will know where to look for information; and he can use it when he finds it. If he meets a phrase he can not construe, he will know how to use his dictionary. A statement couched in chemical language, or symbols, will not make him shut the book like a nineteenth-century chemist confronted with a sign of integration.

Nothing will arouse and retain the student's interest so effectually as frequent references to those points of contact between theory and practise, where the abstractions we are trying to teach him become concrete in the problems he will have to face.

And here let me say what I have hinted before, that it is a mistake, I am sure, to keep organic chemistry a sealed book to the engineer. If we consider the various applications of chemistry to daily life and to industry, it is surprising to note how many of them are concerned with the chemistry of the carbon compounds. Fuel, explosives, sanitation, the decay and preservation of timber, pigments, oils, paper, textile industry, fermentation, the preparation and preservation of food, all have to do with organic chemistry. Let any one read a list of patents, or the classification of abstracts in the *Journal of the Society of Chemical Industry*, and this will be made abundantly clear.

It may be objected that in the time at his disposal the student can only acquire a smattering of this great subject, and that such a smattering is worse than useless. I readily grant the first contention, but I emphatically deny the second. If by the abusive term "smattering" we mean a little knowledge, then that smattering is dangerous only when it carries with it unconsciousness of its own littleness, and I hope I have made myself sufficiently clear as to the importance of keeping always before the student his own limitations.

The cure for superficiality, that bugbear of the pedant, is not to blindfold the eyes, but to train the eyesight, and the student whose mental vision is thus sharpened will not only be able to see clearly the things that lie before him and about him on the threshold of our science, but he it is who will most readily discern the vastness and the richness of the territory at whose frontier he stands; and he who will most humbly and most surely walk in any of its paths along which his business or his pleasure calls him.

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SCIENTIFIC BOOKS

The Integrative Action of the Nervous System. By CHARLES S. SHERRINGTON. New York, Charles Scribner's Sons. 1906. Pp. xvii + 411. $3.50.

This volume contains the Silliman Memorial Lectures delivered at Yale University in 1904. In it the author focuses the work which he has carried on with such assiduity on the functions of the central nervous system considered as an organ for coordination. This side of nervous physiology has perhaps received less attention of late than the study of the activities of the individual nerve fiber or cell; though, to be sure, the author is able to refer to a long list of fellow workers, brought together into a valuable bibliography, among whom the most prominent are perhaps Exner and Goltz. It may, however, be safely said that the author's own contributions, in range and precision, now entitle him to rank at the head of students of this phase of the subject. The function of nervous tissue is, in a word, to conduct, and so to integrate—to enable the organism, in reacting on its environment, to act as a harmonious whole. To understand this function, one must, of course, penetrate the mystery of nerve conduction; but besides, and to some extent independent of that, one must know what are the paths of conduction and how they are interrelated. The present work is not concerned specially with topography, but with the general facts of the interrelation of nerve paths.

The unit of coordination is the simple reflex, though this is itself an artificially simplified unit, "because all parts of the nervous system are connected together and no part of it is probably ever capable of reaction without affecting and being affected by various other parts." Nor does there exist, normally, such a thing as a resting condition, but every reflex supervenes upon a previous condition of reflex activity, and the modifications which it produces in that condition, by reinforcement and inhibition, are part and parcel of itself. The only adequate picture is that of a total reflex "pattern," which may analytically, though somewhat artificially, be considered as made up of a combination of simple reflexes, and which, in response to a stimulus, gives way to a new reflex pattern.

The simple reflex results from the joint action of three organs, the receptor or sense organ, the conductor, and the effector organ, which last is usually composed of muscular or glandular tissue. Regarding the receptor, it may be said that its function is to lower the threshold for a particular sort of stimulus—mechanical, chemical, photic—while simultaneously raising the threshold for other stimuli, so as to make possible different reactions to different classes of stimuli. The "pain" end organs form an exception to this rule, in that they are not specially adapted to any one physical stimulus, but respond to a stimulus of any sort which threatens injury to the part where the pain organ is located. In regard to the effector organ, it may be noted that it is not usually a single "muscle" in the anatomical sense, but may be either more or less than that.

It is, however, the conductor organ, especially that part of it that lies in the nerve centers, which gives to reflex action most of its variety and peculiarity. The characteristics of reflex conduction are brought out by contrasting it with the simpler conduction that is observed in nerve trunks. No less than eleven points of difference are detailed by the author. Some of these, such as the irreversibility of reflex conduction, as contrasted with the reversibility of conduction in nerve trunks, have long been recognized. The slowness of reflex conduction has also often been emphasized, but the author shows that the important difference here is rather the great dependence of speed in reflex conduction on the intensity of the stimulus. When the stimulus is strong, the conduction through the centers shows no special slowness, but when the stimulus is weak the reflex may be very much delayed. Again, in contrast with nerve trunks, which cease their activity promptly on the cessation of the stimulus, the reflex shows "after-discharge," which may be very prolonged when the stimulus is intense. The intensity of the reflex discharge is less closely dependent on the intensity of the stimulus than in the case of the nerve trunk or the muscle. The intensity of reaction of the nerve trunk is a continuous, and almost mathematical function of the intensity of the stimulus; but while something much like this may be said of some reflexes, in others the reaction remains practically constant for all intensities of the stimulus which are strong enough to elicit the reflex at all, and in still others the intensity of reaction remains constant for a considerable range of stimulus, only to make a sudden jump at a certain critical intensity. The threshold value for an effective stimulus is also much more variable in the reflex, since the internal condition of the reflex arc, as dependent on other simultaneous or preceding stimuli, is much more variable than that of the nerve trunk. Summation of subliminal stimuli is in the reflex arc much more likely than in the nerve trunk to produce a response; some reflexes can scarcely be elicited by a single momentary stimulus. When the stimulus is repeated, the rhythm of response in the nerve trunk follows closely that of the stimulus; whereas reflexes are apt to have a rhythm of their own, which is very slightly if at all controlled by that of the stimulus. The rhythm of different reflexes differs; in some it is as high as 12 per second; while in the dog's scratching reflex it is from 5 to 6, and in the "crossed stepping reflex" as low as

2.3 per second; and some reflexes consist of a single indivisible discharge. The rhythm of reflex discharge may be conceived as dependent on a "refractory phase" somewhere in the arc, similar in a broad way to the refractory phase of the heart. Whereas the refractory phase of a nerve trunk is not longer than .001 second, that of reflex discharge, varying in different reflexes, sometimes reaches as high as a second. The author has studied in a penetrating way the question of the seat of the refractory phase in the reflex arc. He shows that it can not lie in the muscle or motor neurone, nor in the sense organ or sensory neurone. It must lie in the central distributing and coordinating neurones, each of which has a refractory phase adapted in duration to the particular use of its reflex. Dependent on the central neurones is also the inhibition of muscular activity opposed to the reflex. As compared with the nerve trunk, the reflex arc is also much more susceptible to fatigue, shock, deprivation of oxygen, and the action of anesthetics. It is interesting to observe that the author inclines to attribute all these peculiarities to the synapse or surface of separation between connecting neurones, and that he is favorable to their explanation by the physical properties of such a surface of separation, with its well-known power to produce partial, selective and polarized osmosis, and to restrict the movement of ions.

Passing from the simple reflex to the combination and coordination of reflexes, the author emphasizes first of all the principle of the "common path." Reflex arcs which start at different parts of the skin or other sense organs may converge so as to act on the same muscle or group of muscles. Thus, for example, the flexors of the joints of the hind limb can be aroused by stimulating almost any point on the skin of that limb, as well as from certain other parts of the surface and interior of the body. More than this, the same muscles are called into play in other reflexes, such as the scratching or the stepping reflexes, in which the time relations differ from those seen in the flexion reflex. It appears that the muscles, and with them the motor neurones which directly control them, can be aroused from various sources, and in ways that differ to a greater or less extent. The motor neurone, extending from the cord to the muscles, is therefore a common path, forming part of many reflex arcs. This fact is important in understanding coordination. There are reflexes which use the same muscles in the same way; they may be called allied reflexes. As they can make simultaneous use of the same muscles without interfering in any way with each other, they tend to reinforce each other. But there are reflexes which make use of a given set of muscles in ways that are incompatible with each other; one may require the inhibition of activity where the other requires the activity, or they both require activity, but in differing intensity or duration or rhythm. Such opposed reflexes could not, and do not, have simultaneous use of the same muscles. When the final path is open to one of them, it is closed to the other. And it is closed absolutely. If the stimuli appropriate to two antagonistic reflexes are simultaneously applied, one or the other appears, but never a compromise or average of the two, which would indeed be a useless reaction. If during the progress of one reflex the stimulus to another is applied, it may cause a cessation of the first and its replacement by the second, but the transition is abrupt; the first does not shade off into the second. If a stimulus, at first weak and arousing a local reflex, is gradually increased in intensity, the reflex tends to spread to other muscles and other members, but all the components so added to the original focal reflex are allied. The total reflex pattern at any moment—except for reflexes neutral to each other and without influence on each other, which may coexist to a very limited extent—may thus be analyzed into a combination of allied simple reflexes.

In the *succession* of reflexes quite a different principle comes into play, for it is commonly true that a reflex is followed by an antagonistic reflex. One frequent form of sequence is the return after a reflex to the posture present before the reflex. This posture was itself reflex, and the return to it is by no means a passive movement, but is an active compensatory reaction. Very frequent in the spinal as well as in the intact animal are alternating reflexes, as stepping, scratching, etc. One of the most important original contributions of the author is the discovery of "successive spinal induction." A reflex which has been just preceded by an antagonistic reflex is found to be more readily excited than usual and to have greater energy. Inhibition of a reflex is "followed by a rebound to superactivity." As is the case in the heart muscle, so also in the spinal cord, the period of inhibition is not simply equivalent to a period of rest, but the activity of a reflex after active inhibition is greater than after repose. This fact has much to do with the orderly and adaptive sequence of an animal's movements.

Since it seldom happens that an animal is subjected to only one stimulus at a time, there is usually a competition between stimuli for control of the common paths. Prominent among the factors which make for success in this competition is intensity, the more intense stimulus having the advantage. But the intensity of the physical stimulus must be considered in connection with its location, for within the "receptive field" of a reflex, the more central portions give the reaction with weaker stimulation than do the more peripheral. Account must also be taken of other simultaneous or immediately preceding stimuli, since simultaneous stimuli that tend to arouse the same reflex, or preceding stimuli that have inhibited it, favor its appearance. The relative fatigue of different reflexes also influences the result of the competition. And, finally, the different *species* of reflexes are elicited with unequal ease. At the bottom of the scale stand the tonic reflexes, which very readily yield to others; and at the top, easiest to arouse, stand the reactions to injurious ("painful") stimuli, or to other stimuli which, considered from the point of view of sensation, have a strong affective tone.

In the chapters devoted to the brain, we find, besides the author's revision of the motor area, which is by now familiar, the observation that cortically originating movements are related in the same ways as spinal reflexes, being mutually allied, antagonistic or neutral. From the cortex, as in reflex excitation, the same stimulus which arouses a movement inhibits the opposing muscles. Also, the species of movements which can most easily be aroused by reflex paths can likewise be most easily aroused from the cortex, while such as can not be easily aroused reflexly are also very difficult of access by cortical stimulation. Flexions are in general easily aroused, extensions with difficulty. This does not mean that the "cortex is in touch with the flexors alone and not with the extensors. It means that the usual effect of the cortex on these latter is *inhibition*." The muscles of the body are not all on a par as regards reaction to stimuli, but may be broadly grouped into two systems, a *tonic* system, in which the extensors of the limbs are prominent, and a *phasic* system, in which the flexors are prominent. The muscles of the tonic system are usually kept in a condition of feeble tonic contraction, by means of which the posture of the animal is maintained. The phasic system responds to intercurrent stimuli; the posture is abandoned, inhibited, and a brief reaction, the first step in which is usually flexion, occurs, after which a compensatory movement brings back the previous posture. The stimuli which bring about tonus originate largely in the interior of the limbs and in the otic labyrinth. This system of sense organs is excited by mechanical means, especially by movements and tensions resulting from the contractions of the muscles and the movements and positions of the body. The chief center of this system, or, as we may call it in terms derived from the segmental conception of the nervous system, the ganglion of the system, is in the neighborhood of the principal sense organ belonging to it; this ganglion is the cerebellum. The cerebrum, similarly, may be considered as the ganglion of the great sense organs of the head, which have as their peculiar function the receiving of stimuli from a distance. It is because they receive stimuli from and make possible reactions to a wider environment that these sense organs of the head dominate the whole system of phasic reactions; it is for the same reason that the cerebrum is dominant.

Bringing as it does the methods of minute and continued observation and of close reasoning into a field where the casual has been the rule, the book deserves, and requires as well, attentive study. Its importance to the physiologist is evident. The physician will find a number of special topics, such as the nervous symptoms of strychnin poisoning, of tetanus, and of shock, made the subject of careful investigation. The psychologist also will find a number of points of special interest, such as a study of certain fundamental aspects of binocular vision, an experimental test of the James-Lange theory of the emotions, and suggestive analogies between certain laws of spinal reflexes, such as reciprocal inhibition and successive induction, and familiar facts of attention and of sensation.

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SCIENTIFIC JOURNALS AND ARTICLES

THE contents of the June number of *The American Journal of Science* are as follows: "Determination of the Molecular Weight of Radium Emanation by the Comparison of its Rate of Diffusion with that of Mercury Vapor," by P. B. Perkins; "Paleozoic Formations in Trans-Pecos, Texas," by G. B. Richardson; "Rectification Effect in a Vacuum Tube," by H. A. Perkins; "Life of Radium," by B. B. Boltwood; "New Occurrence of Proustite and Argentite," by F. R. Van Horn; "Occurrence of Gedrite in Canada," by N. N. Evans and J. A. Bancroft; "Iodometric Determination of Arsenic and Antimony Associated with Copper," by F. H. Heath.

THE editors of *The Botanical Gazette* announce that the price is to be advanced from $5.00 to $7.00 a year on July 1, 1908. They say: "You will easily realize that the financing of *The Botanical Gazette* has always been a problem, and you will not be surprised to hear that the University of Chicago has been obliged to contribute about $2,000 annually toward its support. It is not probable that the amount of this subsidy can be increased in the future, and at the same time the cost of production has been growing greater year by year. An interesting comparison has been instituted between *The Botanical Gazette* on the one hand and five leading botanical journals of Europe on the other in the matter of size and prices. It appears that on the average these journals give their readers 648 pages a year each, 12 plates, and 122 text figures, and the average price is $6.50. The *Botanical Gazette* on the other hand gives 945 pages, 45 plates, and 182 text figures, and its subscription price has been $5.00 in spite of the greater cost of manufacture in this country. The advice of numerous botanists has been sought and freely given, and with great unanimity their opinion favors the maintenance of the present standard of size with an increased subscription price; for it seems evident that the pressure of publication is increasing rather than diminishing. In view of the whole situation, it has been decided to increase the annual subscription to $7.00, in the belief that this represents a fair charge for the service rendered. The new rate will be applied to subscriptions begun or renewed with the July number, 1908, and thereafter."

SOCIETIES AND ACADEMIES

THE CHICAGO SECTION OF THE AMERICAN MATHEMATICAL SOCIETY

THE twenty-third regular meeting of the Chicago Section of the American Mathematical Society was held at the University of Chicago, on Friday and Saturday, April 17–18, 1908.

Professor G. A. Miller, vice-president of the society and chairman of the section, presided at all of the sessions. In opening the meeting he referred to the great loss of the society in the recent death of Professor Heinrich Maschke and appointed a committee, consisting of Professors E. B. Van Vleck, Alexander