental Status:

The Components of Thinking Are Not Easily Isolated

The parts of the mental status examination are listed in Table 2–1; the order in which they are most appropriately performed varies from patient to patient. Language function cannot be properly assessed in someone who is stuporous, and memory cannot be assessed in someone who is severely aphasic. How a mental status examination is conducted thus depends on what is abnormal.

► Alertness and Attentiveness

The mental status examination usually begins with an assessment of alertness and attentiveness, for if either of these faculties is more than mildly compromised, a complete neurological examination becomes impossible (see Chapter 7). A number of terms describe degrees of nonalertness, for example, lethargy (the patient responds to verbal stimuli but tends to nod off when the stimulus is removed), obtundation (at least shouting or shaking is required to produce a response, which is then incomplete), stupor (the patient responds only to pain), and

Table 2-1. The mental status examination.

Alertness and attentiveness
Behavior, mood, and thought content
Orientation and memory
Cognitive abilities
Language
Praxis
Gnosia and spatial manipulation

coma (there is no response, even to pain). Because these terms are not used identically by all clinicians, the examiner should note both the minimal stimulus required to elicit a response and the response elicited.

An impaired attention span is usually apparent during history-taking. It may emerge or worsen as the examination proceeds. Attention span can be more formally tested by having the patient repeat a series of numbers. Most normal adults can repeat seven digits forward and five backward after a single hearing. Sequential digit testing is sensitive but not specific; difficulty may connote impairment of immediate ("working") memory rather than inattentiveness per se. Certain parts of the neurological examination, for example, visual field and proprioceptive testing are more likely to be compromised by inattentiveness than by impaired working memory.

The term *delirium* denotes inattentiveness sometimes so severe that meaningful interaction with the environment is impossible. Mental content, if assessable, is usually abnormal. Such patients are often agitated or less than alert (sometimes rapidly alternating between agitation and obtundation), and in some delirious states, such as delirium tremens of alcohol withdrawal, tremor and hallucinations are prominent.

SEE CASE 59 | p. 231

"Hospitalized for bronchopneumonia, a 55-yearold unemployed accountant becomes anxious and tremulous."

► Behavior, Mood, and Thought Content

Neuropsychiatric abnormalities can be identified in this part of the mental status examination. Affect, the outward expression of mood, may be manifested in clothing, facial expression, amount and type of activity, and stream of conversation.

Mood may be more disturbed than affect suggests, however; patients should be specifically questioned about depression and, if appropriate, suicidal ideation. Patients with cyclothymic mood swings may demonstrate irritation, pressured speech, euphoria, or psychotic mania.

SEE CASE 79 | p. 283

"For several months a 53-year-old lawyer has experienced increasing insomnia and fatigue."

Schizophrenic patients may demonstrate indifference, flattening of affect, or mood inappropriate for a given topic. They may appear hostile and paranoid, with ideas of reference, obsessions, or delusions. Behavior sometimes suggests hallucinations even when they are denied. Schizophrenic speech may reveal distractibility, blocking, stereotypy, loosening of associations, or incoherence superficially resembling jargon aphasia.

SEE CASE 78 | p. 278

"A 17-year-old high school student, always considered by his classmates to be a loner, becomes increasingly withdrawn."

Slowing of speech and activity is also a manifestation of medial frontal lobe damage (abulia). Lesions of the frontal lobe also produce social disinhibition, inappropriate jocularity, and difficulty sustaining goal-directed behavior.

SEE CASE 77 | p. 276

"A 57-year-old high school teacher undergoes a change in personality."

Intermittent or paroxysmal changes in behavior or mood should always raise the possibility of a seizure disorder.

SEE CASE 71 | p. 259

"For 11 years, a 21-year-old woman has had attacks of incapacitating fearfulness."

SEE CASE 72 | p. 263

"A 14-year-old boy has had episodes of altered behavior since sustaining a head injury with loss of consciousness at the age of 3."

▶ Orientation and Memory

People aware of their own identity as well as basic facts of their present surroundings (hospital, home address, city, state; time of day, day of week, month, year) are said to be "oriented to person, place, and time." Memory impairment secondary to brain injury or a dementing illness is usually greater for recent than remote events; such patients are disoriented to place and time but not to person. Disorientation is neither a sensitive nor a specific marker of amnesia, however. Patients with mild-to-moderate memory loss may be fully oriented yet perform poorly on more sensitive testing. Disorientation, moreover, can have causes other than deficient memory or simply impaired recall. Patients who insist that their hospital room is actually their apartment or home have paramnesia, a more complex disturbance; patients oriented to place and time who cannot remember who they are have hysterical amnesia, a psychiatric dissociative state; and patients who identify themselves as Joan of Arc are either psychotic or excessively whimsical.

Memory is conventionally categorized as immediate (working), recent, and remote. As noted, impaired working memory can be inferred in a seemingly attentive patient unable to repeat six or seven digits forward

(the same skill that allows a person to look up a phone number and then dial it). A sensitive test for recent memory is to have the patient repeat three unrelated words (eg, Chicago, orange, thirty-three) and then repeat them again after 5 minutes. If unable to recall the words, the patient is asked to select each word from a list. Amnestic disorders tend to affect spontaneous recall more than recognition.

Long-term memory can be tested by having the patient recall people or events from the past (eg, Where were you born? Where did you attend school? When did you get married?), but the answers must then be verified. Also problematic is using current or historical events such as presidents, sports figures, or television performers to test memory; the examiner should have a good idea of a patient's expected fund of information.

Amnestic patients sometimes fill their gaps in memory with fabricated yet plausible events, so-called confabulation. Although most often encountered in alcoholic patients with nutritional deficiency (Korsakoff syndrome), confabulation occurs in other amnestic disorders as well. Conversely, some alcoholics have profound memory loss without confabulation.

SEE CASE 74 | p. 269

"A homeless middle-aged man is brought to an emergency room having been found sitting on the sidewalk in a daze."

Conventional testing identifies disturbances of *episodic* memory, the recall of particular autobiographical events in time. Other memory systems include *semantic* memory (remembering what things are, such as a knife, a fork, or an automobile) and *procedural* memory (remembering how to perform a skilled motor act). Procedural memory tends to be relatively preserved in most patients with amnestic or dementing disorders. A patient with moderately severe

Alzheimer disease is unlikely to have forgotten how to use table utensils or drive a car.

SEE CASE 73 | p. 265

"A 75-year-old right-handed college graduate becomes forgetful."

► Cognitive Abilities: Manipulation of Old Knowledge

The intellectual skills assessed in this part of the mental status examination, formally assessable in standardized IQ tests, are subject to educational and cultural bias. Questions directed at a patient's general fund of knowledge will produce useful clinical information only if the examiner has a reasonable idea of what to expect. Somewhat more useful are tests of simple calculation (in which performance sometimes improves when the questions are posed in terms of dollars and cents), similarities (eg, How is a dog like a lion? How is a bicycle like an automobile? How is yesterday like tomorrow?), opposites (eg, What word is the opposite of up, summer, north, quick, full?), or proverb interpretation (eg, A rolling stone gathers no moss). Concrete responses such as "A bicycle and an automobile both have wheels" may or may not signify cognitive impairment in a particular patient, but absurd answers or the reply "I don't know" likely indicate that something is wrong.

With mental retardation (failure to achieve normal cognitive development from birth or early childhood), verbal and performance skills tend to be equally affected, and even casual conversation usually reveals that intellectual function is subnormal. With dementia (loss of previously existing cognitive ability), vocabulary tends to be relatively preserved unless there is an obvious aphasic component, and the degree of disability in such patients is often unrecognized until specific tests of memory and other cognitive function are performed. Such dissoci-

ation would be reflected in IQ testing; demented patients tend to achieve better verbal than performance scores.

▶ Language

Aphasia is a disturbance of language that, in contrast to dysarthria, is explained neither by weakness or incoordination of the muscles of articulation nor by impaired hearing or vision. Impairment in nonlanguage cognitive spheres often coexists, and aphasic features are frequently encountered in dementing illnesses such as Alzheimer disease. The pathology responsible for aphasia is in the left cerebral hemisphere in over 98% of right-handed and around 60% of lefthanded people. Cortical opercular structures (bordering the sylvian fissure) are usually involved, but aphasia has also followed damage to the thalamus, caudate, or cerebral white matter. The location and extent of the lesion differentiate the clinical subtypes of aphasia, which can be identified by assessing six basic components of language: spontaneous speech, speech comprehension, naming, repetition, writing, and reading.

Spontaneous Speech

Spontaneous speech is assessed by posing questions or remarks designed to elicit fullsentence replies. (Asking "Is your right arm weak?" does not accomplish this goal. Asking "What happened that caused you to come to the hospital?" does.) Fluency refers to the amount of speech produced over time (normally more than 50 words per minute). Word-finding difficulty can produce nonfluent hesitations, but except with very severe anomia the patient is usually able to produce several consecutive words or syllables at a normal rate. By contrast, the speech of Broca aphasia is severely and consistently nonfluent independent of word-finding and is often marked by long delays in initiation and hesitations between words and syllables.

Prosody refers to the musical qualities of speech, including rhythm, accent, and pitch. It gives languages and dialects their special oral character and serves different functions. Prosody can convey the emotional quality of speech (sad, glad, mad; this probably depends on right hemispheric processing), can provide propositional information (eg, the pitch inflections that characterize a sentence as interrogative or imperative), and, in languages such as Chinese or Thai, can convey semantic meaning.

The term paraphasia describes the unintentional substitution of incorrect for correct words. There are two types of paraphasic errors, literal and verbal. Literal (or phonemic) paraphasias involve words that phonetically resemble the intended word but contain one or more substituted syllables (eg, bistbatch for wristwatch). When such alterations have the character of real words, they are called neologisms. Verbal (or semantic) paraphasias involve real but unintended words (eg, clock for wristwatch); the substituted word is often semantically close to the intended word. In some patients, paraphasic errors are occasional contaminants of speech. In others, they almost entirely replace it; such incomprehensible speech is called jargon.

Even in the absence of paraphasias, the content of aphasic speech may be difficult to grasp. Severely restricted vocabulary may cause logorrheic but empty speech rather than word-finding hesitations. Paragrammatism refers to seemingly preserved syntax amid such profoundly restricted semantic content. By contrast, syntactic or relational words (such as prepositions, conjunctions, possessives, or verb tenses) are sometimes conspicuously absent in aphasic speech, particularly with Broca aphasia; such speech, practically reduced to nouns and verbs, is called agrammatic or telegrammatic.

SEE CASE 63 | p. 245

"A 55-year-old right-handed man suddenly develops difficulty speaking and weakness of his right side."

Speech Comprehension

If a patient's speech comprehension is impaired, the rest of the examination must be restructured. Strikingly abnormal speech comprehension may become apparent only on shifting from open-ended conversation to specific testing. Moreover, abnormalities of speech comprehension (like any neurological sign) may be mild or severe, or may become more severe as the examination progresses.

Assessment of speech comprehension should not depend on the patient's own verbal output; a wrong answer to a question could signify a paraphasic error rather than failure to understand the question. Asking the patient to follow spoken commands is also potentially problematic. If a command, simple or complex, is followed, and if the examiner has avoided nonverbal cues, it can be presumed that the command was understood. Failure to follow a command, however, could have different possible explanations, for example, paralysis, apraxia, pain, or negativism.

A more reliable method of testing speech comprehension is to ask yes—no questions. Even patients with severely restricted speech output can usually indicate affirmative or negative. The correct answers must of course be known to both the patient and the examiner. Still another way of testing speech comprehension is to ask the patient to point to objects or body parts.

These strategies detect disorders of semantic comprehension. As with abnormal speech output, semantic and syntactic (relational) comprehension can be dissociated. Syntactic comprehension can be assessed (in patients with adequate motor ability) by object manipulation. First identifying a comb, a pen, and a key, the patient is asked to put the key on top of the comb or the comb between the key and the pen. Alternatively, the patient can be given a statement such as "Tom's uncle's wife has blue eyes," and then asked, "Is the person with blue eyes a man or a woman?"

SEE CASE 64 | p. 247

"A 53-year-old woman abruptly begins 'talking out of her head.'"

Naming

Naming ability is tested in patients with adequate vision by showing them objects, body parts, colors, or pictures of actions (confrontation naming). Patients with impaired speech comprehension may not grasp the nature of the task. A variety of abnormal responses indicate anomia. Some patients produce literal or verbal paraphasias, which may or may not then be self-corrected. Some hesitate and effortfully grope for the correct word (tip-of-the-tongue phenomenon); such patients, though unable to come up with the word on their own, may correctly select it from a spoken list or say it correctly after being given its first letter. Other patients describe rather than name the object. For example, instead of saying "necktie," the patient says, "It's what you wear around your neck."

Repetition

Repetition is tested by having the patient repeat several sentences such as "Today is a sunny day" or "In the winter the President lives in Washington." Syntactically loaded sentences may be particularly difficult (eg, "If he were to come, I would go out"). Repetition errors most often consist of paraphasic substitutions.

Writing

Testing of writing begins by having patients sign their names. If that cannot be accomplished, more elaborate tests will almost surely fail. (Writing one's name does not necessarily rely on language processing per se; in many people it is an "overlearned motor act" more akin to a golf swing than true graphia.) More specific tests of writing include dictated sentences, words, or letters, as well as spontaneous writing, for example, describing what is seen in a