Present illness (Dec. 14, 1907).—Coughing for two months, gradually getting worse. No expectoration. Night sweats. Chills. Dyspnea. Pain in left side. Breathes through mouth. Appetite poor. Subject to colds.

Physical examination.—Temperature, 99.6. Pulse, 84. Weight, 58 lb. Lungs affected. See chest diagram.

Fluoroscope examination.—Shadow in left upper quarter. Diaphragm lower on left side than on right. Excursion increased on right.

I wish to thank Dr. Francis H. Williams and Dr. Edwin A. Locke for the opportunity given me in making this study; also Dr. E. O. Otis for his valuable suggestions.

THE NEUROLOGY OF APRAXIA.

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THE title chosen for this paper would be more properly "Suggestions toward the Probable Neurology of Apraxia," for in our relative ignorance as to the action mode of the brain no one may be quite certain of scarcely anything as yet relating to precise cerebral processes; much indeed hangs upon the nature of the nervous impulse. Does not Ramon y Cajal say under date of 1910 (Vol. II, p. 869, of his elaborate "Histologie"): "A dire vrai, il n'est pas possible, dans l'état actuel de nos connaissances, de formuler une théorie définitive du plan architectural et fonctionnel du cerveau"; and do not doctors as competent as Bastian and Ferrier diametrically disagree on nearly all essential matters concerned with the physiologic nature of the cortex? If one's suggestions, therefore, seemingly look forward and not backward, one need never be ashamed; and simplicity certainly we can never hope to find, but only the outline of the intricate plan.

In the usual discussions of the mechanism of voluntary movement (most of the actual research and thought have been classed as psychological), one of the most important factors of the complex neural process has been generally overlooked, namely, the spatial nexus in which all bodily action neurally considered has its rise. The more metaphysical discussions of movement have given it due consideration, but its physical basis in the organism has certainly been unduly ignored. It is to this as a factor in apraxia that the present writing intends to call attention. All apraxia includes ataxia!

As the writer has elsewhere (*Moto-Sensory Development*, 1910) in a general way suggested, observation of the development of voluntary movement in the infant during the first three years or so (a much-neglected medical field) indicates that power of deliberate action, save in the simplest innate movements of reaching and clasping with the fingers, develops *pari passu* with the conceptualization of space. This, we may not doubt, is much more than a coincidence. The infant is at first an all but reflex thing, moving under the stimulus of the inherent impulse to activity, and he becomes a free agent, personality,

only as he becomes aware of the empirical three dimensions in which his body, like his wholly objective world, is constructed, and in terms of which alone initiative movement acquires meaning in any logical sense. In these terms alone to the finite mind is orientation or order; can any one, then, suppose that this universal ground of action is unrepresented in the integration of his will?

Physiologists more and more insistently are emphasizing the afferent or centripetal side of the motosensory circuits of the nervous system, as, indeed, our rapidly better appreciation of kinesthesia necessitates. For example, Wm. MacDougall, an English leader in the doctrine of muscle-action, in *Brain*, 1909, says, "The conception towards which the study of the organism as a whole points is that the neurones of the afferent side of the nervous system (including the cerebellum) constitute a great common reservoir of free energy, in which the head of pressure varies from moment to moment with the ratio of the inflow to the outflow, and on which all efferent pathways may draw in turn when they come into activity." So far as spatiality is concerned (surely in its relation to deliberate movement a case in point) the "reservoir" in the young infant's brain fills from many afferent sources indeed, and they, like other complex neural conditions, are beyond present exact detailing. Because he could not draw them wholly on the map, no one doubts that New England is covered with a network of railway tracks. Among the factors of this working knowledge of spatiality, however, in the evolving infant mind and therefore mechanized in the adult, are certainly these: A, the resident kinesthetic influences from the limbs moving so continually under the impulse to activity, and especially those coming from the joints, muscles, tendons, skin and bones of the arms and hands, pioneers in the evocation of the deliberate will. B, the kinesthesia from the extrinsic eye-muscles and from such other important and widespread muscles (of the neck, back, abdomen and even legs) as assist in directing the line of sight always on the (stereoscopically placed) foveæ centrales. C, the kinesthetic and special impressions integrating into equilibrium and coming from the semicircular canals, the eyes, and perhaps from the protopathic receptors of the abdominal viscera. D, in some way as yet hard to understand, the local signs of the surface and perhaps somewhat of the interior of the body, especially of the mouth cavity. E, the motor mechanisms of each of the senses so far as involving adaptive or adjustive muscular movements that afford awareness of direction or of space directly, for example the tongue, the retina being a conspicuous other example on the olden-time natavistic theory of spatiality. All these and probably other afferent influences gradually teach the baby that there is a *depth* for his deliberate exploration. A little later the kinesthesia from the locomotor mechanism, that of creeping, tumbling, walking, etc., enlarge and vigorously confirm the spatial concept thus in-

trinsically developed. Into the details of these various factors of original space-conception we need not even attempt to go, nor is it necessary to do so in order to be assured that their afferent impulses come from every portion of the body and directly or "symbolically" involve every portion of the brain. One need only consider how widespread is the visual "tract" through the hemisphere 'fore and 'aft; how expanded and how involved are the auditory centers if we include the essential vestibular functions; how spread-out and interknit are the taste-"centers," those of smell, of touch (shown by Van Biervliet recently to be a phase of kinesthesia), and of orientation, equilibrium and local signs. Such in the sketchiest of outline only is something of the brain-neurology, it may be, of the afferent intelligence that fuses into the fast-growing infant mind as a basal working knowledge of the space in which alone he can move and so have his being.

In proportion as the individual intimately knows this space as represented to him thus by the nervous system is he capable and skillful and efficient, master of himself and of his plastic environment. In short, in the neural (and muscular) mechanism that develops originally a personality's notion of space we appear to have the foundation more or less of the neuromuscular mechanism of voluntary movement in its most obvious details and framework both at once, and what develops in the infant becomes the (often subconscious) determinant of the behavior of the adult.

Of course there is much more than this complex set of spatial neurograms that determines the co-ordination of the deliberate movements. Brain processes that represent concepts of objects (see below), of quality, of self-confidence, of interest, of relation of every kind, stand behind voluntary movement and these would be especially hard to localize in the cerebral cortex. There are furthermore relations to all kinds and degrees of emotional tones to be considered and innumerable and, in fact, indefinite connections with the intricate life's store of experiences.

"Thoughts hardly to be packed
Into a narrow act,
Fancies that broke through language and escaped."

In short, the whole nameless and indefinable associated memory, conscious or subconscious, of the individual enters more or less, or may enter, into the immediate resolution of a deliberate action however trivial or important. All this means cerebral traces or cerebral action whose intricacy of pathway along the neurones no man can specify at present or even understand. The neurology of behavior in its sum involves all this and greatly more besides; motives and intentions, however well or ill-defined, could be really explained on certainly no simpler plan. Even if we may suppose some mode of simplification in the controlling neurogram of a simple voluntary act so far as the circuit around through the receptor, "motor center" and muscle is concerned, then even it would be, we may be sure,

only a relative simplification, the work of "symbolic" knots of neurones that have undertaken familiar combinations in the course of years or centuries.

Besides all this, there must come out of the cortical maze, somewhere or at least somehow representing all this product of experience, the determination to make the movement at the time, perhaps the resultant of a host of afferent impulses from the relative periphery representing attentive effort. Lastly we may one day have to account for myriad intricate impulses that inhibit, — and this last presents a whole possible new field for neurologic search and research whose further boundary no one can as yet surmise and much less see.

Unless we cease to ignore the surpassingly complex determinants of voluntary behavior thus inadequately suggested we can in no wise even approach the solution of the neurologic problem. Here, as so often elsewhere, the first step to real explanation is appreciation of the intricacy of the conditions — and this the clinician too seldom stops to consider.

Apraxia has had various shades of meaning since Hughlings-Jackson first called attention to its interesting nature and the word later came into use, but at last there seems to be some general agreement to follow Liepmann's definition and to consider the condition "an incapacity for subjectively purposive movements of the limbs, with conservation of the power of movement." It is obvious that this conception is a broad and scientifically adequate idea notwithstanding its non-inclusion of voluntary movements other than those of the limbs; if one leave out of Liepmann's definition the words "of the limbs" the formula is exact and fundamental for all future discussion. Heilbronner's usage of the term includes various phases of the general condition but does not differ materially from this. On the other hand, the short and definite term "agnosia" for the failure to recognize objects has advantages that should make it regularly preferred (and used) to any expression that includes apraxia, for the two concepts are logically entirely distinct however close their alliance in clinical neurology. We discuss, then, in this essay in neurology, briefly as is fit, pure motor apraxia — a form of will-palsy basally unlike abulia.

Out of all the leading descriptions of apraxia (those, for example, of Liepmann, Bianchi, Heilbronner, Lewandowsky, Pick, Wilson, Coriat) two facts especially have eventuated — the reasonable probability of eupractic "centers" in the two upper, especially the left, frontal lobes (above Broca's); and second, the frequent involvement of the corpus callosum in this particular form of will-defect. With the former proposition only are we here concerned, except in the general way allowed by our relatively scanty certain knowledge of the corpus callosum — to know which thoroughly would be to understand practically the whole of the cerebral cortex.

Many of the discussions of apraxia have clung perhaps somewhat too closely to the narrow clinical facts revealed by inadequate tests or to the still less informing conditions found in a few cases at the necropsy, thus ignoring generalities that are at once quite as certain and more instructive for general diagnostic use. As one may see from his above-quoted definition Liepmann has done better, for he discusses the condition on a basis that is not only clinical but thoroughly scientific and enlightening. It is then not only in the inability to use a few familiar objects, pencils and pocket-knives and the other things at hand on a physician's table, but it is likewise, and quite as importantly, in the patient's failure in voluntary movement generally involving no "use" of any thing outside the organism, that apraxia consists. In trying to extend his index finger outwards to touch the corner of a picture-frame on the wall a man may exhibit apraxia quite as well as in his ignorance of how to use a corkscrew or a thimble and yet the intended movement be apraxic and not merely ataxic. Indeed, for our present purpose, all voluntary movements or acts may be classed under two wholly arbitrary heads, namely, those that involve the using of objects whose use has been recognized, and those involving the use or practice of another object of consciousness whose basal nature the whole mechanism of efficiency recognizes, namely, *space*. Every voluntary act includes the use of this (universal?) spatial object, while only a relatively few base their co-ordination, following recognition, on material objects.

As the by-product of an apparatus—research under way in a somewhat different direction, it has recently been strongly impressed upon the writer how little the imagery experienced just before or during a careful voluntary movement has to do with the voluntary control as a performance in space with definite direction, speed, extent and force. Introspective reports in connection with exact objective records have made this matter distinct. Notwithstanding an essential identity of performance, the introspective experiences varied widely—the imagery of no two were alike. Kirkpatrick, Woodworth, Stout, Bair, Judd and many others before them as well as since have discussed imagery almost indefinitely, forgetful that consciousness, never lapsing, has to have some content, forgetful, too, as it seems, how competent a machine is the mechanism of human efficiency. No one in these days when psychologists, even, are beginning to understand what the subconscious is, should thus ignore the basal consideration that in the first years of life voluntary control became a well-developed psychomotor system competent to perform all ordinary movements, not new, with only symbolic control from centers working subconsciously whose function it is thus to direct familiar expressions of individual intention. The "reservoir" of afferent influences attends to the motivity of this, and consciousness only "says the word." The precise "imagery" that is attendant on a voluntary movement seems to have little effect

on the accuracy of the movement save as it detracts from or increases the attention-effort exerted by the psychomotor (eupraxic plus the Rolandic?) centers on the musculature, on the particular action system in use at each moment. Out of the maze of brain and cord and sympathetic the deliberate will chooses for itself a pathway always complex and intricate. Physiologically the will is "viatility," but none the less human or divine on that account.¹

Save in new and hence really difficult movements, much of the nerve-control apparently has been assumed by psychomotor-complex neurograms perhaps of the frontal lobes efferenting by way of the central convolutions, but, however, in a way the normal adult knows little of so far as direct experience goes. If, on the other hand, the motor idea of the action be intently conscious (as is always the case in really new co-ordinations) the attention is largely in terms of spatial relationship plus a more or less accidental and unimportant fusion of visual sensations; resident kinesthesia; ill-defined consciousness of effort or strains; and extraneous sense-impressions of many possible kinds. There is evidence that the resident kinesthesia may mean much in the acquirement of new and difficult control just as there is evidence likewise that in the average seeing person doing familiar things it means usually nothing at all for consciousness. In the blind the foundation space-consciousness is certainly much more definite and distinct than in normal individuals, as is also their resident kinesthesia (called by them touch). The relative inaccuracy of voluntary movement in the blind is not hard to understand when we consider the relative paucity, inevitable and great, of their eupraxic centers, products largely of experiences that they cannot have had.

The early elaboration of human behavior into very numerous psychomotor complexes on a basis of economy and habit devolves especially, we may reasonably presume, on two important portions of the brain (connected intimately, however, with all the rest)—the frontal lobes (via the central) and the cerebellum. If we know anything at all of the frontal cortex it is that one at least of its duties is this elaboration of motor ideas, how to use objects, for example, or how to rotate the arm or roll a shot between the fingers. These centers have in early years elaborated many such psychomotor complexes, have interrelated them, and have put them in bewildering intimacy with all the other centers in the brain and below it. Broca's convolution furnishes what is probably by far the most complex example of an eupraxic center, and its function is just the elaboration, interrelation, and extra-relation of a certain set of objects, namely, words. These, spoken, written, printed, graven, depicted, sculptured or materialized by the sign-manual constitute the physical basis, so to say, of the one uniquely human process of language-formation

¹ Some of the possible details of this neuromuscular process especially in the cord have been recently discussed by the writer in an essay on Attention in the *American Physical Education Review*, for November and December, 1910, and January, February and March, 1911.

and language-expression. Need one try to imagine the details of Max Mueller's speech-center in terms of neuraxones, dendrites, nerve-cells, or of ions and osmosis and reversing colloids? Yet this must be done some time and by some one or else all our fashionable localization be given up.

In a way quite homologous to this, every common object other than words must have representation in the frontal cortex, we may assume. If then a man does not know how to use a sextant or an eidograph or a planimeter, or a pencil or a pair of shears, it is so only because his frontal cortex has never acquired or, from disease, has lost that particular psychomotor complex. No more can be taken out than has been put in. As has been often well pointed out, the newborn child is almost wholly apraxic, although even then something in his mechanism of efficiency represents the use of his mother's breast just as it represents and provides the means of finding it in space. The cleverest adult obviously is he who has in his frontal cortex the greatest number and the greatest perfection of detail and relationship of these motor ideas (neurograms) of movements of utility.

Voluntary movements of the other of the two suggested classes, those not involving the use of particular material objects, employ a center commensurate in elaboration and universality of use with the "object" that they do employ, namely, space. The first part of this paper has tried to briefly suggest how manifold and complex and withal how fundamental is this spatial ground of all our neurally controlled behavior; we make our space and cannot move outside of it. We have already mentioned the most important of the factors that fuse into our voluntary development and give us the basis of our deliberate activity. The "center" of this voluntary nexus of movement is undoubtedly in some manner the cerebellum under the continual control of supranuclear influence. To leave the cerebellum out of any discussion of the neurology of apraxia is to dehamletize, so to say, the text, for without this all-related center voluntary movement has no principle of action, no rule of conduct. It needs only a drunken man reeling home or other afferent ataxia to demonstrate the proposition. We can almost, then, speak of the cerebellum as the space center, at the physiologic foundation of all voluntary movement, its "immanent idea."

Through the ipsilateral pons each frontal lobe is in close connection with the contralateral lobe of the cerebellum. We may, therefore, be reasonably sure that the so-called eupractic centers of the frontal cortex receive therefrom continually the nervous co-ordinations by which alone they can control the movements made in using objects. It is in making this connection between the hind-brain and the fore-brain that lesions of the corpus callosum may be involved in apraxia, as has recently appeared to be sometimes the case, for thus the space-co-ordinations of the contralateral lobe of the cerebellum might be cut off from the eupractic centers, — for example,

those coming from the right cerebellum to the left frontal lobes. This is the more important because lesions in the latter region have recently been found coincident with apraxia oftener than any where else.

It is difficult, however, to accept one suggestion made in current apraxic discussions, that, namely, of a single dominant center of eupraxia controlling all the rest. By the logical nature of use, unique for each kind of object, this idea seems to be untenable. If such a center be postulated, its most likely position would be in the Rolandic region where the general psychomotor co-ordinations of voluntary action are commonly supposed to arise. To cite Broca's center as an homologous instance of dominancy were to ignore the unequalled complexity of language and of language-expression. This center, if for convenience the term be retained for it, is in reality a large and intricate region of interwoven neurones out of all comparison with the requirements of a center that may be thought of as dominating numerous other centers each with co-ordinating duties of its own. In some such way as this altogether, the nature of the observed administration of the voluntary movements said to be defective in the clinical histories of actual apraxias may perhaps be tentatively better understood.

In many voluntary movements, then, spatiality seems to constitute the neural motor idea necessary for their co-ordination and muscular accompaniment, but in the movement of using an object space may be oftentimes only of secondary importance, although, we may presume, always underlying the cortical associations in its influence on the actual innervations. When the clinical observation of apraxia is regularly extended to cases or aspects presenting apraxic movements other than those concerning the use of small familiar objects, it can hardly be doubted that this important relationship of space-conditions will promptly appear.

The importance of the neurology of apraxia, as set forth by all recent writers, in relation to the baffling educational problem of ambidexterity presents itself for consideration, and the problem itself urges solution by comprehensive experimental methods.

ACCURATE OPTICS.

BY ISAAC HARTSHORNE, M.D., POUGHKEEPSIE, N. Y.

EXISTING inaccuracy in optical production and the failure on the part of many oculists to recognize the same. — Trial lenses. — Prescriptions inaccurately filled. — Opticians and oculists both to blame, especially the oculists, since the responsibility to the patient is theirs. — Absolute accuracy can be obtained when demanded and the finished lens properly inspected by the oculist. — The commercial element. — The remedy is for oculists to verify the claims of accuracy of optical houses.

THE progress of medicine and surgery during the past thirty years has been so tremendous and so revolutionary that it must be difficult for most medical men of to-day to realize what it meant to practice medicine and surgery in and before the eighties. Suffice it to say that surgery is now aseptic instead of septic; diphtheria, smallpox and yellow fever have none of their former whole-