capacity was found to be practically independent of the electrolyte so long as water solutions are dealt with. Since, *cet. par.*, the capacity decreases proportionally to the thickness of the film, for the sulphuric-acid films to have a capacity as large as the films formed in other solutions seemed to be contradictory to the observation of others who had investigated the question of the thickness of the films; the sulphuric-acid films always having been found to be much thicker than those in other solutions.

Further experiments by the writer have confirmed the results as to the greater thickness of the sulphuric-acid film, as well as the fact that they do not have any smaller capacity than the others. With water-cooled tubular electrodes sulphuric-acid films more than 0.3 mm. thick were formed; but their minimum capacity values were slightly larger than those of other films whose maximum thickness could not have been more than 0.001 mm. Sodium sulphate gives films similar to those in sulphuric acid as to both thickness and capacity.

These results necessitate the conclusion that with the sulphates *the insulating film is not the whole film;* but that we have, superimposed on the insulating film, whose capacity is measurable, a conducting film many times thicker. For solutions other than the sulphates there is no evidence for any such dual-natured film.

The resistance of these films as measured by the Wheatstone bridge with small alternating current is much smaller than the apparent resistance as calculated from the residual direct current.

Bridge measurements were taken both while the direct current was still acting and after it was turned off, while the switching on or off of the direct current made no change in the capacity, the resistance of the films was only about one third as large with the current on as with it off.

Spark Potentials between a Point and Plane, for Small Distances: ROBERT F. EARHART, Ohio State University.

Measurements were made on the P.D. required to cause a spark to pass between a needle point and plane surface. The P.D.'s were secured from an A.C. transformer and were measured with a Weston voltmeter. No. 10 Sharp needles were used as the point electrode. A large number of needles were examined with a microscope and points approximating a pattern needle were chosen.

Distances separating the electrodes were measured with an interferometer.

Curves representing the relation between spark-potential and distance are similar to those showing the same relation between a spherical electrode and a plane.

For air, at atmospheric pressure the so-called 'minimum potential' was found to lie between 290 and 310 volts.

This value does not agree with results secured by other observers from static machines. The value given by Tamm is 2,150 volts when the point is negative and 3,300 for a positive point.

DAYTON C. MILLER,
Secretary of Section B.

THE SCIENTIFIC INVESTIGATION OF THE PSYCHICAL FACULTIES OR PROCESSES IN THE HIGHER ANIMALS.[1]

FOR a consistent investigator there is in the higher animals only one thing to be considered—namely, the response of the animal to external impressions. This response may be extremely complicated in comparison with the reaction of animals of a lower class. Strictly speaking, natural science is under an obligation to determine

[1] The Huxley lecture on recent advances in science and their bearing on medicine and surgery. Delivered by Professor Ivan P. Pavlov at Charing Cross Hospital on October 1, 1906. From the report in the *British Medical Journal.*

only the precise connection which exists between the given natural phenomenon and the responsive faculty of the living organism with respect to this phenomenon—or, in other words, to ascertain completely how the given living object maintains itself in constant relation with its environment. The question is simply whether this law is now applicable to the examination of the higher functions of the higher quadrupeds. I and my colleagues in the laboratory began this work some years ago, and we have recently devoted ourselves to it almost completely. All our experiments were made on dogs. The only response of the animals to external impressions was a physiologically unimportant process—namely, the excretion of saliva. The experimenter always used perfectly normal animals, the meaning of this expression being that the animals were not subjected to any abnormal influence during the experiments. By means of a systematic procedure easy of manipulation it was possible to obtain an exact observation of the work of the salivary glands at any desired time.

It is already well known that there is always a flow of saliva in the dog when something to eat is given to it or when anything is forcibly introduced into its mouth. In these circumstances the escaping saliva varies both in quality and quantity very closely in accordance with the nature of the substances thus brought into the dog's mouth. Here we have before us a well-known physiological process—namely, reflex action. It is the response of the animal to external influences, a response which is accomplished by the aid of the nervous system. The force exerted from without is transformed into a nervous impression, which is transmitted by a circuitous route from the peripheral extremity of the centripetal nerve through the centripetal nerve, the central nervous system, and the centrifugal nerve, ultimately arriving at the particular organ concerned and exciting its activity. This response is specific and permanent. Its specificity is a manifestation of a close and peculiar action of the external phenomena to physiological action, and is founded on the specific sensibility of the peripheral nerve-endings in the given nervous chain. These specific reflex actions are constant under normal vital conditions, or, to speak more properly, during the absence of abnormal vital conditions.

The responses of the salivary glands to external influences are, however, not exhausted by the above-mentioned ordinary reflex actions. We all know that the salivary glands begin to secrete, not only when the stimulus of appropriate substances is impressed on the interior surface of the mouth, but that they also often begin to secrete when other receptive surfaces, including the eye and the ear, are similarly stimulated. The actions last mentioned are, however, generally considered apart from physiology and receive the name of psychical stimuli. We will take another course, and will endeavor to restore to physiology what properly belongs to it. These exceptional manifestations unquestionably have much in common with ordinary reflex action. Every time that there is a flow of saliva attributable to this cause, the occurrence of some special stimulus among the external influences may be recognized. On very careful exercise of his attention, the observer perceives that the number of spontaneous flows of saliva forms a rapidly diminishing series, and it is in the highest degree probable that those extremely infrequent flows of saliva for which no particular cause is at first sight apparent are in reality the result of some stimulus invisible to the eye of the observer. From this it follows that the centripetal paths are always stimulated primarily and the centrifugal paths secondarily, of course, with the interposition of the central nervous system.

In the first place, they arise from all the bodily surfaces which are sensitive to stimulation, even from such regions as the eye and the ear, from which an ordinary reflex action affecting the salivary glands is never known to proceed.

It must be observed that ordinary salivary reflexes may originate not only from the cavity of the mouth, but also from the skin and the nasal cavity. In the second place, a conspicuous feature of these reflexes is that they are in the highest degree inconstant. All stimuli introduced into the mouth of the dog unfailingly give a positive result in reference to the secretion of saliva, but the same objects when presented to the eye, the ear, etc., may be sometimes efficient and sometimes not. In consequence of the last-mentioned fact, we have provisionally called the new reflexes 'conditioned reflexes,' and for the sake of distinction we have called the old ones 'unconditioned.' Every conditioned stimulus becomes totally ineffective on repetition, the explanation being that the reflex action ceases. The shorter the interval between the separate repetitions of the conditioned reflex the more quickly is this reflex obliterated. The obliteration of one conditioned reflex does not affect the operation of the others. Spontaneous restoration of the obliterated conditioned reflexes does not occur until after the lapse of one, two or more hours, but there is a way in which our reflex may be restored immediately. All that is necessary is to obtain a repetition of the unconditioned reflex—as, for instance, by pouring vinegar into the dog's mouth and then either showing it to him or letting him smell it. The action of the last-mentioned stimuli, which was previously quite obliterated, is now restored in its full extent. If for a somewhat long time—such as days or weeks continuously—a certain kind of food is shown to the animal without being given to him to eat, it loses its power of imparting a stimulus from a distance—that is, its power of acting on the eye, the nose, etc.

We may, therefore, say that the conditioned reflex is in some way dependent on the unconditioned reflex. At the same time we see also the mechanism which is necessary for the production of our conditioned reflex. When an object is placed in the mouth, some of its properties exercise an action on the simple reflex apparatus of the salivary glands, and for the production of our conditioned reflex that action must synchronize with the action of other properties of the same object when the last-mentioned action, after influencing other superficial parts of the body that are sensitive to such stimuli, arrives in other parts of the central nervous system. Just as the stimulant effects due to certain properties of an object placed in the mouth may be associated as regards time with a number of stimuli arising from other objects, so all these manifold stimuli may by frequent repetition be turned into conditioned stimuli for the salivary glands. It must be remembered that in feeding a dog or forcing something into its mouth each separate movement and each variation of a movement may by itself represent a conditioned stimulus. If that is the case, and if our hypothesis as to the origin of the conditioned reflex is correct, it follows that any natural phenomenon chosen at will may, if required, be converted into a conditioned stimulus. Any ocular stimulus, any desired sound, any odor that might be selected, and the stimulation of any portion of the skin, either by mechanical means or by the application of heat or cold, have in our hands never failed to stimulate the salivary glands, although they were all of them at one time supposed to be ineffective for such a purpose. This was accomplished by applying these stimuli simultaneously with the action of the salivary glands, this action having been evoked by the giving of certain kinds of food, or by forcing certain substances into the dog's mouth. These artificial conditioned reflexes, the product of our training, showed exactly the same properties as the natural conditioned reflexes previously described. As regards their obliteration and restoration, they followed essentially the same laws as the natural conditioned reflexes.

Up to the present time the stimuli with which we had to do were comparatively few in number, but were constant in action. Now, however, in another more complicated portion of the nervous system we encounter a new phenomenon—namely, the conditioned reflex. On the one hand, the nervous apparatus is responsive in the highest degree—that is, it is susceptible to the most varied external stimuli, but, on the other hand, these stimuli are not constant in their operation and are not uniformly associated with a definite physiological effect. The introduction of the idea of conditioned reflexes into physiology seems to me to be justified because it corresponds to the facts that have been adduced, since it represents a direct inference from them. It is in agreement with the general mechanical hypotheses of natural science. It is completely covered by the ideas of paths and inhibition, ideas which have been sufficiently worked up in the physiological material of the present day. Finally, in these conditioned stimuli, looked at from the point of view of general biology, there is nothing but a very complete mechanism of accommodation or, which amounts to the same thing, a very delicate apparatus for maintaining the natural equilibrium. There are reasons for considering the process of the conditioned reflex to be an elementary process—namely, a process which really consists in the coincidence of any one of the innumerable vague external stimuli with a stimulated condition of any point in a certain portion of the central nervous system. In this way for the time being a path is made by which the stimulus may reach the given point.

Although there are differences in the time required for the establishing of the conditioned reflexes, some proportionality may be perceived. From our experiments it is very evident that the intensity of the stimulation is of essential importance. In contradistinction to this we must state with regard to acoustic impressions that very powerful stimuli, such as the violent ringing of a bell, were not, in comparison with weaker stimuli, quick to produce conditioned increase of function in the salivary glands. It must be supposed that powerful acoustic stimuli produce in the body some other important reaction which hinders the development of the salivary reaction.

What is it that the nervous system of the dog recognizes as individual phenomena of external origin? or, in other words, what are the elements of a stimulus? If the application of cold to a definite area of the skin acts as a conditioned stimulus of the salivary glands, the application of cold to another portion of the skin causes secretion of saliva on the very first occasion. This shows that the stimulus of cold generalizes itself over a considerable portion of the skin, or perhaps even over the whole of it.

Stimulation by musical sounds or by noise in general is remarkably convenient for determining the discriminating or analytical faculty of the nervous system of the dog. In this respect the precision of our reaction goes a great way. If a certain note of an instrument is employed as a conditioned stimulus, it often happens that not only all the notes adjoining it, but even those differing from it by a quarter of a tone, fail to produce any effect. Musical *timbre* is recognized with similar or even much greater precision.

We have hitherto spoken of the analytical faculty of the nervous system as it presents itself to us in, so to say, the finished condition. We have now accumulated material which contains evidence of a continuous and great increase of this faculty if the experimenter perseveres in subdividing and varying the conditioned stimulus, and thereby makes it coincide with the unconditioned stimulus. Here, again, is a new field of enormous extent. In this material relative to the conditioned stimuli there are not a few cases in which an evident connection between the effect and the intensity of a stimulus can be seen. As soon as a temperature of 50° C. had begun to induce a flow of saliva it was found that even a temperature of 30° C. had a similar effect but in a much less degree. Trial was then made of combinations consisting of stimuli of the same kind and also of stimuli of different kinds. The simplest example is a combination of different musical notes, such as a harmonic chord, which consists of three notes. When this is employed as a conditioned stimulus each two notes together and each separate note of the chord produce an effect, but the notes played two and two together accomplish less than the whole, and the notes played separately accomplish less than those played in pairs. The case becomes more complicated when we employ as a conditioned stimulus a combination of stimuli of different kinds, that is, of stimuli acting upon different kinds of susceptible surfaces. Only a few of such combinations have been provisionally experimented with. In these cases for the most part one of the stimuli was a conditioned stimulus. In a combination in which rubbing and cold were employed the former was preponderant as a conditioned stimulus while the application of cold taken by itself produces a hardly perceptible effect. But if an attempt is made to convert the weaker stimulus separately into a conditioned stimulus it soon becomes an energetic conditioned stimulus. If we now apply the two stimuli together we have before us an evident case of them acting in combination. The following problem had for its object to explain what happens to an active-conditioned stimulus when a new stimulus is added to it. In the cases that were examined, the action of the preexisting conditioned stimulus was hindered when a new stimulus of a like kind was added to it. A new odor of a like kind hindered the operation of another odor which was already acting as a conditioned stimulus; a new musical note similarly hindered the operation of the note previously employed which was a conditioned stimulus. After a conditioned stimulus had been applied, together with another one which inhibited its action, the action of the first one alone was greatly weakened and sometimes even stopped altogether. This is either an after-effect of the inhibiting stimulus which was added or it is the obliteration of the conditioned reflex, because in the experiment of the added stimulus the conditioned reflex is not strengthened by the unconditioned reflex. The inhibition of the conditioned reflex is also observed in the converse case. When you have a combination of stimuli acting as a conditioned stimulus—in which, as has been already stated, one of the stimuli by itself produces almost no effect—frequent repetition of the powerful stimulus by itself without the other one leads to a powerful inhibition of its action, even to the extent of its action being almost destroyed. The relative magnitudes of all these manifestations of stimulation and inhibition have a very close connection with their dependence on the conditions under which they originate.

Experiments have been made in the production of conditioned reflexes by traces or latent remnants both of a conditioned and of an unconditioned stimulus. The method was that a conditioned stimulus was either allowed to act for one minute immediately in advance of an unconditioned stimulus or it was even applied two minutes earlier. Conversely, also, the conditioned stimulus was not brought into action until the unconditioned reflex was at an end. In all these cases the conditioned reflex developed itself; but in the cases in which the conditioned stimulus was applied three minutes before the unconditioned one, and was separated from the latter by an interval of two minutes, we obtained a condition which was quite unexpected and extremely peculiar, but was always repeated. When scratching was applied to a particular spot—for instance, as a conditioned stimulus—after it began to produce an effect it was found that scratching of any other place also produced an effect, just as in the case of cold or heat applied to the skin, new musical sounds, optical stimuli and odors. The unusually copious secretion of saliva, and the extremely expressive movements of the animal attracted our attention. It may appear that this manifestation is of a different kind from those with which we have hitherto been occupied. The fact was that in the earlier experiments at least one coincidence of the conditioned stimulus with the unconditioned one was necessary, but on the present occasion manifestations which had never occurred simultaneously with an unconditioned reflex were acting as conditioned stimuli. Here an unquestionable point of difference naturally comes to light, but at the same time there is also to be seen another essential property of these manifestations which they have in common with the former ones—that is, the existence of a very sensitive point in the central nervous system, and in consequence of its position this point becomes the destination of all the important stimuli coming from the external world to make impressions on the receptive cells of the higher regions of the brain.

Three characteristic features of this subject make a deep impression upon him who works at it. In the first place, these manifestations present great facilities for exact investigation. I am here referring to the ease with which they may be repeated, to their character of uniformity under similar conditions of environment, and to the fact that they are capable of further subdivision experimentally. In the second place, it is inevitable that opinions formed on this subject must be objective only. In the third place, the subject involves an unusual abundance of questions. To what departments of physiology does it correspond? It corresponds partly to what was in former days the physiology of the organs of special sense and partly to the physiology of the central nervous system.

Up to the present time the physiology of the eye, the ear and other superficial organs which are of importance as recipients of impressions has been regarded almost exclusively in its subjective aspect; this presented some advantages, but at the same time, of course, limited the range of inquiry. In the investigation of the conditioned stimuli in the higher animals, this limitation is got rid of and a number of important questions in this field of research can be at once examined with the aid of all the immense resources which experiments on animals place in the hand of the physiologist. The investigation of the conditioned reflexes is of very great importance for the physiology of the higher parts of the central nervous system. Hitherto this department of physiology has throughout most of its extent availed itself of ideas not its own, ideas borrowed from psychology, but now there is a possibility of its being liberated from such evil influences. The conditioned reflexes lead us to the consideration of the position of animals in nature; this is a subject of immense extent and one that must be treated objectively.

Broadly regarded, physiology and medicine are inseparable. Since the medical man's object is to remedy the various ills to which the human body is liable, every fresh discovery in physiology will sooner or later be serviceable to him in the preservation and repair of that wonderful structure. It is an extreme satisfaction to me that in honoring the memory of a great physiologist and man of science I am able to make use of ideas and facts which from a unique standpoint affording every prospect of success throw light upon the highest and most complicated portion of the animal mechanism.

SCIENTIFIC BOOKS.

Lehrbuch der Anorganischen Chemie. Von Professor Dr. H. ERDMANN, Direktor des anorganisch-chemischen Instituts der königlichen technischen Hochschule zu Berlin. Vierte Auflage (neuntes bis zwölftes Tausend) mit 303 Abbildungen, 95 Tabellen, einer Rechentafel, und sieben färbigen Tafeln. Braunschweig, F. Vieweg und Sohn. 1906. Pp. 796. In Leinwand gebunden M. 17.

A long review of the second edition of this book appeared in SCIENCE in 1901.[1] The present edition has been thoroughly revised, and contains valuable additions to text, to illustrations and to tables.

The weaknesses and the strong points of the book remain practically the same, as both are inherent in the author's scheme. Erdmann believes that a text-book of inorganic chemistry should describe the occurrence, properties, reactions, manufacture and uses of all inorganic elements and compounds, with liberal illustration of instructive experiments, of apparatus and of technical processes. No other one-volume text-book is so complete, so well illustrated and so thoroughly up to date in these respects.

Erdmann does not believe in the introduction of physical chemical theory in the descriptive text, but makes a brief résumé of general chemistry in the 87 pages of the introductory chapter. There are those who will sympathize with Erdmann in this arrangement, others who may be reminded of the eccentric American author who left his book unpunctuated and put several pages of commas, periods, etc., at the end of the book for use as the reader might please. Certainly many phenomena in the field of inorganic chemistry find the clearest explanation by the application of the laws of physical chemistry, and remain obscure if such explanation is not given.

This objection, however, does not lessen the practical value of Erdmann's book, because there is no text-book of inorganic chemistry written from a physical chemical point of view which is comparable with Erdmann even in general descriptive data, still less in technical information. It is, therefore, to be expected that this fourth edition will meet the same cordial reception and large sales as its predecessors. E. R.

[1] SCIENCE, Vol. XIII., pp. 268–70.

Vermehrung und Sexualität bei den Pflanzen. Von E. KÜSTER. Leipzig, B. G. Teubner. 1906. Pp. vi + 120. 38 figures.

In America one is accustomed to look with suspicion upon all books in which an attempt is made to popularize science. All too often this suspicion is justified, for who has not met with books in which scientific accuracy has been sacrificed to the sensationalism demanded by a certain class of the public or where the science is so diluted by allegory or fable as to be unrecognizable. The book before us is, however, of an entirely different type. It is one of a series of popular scientific works ('Aus Natur und Geisteswelt') in which each book is written by a specialist who knows his subject.

The subject of reproduction and sexuality in plants is a difficult one to handle so as to be comprehended by persons who have studied but little or no botany and it is in this connection that the chief criticism can be made, to the effect that it is to be feared that parts of the book will be found too technical to be