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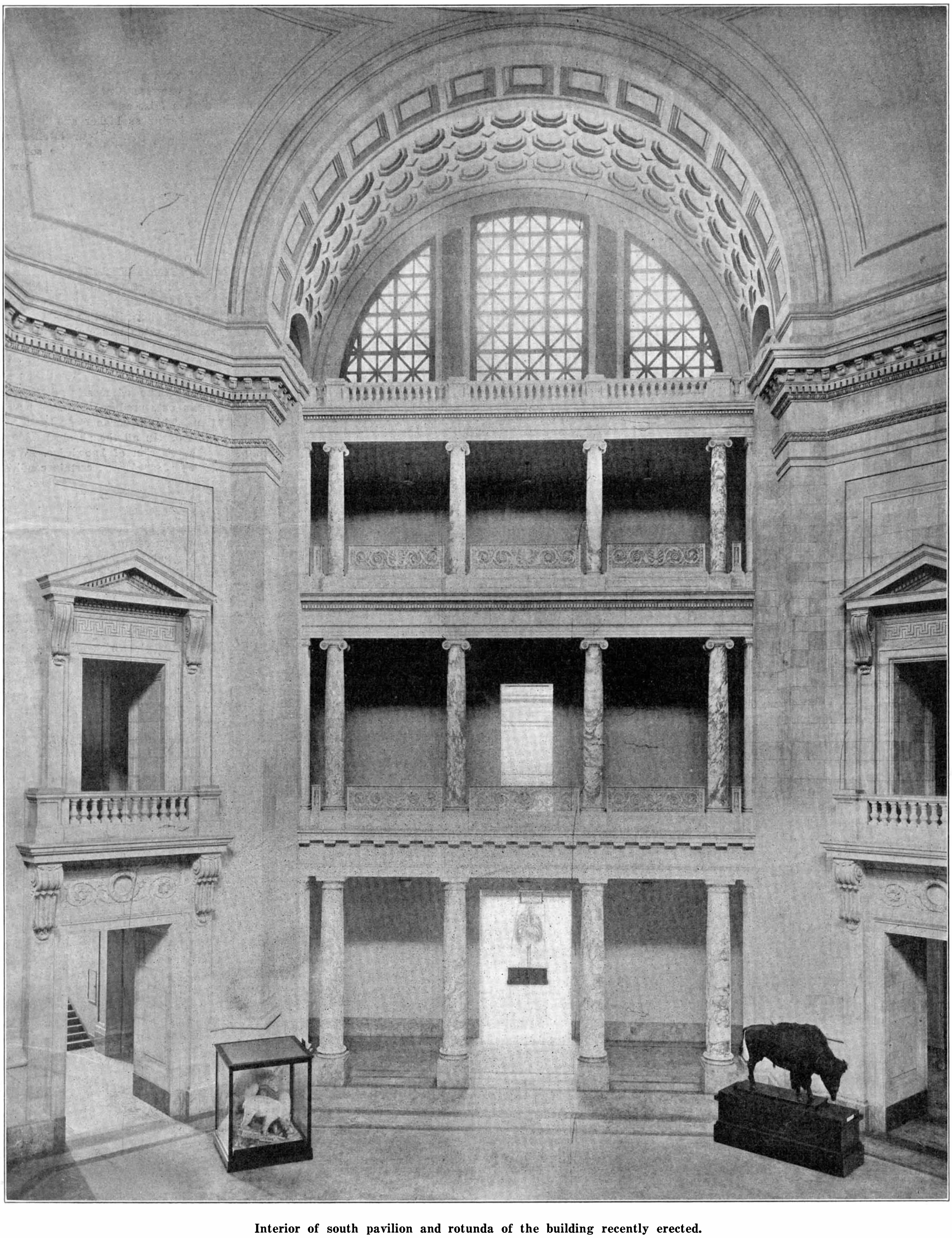


Interior of south pavilion and rotunda of the building recently erected.

THE SMITHSONIAN INSTITUTION, AT WASHINGTON, D. C.—[See page 376.]

Bergson's Theory of Intellect and Reality—I*

Is Our Intellect Limited in Its Powers?

By Norman J. Symons

FOREMOST of the philosophies of the present day stands the system of Henri Bergson. Along with much that is unique and original it combines a background of thought which comes from older sources. A few preliminary considerations will bring this background into view. However much individual thinkers may differ, philosophy as a whole has always centered around the attempt to understand the universe in its innermost being. The great systems of different ages have in fact arisen as so many answers to the imperious demand of our intellect that it should probe to the foundations of reality and encompass the whole circle of existence. But the very nature of this task raises the question as to whether our intellect is not after all limited in its powers and whether some aspects of reality must not always remain impenetrable by human thought. No conscientious philosophy can avoid this question; and the suggestion which it contains has been entertained by various thinkers. It will be sufficient here to refer to the attitude of the British philosopher Locke who found in the unwillingness of intellect to recognize its limitations, the chief source of its own confusion; while Kant, at a later date, was led to define this line of thought by limiting the grasp of our scientific understanding to the world of sense-appearances.

It is with this question as to the inherent limitations of our intellect that Bergson is throughout concerned. The movement of German idealism subsequent to Kant claimed to have transcended the Kantian position. Yet there are not lacking to-day those who see in intellect a very limited instrument of philosophical explanation. Among them we may count Bergson. "Our reason," he says, "incorrigibly presumptuous, imagines itself possessed, by right of birth or of conquest, of all the essential elements of the knowledge of truth." In opposing this assumption he is led to draw a fundamental distinction between life and inert matter, with a view to showing that in life we confront a mystery which intellect cannot fathom. Upon this distinction is based the peculiar form of his theory of knowledge. No longer, as with Kant, is it the existence of God, freedom and immortality which are said to pass the comprehension of pure intellect; rather is it life and living processes, such as the biologist studies, that our intellect, in Bergson's opinion, fails radically to understand; while it is in explaining dead matter and merely physical changes that this same intellect naturally achieves its triumphs. There is, however, another aspect to Bergson's teaching. If intellect can never hope to understand life's nature and operations, but only the physical changes of dead matter, we yet possess in instinct or intuition, as opposed to intellect, a key to life's secret. We shall ask therefore (1) whether Bergson's specific contentions about life, intellect and intuition can be upheld; and (2) if not, to what extent and under what form we can endorse the more general conception of intellect as being fundamentally limited in its powers of explanation.

To understand Bergson's contentions about life, matter, intellect and intuition, we should replace these four conceptions within their original setting. We find then that the opposition which exists for this philosopher between life and matter is based upon his beliefs as a biologist and an advocate of the theory of evolution. In an admirable review of current theories of evolution, he has shown the impossibility of giving a purely materialistic explanation of the development of living organisms. Life cannot therefore be reduced to a mere product or aspect of matter; from the outset it stands out as something unique and distinct in character; and the history of evolution becomes, in general outline, the history of the increasing organization of matter by this active, independent force called Life. Such, indeed, is Bergson's view. "We must," he says, "no longer speak of life in general as an abstraction. At a certain moment in certain points of space, a visible current has taken rise. This current of life, passing from generation to generation, has distributed itself among individuals without losing anything of its force, rather intensifying in proportion to its advance."

This image of evolution as consisting in the penetration of matter by an independent stream of life shows how Bergson introduces his two main conceptions—life and inert matter. To pass on to intellect and intuition, we find that it is life itself which has produced these two forms of consciousness. Although in its work of organizing matter life has developed species in a multitude of different directions, it has followed, Bergson thinks, three main paths, viz., that which terminates in the vegetable world and those which, parting company within the animal world, have led respectively through the arthropod series to insects such as bees and wasps and through the vertebrate series to man. The original current of life in short has distributed itself along three branches, evolving three distinct types of organization each of which has a distinct character. The typical features of vegetables are found in their immobility and lack of consciousness. On the other hand, both arthropods and vertebrates, unable to sustain themselves like vegetables by an immediate contact with earth, air and water, have had to pursue a more active course of existence. In them, therefore, life has evolved a nervous system which represents the power both for movement and also for the consciousness which guides movement. But while both arthropods and vertebrates are alike in this respect, they differ with regard to the types of consciousness which life has conferred upon them. While the consciousness which animates man as the highest vertebrate is essentially intelligent, behind the marvelous activities of organisms such as bees and wasps Bergson detects a consciousness which is instinctive rather than intelligent—a kind of consciousness which attains its ends by direct intuition rather than by reasoning. While this instinctive consciousness has been mainly developed in the hymenoptera, there remains, however, a fringe of intuitive apprehension around the intellect which has been perfected in man. From this point we may return to Bergson's contention, which may be restated thus: (1) Evolved by life our intellect cannot understand life; it understands only dead matter and purely physical processes. (2) To learn life's secret we must turn to instinct or intuition, a pure form of consciousness which cannot be reduced to intellect.

Why does Bergson attribute to intellect a natural capacity for understanding inert matter and an equally inherent inability to understand life? He is guided in the first place by an observation of the great success which has attended the sciences of the inanimate, such as physics, chemistry and astronomy; and secondly, by the fact that in dealing with life the biologist seems brought to a standstill as before a mystery. But the sources of his theory lie deeper than this. Our intellect seems above all a means of guiding our actions upon matter; and the high degree of intelligence which distinguishes man from other organisms is read primarily in the complex and studied character of his actions and reactions upon the material world.

As intellectual beings, Bergson continues, our progress has depended upon our ability to seize upon the advantages which matter presents, to put it into harness, so to speak, by fashioning it into implements and machines which we turn against itself. Hence, he infers that intellect has been evolved by life as an instrument whereby we should be able to grapple with matter, handling it to our own advantage. It will, therefore, be molded, so to say, upon matter. Evolved by life to exploit, by its powers or reflexion, the resources of matter, intellect must above all else understand matter; and the principles of interpretation with which it has been equipped by life will be nothing but a counterpart in mind of the principles which determine matter and physical change. This explains, says Bergson, both why intellect is at home in the sciences of inert matter and why it cannot understand life which is different from matter.

Why should intellect, simply because it is at home in inert matter, be therefore wholly incapable of understanding life? Might it not be urged that, although life cannot be reduced to a dead mechanism, yet the principles which underlie matter may not be simply reversed within life but rather caught up into a higher synthesis, supplemented and transmuted, it may be, yet still in some sense preserved? If that were so, our intellect could comprehend, along with matter, something also of life; and if ever it could understand life entire, it would be by extending or deepening its own process and not by simply falling back upon intuition which, we are told elsewhere, is intellect's opposite. To raise this objection is to bring out a point not otherwise sufficiently clear. In so far as Bergson holds that intellect, just because it understands matter, is therefore unable to understand life; in so far as he maintains that it is by intuition, the opposite of intellect, that we can alone hope to penetrate life's secret—just in the same measure are life and matter for him, not simply higher and lower aspects of a single reality, but radically opposed halves of a reality which falls asunder into two pieces. It is this dualism of life and matter which brings us to the main objects of this paper. We shall examine it with a view to showing that it rests upon a false antithesis, and that life and matter though differing as higher and lower are not simple opposites. Consequently our intellect may be supposed capable of understanding also something of life. We shall then show more directly how in his anxiety to preclude intellect from an understanding of life, Bergson puts forward a theory of intellectual operations which is simply a travesty of the facts. Thirdly, we shall attempt to characterize logically the essential movement of life with a view to showing that the epistemological implications of instinct or intuition make the latter unfitted for the understanding of life; while in intellect we have the key to life's interpretation. Having thus overthrown or inverted Bergson's main contentions, it will remain to ask what is left of permanent value in his thought.

Coming then to the first point, the opposition which Bergson postulates between life and matter consists for him in the opposed character of vital and physical changes. In the sphere of merely physical events, change, he points out, produces no real novelty, no genuine creation. This is made clear by a reference to scientific method. In all the physical sciences predictability is the criterion of knowledge. We understand phenomena just so far as, certain conditions being given, we can foretell what will follow. But this ideal of predictability casts a light upon the nature of physical change in general. It implies that the present is determined by the past, the future by the present, according to necessary relations which science may discover. Extend this conception to the whole series of changes throughout time and space and it is implied that an omniscient intellect from a study of the beginnings of the universe could have foretold infallibly the whole of its subsequent history. The whole of exact science rests upon this belief. But does not this mean that the whole series of physical changes which might have been predicted from the outset, was also in some sense already given from the outset? If this is so, however, the passage of time, so far as physical change is concerned, brings to birth no real novelty, no genuine creation. It merely makes patent what was latent, evolving what was from the start involved. Because the whole of its subsequent history was already, in some sense, given along with its first beginnings, the changes which dead matter undergoes can produce no real or substantial novelty.

When we turn to life and living processes such as the biologist studies we find, says Bergson, nothing of the sort. Where there is life time seems very real; it brings to birth real novelty, genuine creation. For life is possessed of that spontaneity and freedom which matter lacks; and this spontaneity manifests itself above all in the absolute inpredictability of the future where life is concerned. Upon this absolute inpredictability Bergson insists most strongly. It is the meaning he attaches to freedom. But this inpredictability carries us at once to a deeper opposition between vital and physical changes. It means that where life is at work, the future right up to the moment of its occurrence is undetermined by the present. Life's future overflows its present so that it cannot conceivably be sketched out therein in an idea. In short, wherever there is life, says Bergson, there is radical contingency in change, incommensurability between past and present, present and future. Because therefore life's future is inpredictable and indeterminate, vital changes produce that real novelty which is lacking in matter where all is given in advance. It is largely upon the basis of this antithesis that Bergson affirms that our intellect, evolved exclusively to understand matter and being therefore pledged to the standards of predictability and mechanical determination, is unable to understand the creative character of life. But the opposition in question does not appear to be valid. For Bergson's characterization of real novelty as implying radical con-

*Queen's Quarterly.

tingency in change and his attempt to oppose life to matter in this respect lands him in fundamental contradiction. It is the continuity of life upon which Bergson everywhere insists.

Wherever a process is distinctly vital in character, he tells us, there we have a change which is single and indivisible, however many successive phases our intellect may distinguish within it. But how can we hold by this real indivisible continuity of living processes and yet maintain that every successive phase in a vital change is marked by a relation of radical contingency to that which precedes and that which follows it? To postulate absolute incommensurability between the successive moments of a process is to break up the process itself into an infinity of disconnected fragments. Radical contingency, in short, strikes right at the heart of continuity. Just as the continuity of an inference is broken if the conclusion does not really follow from the premises, so also a living process cannot be continuous if its successive phases do not flow out of one another by some kind of necessity. It is indeed instructive to note that on more than one occasion Bergson is compelled to deny his own teaching. In explaining the presence of similar organs in different lines of evolution he says, "species must evolve identically if the hypothesis of a common vital impulse be accepted." The use of the word "must" here implies that Bergson partially rejects his doctrine of radical contingency in life. His acceptance of the theory of definite periods of mutability and constancy in species also points in the same direction. In any case our point is this: In so far as Bergson believes in the concrete continuity of living processes, he must also believe that in vital as well as physical changes the past determines the present, the present the future. To admit this, however, is to do away in a large measure with his antithesis between life and matter.

That antithesis indeed rests in the end upon a false conception of what "real novelty" means. If the phases of a vital process are related to one another by necessary connections must we therefore, as Bergson implies, deny to life the production of novelty? We can answer this question most easily by turning again to inference. There is here logical continuity between premises and conclusion; but there is also novelty in the conclusion. Though the latter may be implicated in the premises its novelty is sufficiently assured if when once made explicit it does not simply repeat the premises. So also we would urge that logical continuity between the successive phases of a vital process is quite compatible with that real novelty which consists in the fact that no single phase simply repeats its predecessor and that what was only implicitly present is now actually present. To understand novelty in any other sense is to follow a path which leads nowhere. On the other hand, if we understand novelty in the sense we have urged, there will be no novelty in both the vital and the physical series. Predictability does not mean lack of novelty nor is spirituality equivalent to utter contingency. There may, indeed, be more in life than in mechanism; there certainly will not be less; and the principles of matter are not simply reversed within life.

By breaking down the Bergsonian dualism of life and matter there has been shown to be at least a possibility that our intellect, although it understands matter, may also comprehend something of life. There is, however, Bergson tells us, another deep-seated opposition between life and matter, which makes the former beyond our understanding. If physical science has succeeded in satisfying the test of predictability it has done so by refusing, in a new and special sense, to see any real novelty in the changes of inert matter. In all such changes it sees only a spatial rearrangement of old unchanging parts—a mere redistribution of changeless atoms. What appears new is therefore resolved into what is really old; all remains the same as it was except for the changed positions of the old atoms. In a new sense, therefore, the changes to which dead matter is subject appear to produce no real or substantial novelty. When we turn to life, however, the case is just the opposite. Where life is at work, change refuses to be analyzed into such a mere regrouping of old parts. We cannot represent the ripening of our consciousness simply as a redistribution of old psychical elements; nor can we find, say in the embryological development of the individual, a mere rearrangement of factors present from the outset. In both cases because life is operating there is a genuine creation of new parts within new wholes. And what is true of the production of an individual is true also of the production of a species and more generally of any moment of a living form. Proceeding with a single indivisible sweep life actually creates the parts which go to form new wholes. It does not simply rearrange the old.

The opposition which thus exists between the ways in which vital and physical changes are carried out, shows us, says Bergson, why our intellect cannot understand life. Evolved essentially to comprehend the laws and operations of inert matter, our understanding is entirely analytic in principle. Occupied with the task of analyzing the given into pieces, the only construction it is capable of consists in arranging these old pieces in fresh combinations. All this is expressed by Bergson when he tells us that it is the essence of reason to shut us up within the given and when he compares our intellect to a kaleidoscope which produces its effects by a mere reshuffling of the old. As intellectual beings, he continues, we are above all fabricators or makers of machines. But fabrication consists in cutting up matter into pieces and rearranging these according to a plan. Hence it is but natural that intellect, even when it refrains from action, can do nothing but analyze, regroup old parts and represent all novelty as such a regrouping of the old. And in proceeding thus, intelligence takes its cue from matter which naturally falls into unchanging atoms and comprises in the novelty of its changes nothing more than a rearrangement of these. But because it is thus analytic, our intellect cannot understand the creative movement of life which produces new wholes that refuse to be analyzed into a mere regrouping of old parts.

The reasons which Bergson gives why intellect is wholly incapable of understanding life, may, therefore, be compressed into these two statements: (1) Unlike life, intellect is incapable of any construction which implies more than a regrouping of old parts; (2) it cannot understand novelty unless the new situation can be resolved into old elements. To understand novelty in short we must first somehow get rid of it. Both of these assertions may be shown to be false. To take the second first, it would certainly seem that our intellect has been designed expressly to deal with novelty. When we are confronted with the same situation recurring over and over again there is no need for intelligence to guide the accustomed action which forms the response. In the life of routine activity intellectual control sinks almost to zero. On the other hand, when the situations in which we are placed become so varied as to demand fresh actions upon each occasion, it is then, both in the history of the race and of the individual, that thinking becomes necessary.

(To be continued.)

Arsenic and Manganese in Plants

THE extensive researches made by Profs. F. Jadin and A. Astruc of France upon the presence of arsenic and manganese in the vegetable kingdom as well as in animals have awakened quite a little interest, and will no doubt throw considerable light upon various questions relating to organic life. For a long period the cellular contents of plants was but little known, but this has lately attracted the attention of numerous scientists, and the question has now reached the point where the elementary composition of the plant is known to a great extent. Outside of the elements which are found in great abundance and which represent the principal makeup of the plant, namely, carbon, hydrogen, etc., there are other elements that are found in smaller quantities but which a careful analysis shows to be present, such as iron, phosphorus, arsenic, manganese, copper, fluorine and others. Without laying too much stress on the biologic rôle of these different bodies, we are authorized to suppose that their constant presence, even in minute quantities, corresponds to an organic function of one kind or another, and this part of the question presents a series of problems which remain to be solved. The authors now make a valuable contribution to the analysis of the plant cell, and for a period of five years their object was to determine the presence and amount of arsenic and manganese in the vegetable world. They first make it clear that the work of previous experimenters was very incomplete, and they have now made a long series of researches upon numerous plants of various species. After describing the technical method of making the chemical analyses, the authors bring out the various conclusions of their researches.

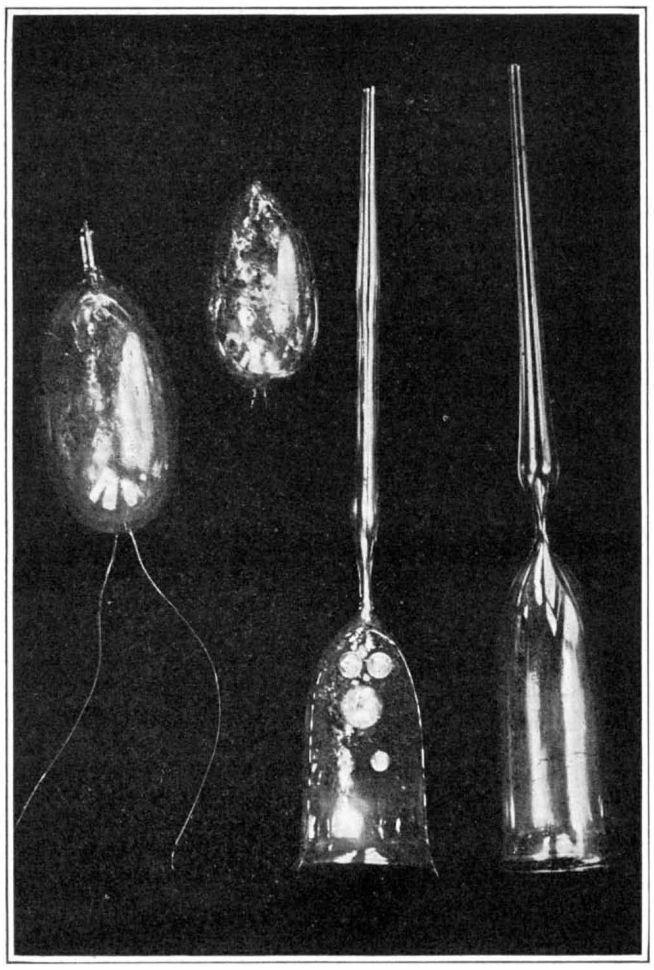
The first point to be noticed is the constant presence of arsenic and manganese in all the plants. This quantity is small and not uniform, and for arsenic it is found in fractions of a milligramme per 100 grammes of fresh or even dry matter, for instance, a few thousandths of a milligramme in the bean, pea, date, rice, etc.; a few hundredths in cabbage, orange, apple, almond, oak, banana, oats, etc.; a few tenths in radish, gourd, carrot, lettuce, etc. The standard weight used is always 100 grammes. In the case of manganese, the figures are much higher, for instance several centigrammes for some plants. When we calculate the percentage from the ash, which is the usual way for analysis of mineral substances, we find quite high values, for instance 10 to 13 centigrammes for corn, barley and oats; 45 to 65 for mistletoe, nearly 1 gramme (i. e., 1 per cent) for the pine tree, etc. They find, however, that a near relationship of various plants does not mean a corresponding similarity in the amounts of these elements. From their researches they come to the first important conclusion, namely, that arsenic and manganese are normally present in all plants and in all their parts, but in spite of certain similarities it is impossible within the limits of such researches to obtan any clear indications as to other members of a given family, and there are even found considerable variations in the amounts observed in the same vegetable species.

It was then asked whether the most active parts of the plant, in which the cellular work seems to go on with the greatest intensity, did not contain more of these elements. They find that the aerial portions and chlorophyl tissues contain more arsenic and manganese than the parts lying underground and deprived of light. This is the case for leaves of the radish, beet, carrot, etc., compared with the edible part. The differences are not always strongly marked, but the figures which were found are clear in this regard. The authors therefore come to a second conclusion, namely, that in a given plant, the chlorophyl parts contain more arsenic and manganese than the underground parts, and the leaves show some difference according to whether they are young or old, these latter containing a somewhat greater amount.

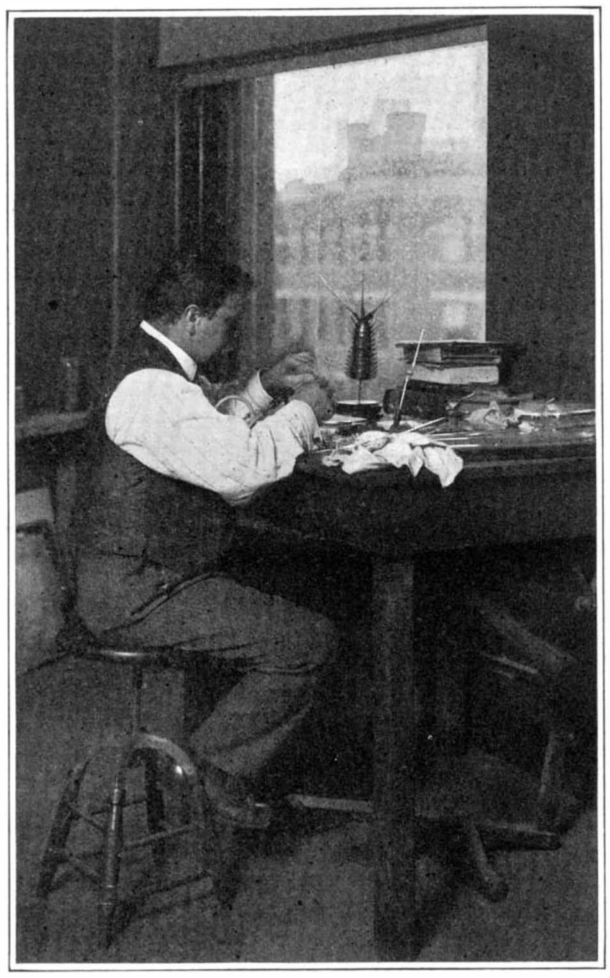
Another point relates to the amount of arsenic and manganese in parasitic plants. The roots of normal plants take up these elements from the soil along with the others, so that the nature of the soil has necessarily a certain influence, though this must not be exaggerated. In order to observe the influence of the soil, the authors had the idea of studying parasite plants, for in this case the sucking organs of the plant have no direct connection with the soil, and the other plant furnishes all the material from its cellular tissue. In this case the parasite absorbs the arsenic and manganese which are needed for its cells. There is no exception found to this rule, and the authors examined some twenty species of parasites which live upon different plants, among others the mistletoe, and in every case they found appreciable amounts of the two elements. For manganese the amount rises as high as 0.5 per cent (in the ash). They could not find any proportion between the parasite and the plant it lived upon, but what is remarkable is that the parasite sometimes has a higher proportion. From this series of researches they find the following result: The amount of arsenic and manganese in the soil has no very special influence upon the amount contained in the plant, and, according to their needs, the plants take these elements where they find them and even take them from other plants.

After considering the way in which these two elements enter into the growth of plants, it becomes a simple matter to explain their origin in animal tissues. Since vegetable matter forms a large part of human and animal food, we can consider them as a source of arsenic and manganese in the animal organization in general. Of course plants are not the only sources, for water is also an important one. In fact these elements occur very generally in mineral waters, and even usual drinking water contains small traces. The authors accordingly desired to make matters very clear on this subject and they found the amounts of these elements in human food plants, then in domestic animal food, including 17 fresh vegetables, 4 dried fruits, 7 fresh fruits, etc.

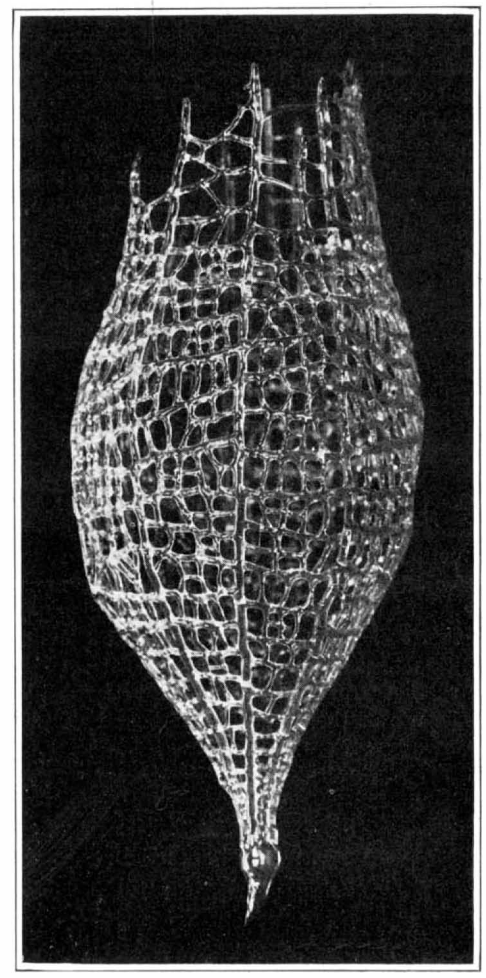
Although the amounts are quite variable for all these, the data are sufficiently exact to be able to calculate the amount absorbed by a given animal according to his daily consumption of food. The conclusion is reached that if although vegetable food is not the only source it is at least the most important one of the arsenic and manganese which are considered as normal in the animal tissues. As concerns the part which these two elements play in the makeup of the cell and its functions, this point is not nearly as clear as the foregoing, and is one upon which various researches are being made at present. We will therefore reserve the discussion of this question for another time. The authors, however, come to the conclusion that arsenic and manganese play a most important part in the plant cell. The first of these exercises an action which may be compared to that of phosphorus; the second element gives a great stimulus to the reactions of oxidation and the development of the plant



Stages illustrating the modeling of the microscopic animal, Gonium.



An expert glass worker at his bench using the blast lamp.



Model of the skeleton of a radiolarian, magnified.

Animals of Blown Glass*

Beautiful Scientific Reproductions Made at the American Museum of Natural History

By Herman O. Mueller

THE technique of glass-blowing is many sided and allows construction of intricate and truthful models from life, of animals as well as of plants such as the famed Harvard glass flowers. The invention of the blowpipe at the early date of the first century before Christ, opened up an era for glass-modeling. In the process previous to that time molten glass or "glass paste" had been molded free-hand over a clay form, which could be easily removed after the glass cooled.

The blowpipe consists of an iron tube about one and one half inches long and one and one fifth inches in diameter, with the aid of which the glass paste is blown to the desired shape. The mechanical tools which the glass-blower uses have always been very simple and relatively unimportant, but the natural instruments—the eye and the hand of the worker—are of the greatest significance.

The most important instrument in glass-blowing is the blast lamp. This is a very simple affair and consists of a brass tube about three quarters of an inch in diameter and three to four inches long, into which a small tube is inserted. The larger tube supplies the gas and the smaller one the air. The relative quantity of gas and air is regulated by means of cocks attached to the tubes. A steady air pressure to increase the heat intensity of the flame is created by means of bellows, or still better by a compressed-air pump.

In early times an oil lamp was used in this apparatus, and the name "lampen arbeiter" was applied to the users to distinguish them from the workers in the glass factories. In some of the European glass-blowing districts the oil lamp is still used for glass-blowing. The gas lamp, however, is, of course, far superior. It naturally produces a considerably more powerful flame, and this makes possible the modeling of much larger objects. Other tools for glass-modeling are forceps of various shapes, scissors, carbon and iron pencils of different sizes and forms, and files. The forceps are used for handling the separate pieces of glass while being welded; the scissors are used for cutting away the superfluous glass; the carbon and iron pencils for widening the openings in glass tubes or finished parts, and the files for cutting glass tubes and rods. No iron molds of any kind are used for preparing glass models in the American Museum, but all parts are shaped free-hand from glass tubes and rods. Colored glass is frequently used for the colored parts, but if the desired tints and shades of glass are not available, plain crystal glass is molded into shape and the colors applied later with the brush or with an air-brush.

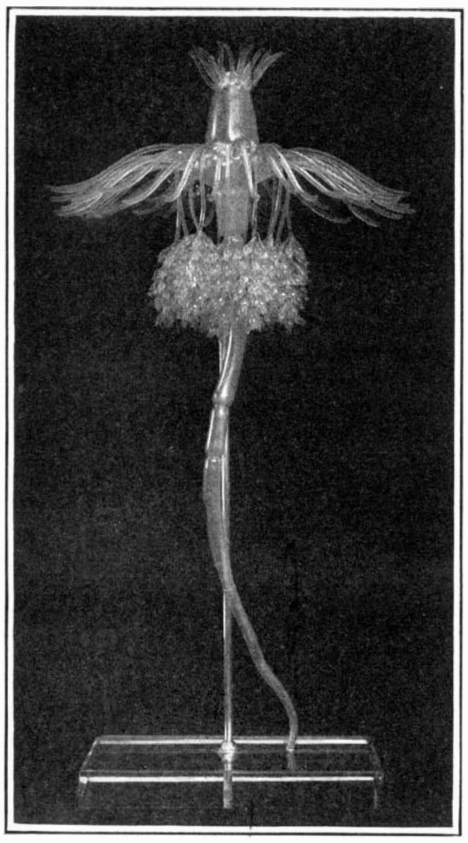
The process of using glass as a medium for representing animals will be realized in some degree if we follow the construction of a glass model—for example, that of a colony of the protozoan *Gonium*. From a glass tube of about one half inch diameter, a piece about two inches long is separated by means of the blast lamp, blown in the flame to a cup-like shape and opened out to its whole width at one end. The gas flame is brought into action on the opening and the force of the flame will by itself enlarge the opening; but if the carbon pencil is rotated inside the heated area at the top of the cup this will flange it out more quickly.

To imitate the coloring seen in the living *Gonium* individual, which seems to shade from a deep green below to a light, almost transparent tint above, hundreds of little green glass particles are welded to the inner surface of the glass cup before it is widened out, until the desired tints are secured. To do this a green-colored glass rod is broken up into small pieces and these are further ground in a mortar to the desired grain. A small quantity of these particles is strewn inside the cup which is then rotated in the gas flame until the green parts begin to fuse and adhere to the wall of the cup. This process is repeated until the desired intensity of the color is secured. When the green particles are applied thickly the color is more intense; when scattered, a lighter tint results.

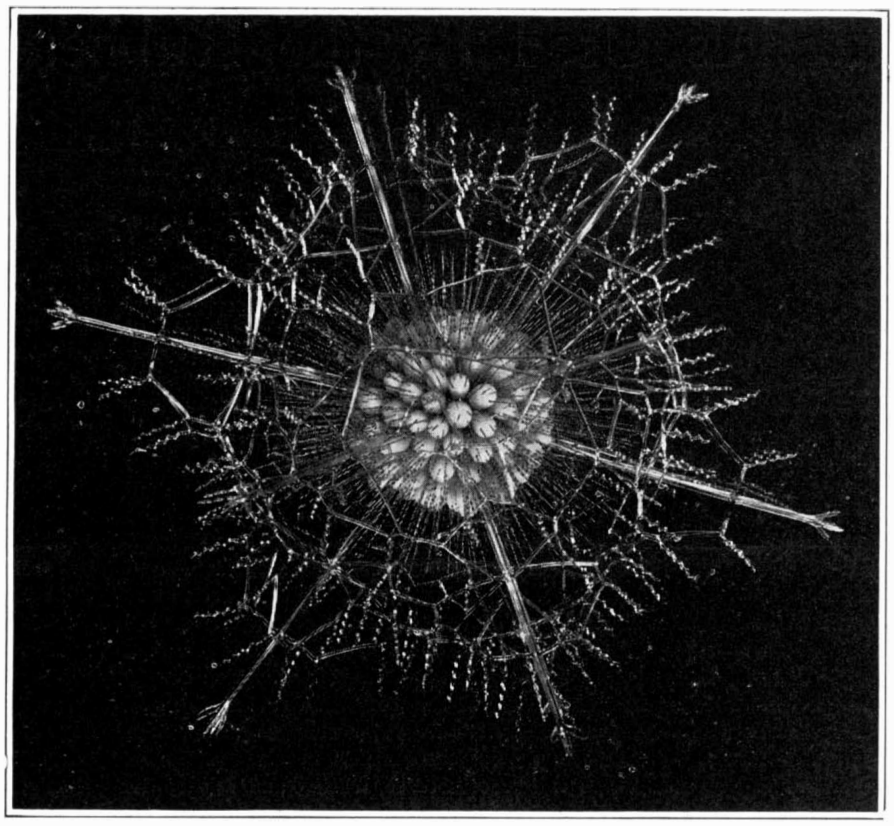
After this the other parts of the animal, such as nucleus, vacuoles and chromatophores, are fashioned separately from small tubes or solid rods of colored glass and fastened within the cup. The nucleus is blown from a small green glass tube into a hollow ball about one quarter inch in diameter. One end is cut open for inserting the nucleolus which has been previously shaped from a green rod into a little solid bead. This is of a darker color than the tube used for the nucleus. To the solid bead, or the nucleolus, a short glass stem is attached by which it is to be supported within the hollow ball. When the nucleolus is inserted into the ball, a little spot of the shell of this ball is heated and the support of the nucleolus is fused to the wall of this shell. Then the opening of the shell is covered with enough hot glass to close it, and the nucleus is completed. The vacuoles are blown in the same manner as the nucleus, only they are of crystal glass and consist of only one shell. Nucleus and vacuoles have little stems attached to them by which they are fastened in the cup. The supports are placed where they will show least.

After all the parts are ready to be inserted in the cup, one after the other, they are held in place by the forceps, a small area of the outer wall of the cup is heated and the supports of the parts are fused to the inner cup wall. When this is done, the cup is closed by heating the glass around the rim opening and drawing it together until a rough closing is obtained. The superfluous glass which forms in this manipulation, is pulled away little by little, and the resulting unevenness of the surface is smoothed out by reheating the closed portion and blowing several times through the hollow handle at the base of the cup. The air blown through the handle expands the heated glass and rounds off the cup. Then two short glass stumps (to which later flagellæ are to be attached) are fused to the top. Finally the point at the lower end where the cup was attached to the original tube, is melted off and a short glass stem to serve later for the concealed attachment is fastened in its place, but a little to one side of the axis. Following this a somewhat larger cup is made and the finished closed cup is inserted into it, the outer cup is in its turn closed and rounded off, and to this finally the two whip-like flagellæ are attached. These are first drawn out from a glass rod into straight threads about the thickness of a fine needle, and then are curved by passing the glass threads through the flame several times in different directions. Now the glass stem retained at the lower end of the outside cup for a handle, is cut off short to serve as a concealed support for attachment to the final mount. Models for the other fifteen individuals composing the colony are now constructed in the same way and arranged on the mount in their proper places—and the model is complete.

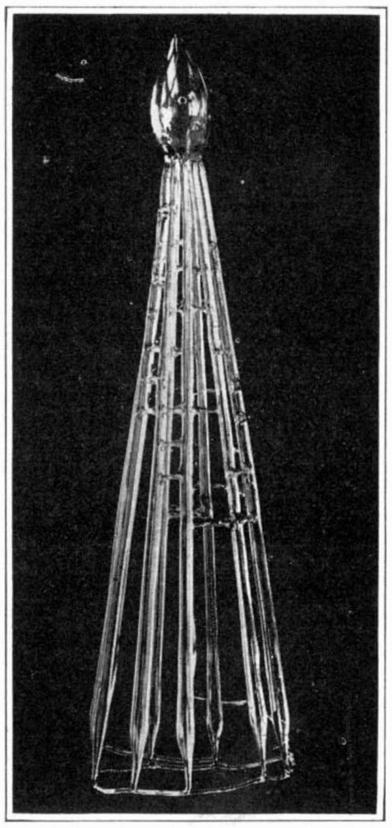
*From the *American Museum Journal.*



Model representing a highly magnified specimen of the hydrozoan[1] tubularia harrimani.



Complicated models like this radiolarian[2], a tiny, one-celled animal, found in both fresh and salt water, often require two or three months to construct.



Early stages in the modeling of a simple radiolarian, involving great skill.

The model of the radiolarian further illustrates methods of glass-modeling. From a solid glass rod one quarter inch in diameter, nine smaller rods are fashioned, each about one eighth inch in diameter and about four inches long. These are somewhat bent and attached at equal distances to the rim of a perforated cup previously blown to represent the skeleton of the central capsule. In this way the principal framework of the skeleton is prepared. In order to give it greater stability during the work, slender glass supports are welded temporarily to the lower ends of the rods. Then beginning at the central capsule small glass rods are welded horizontally to connect the larger elements of the skeleton, until finally the whole network is completed as shown in the figure of the finished model.

Many protozoa are beset with countless hairs or cilia, and in representing these the welding of such closely set, fine structures on the models involves great difficulty. Even on models representing great magnification these cilia are often so fine that a little careless manipulation with the blast lamp will cause whole areas of the heated cilia to collapse, mowed down like grass before the mower's scythe.

Although molten glass may be brought into hundreds of different shapes, nevertheless the methods of blowing are always practically the same. It is the setting together of the separate parts, however, which requires great care and alertness, for when once the parts are wrongly joined they can be corrected only with difficulty or not at all, and it is usually necessary to reconstruct the entire piece from the beginning.

In many cases, where several parts are welded together, the finished structure must be thoroughly annealed. This is best done by greatly diminishing the air pressure in the blast lamp, when the glass parts are rotated steadily for some time in the smoke and flame of the weakened jet. This is necessary because in working the glass for a long time, alternately thinner and thicker places will occur. These produce an uneven tension and the glass will break if it is not carefully annealed.

As mentioned above the methods of glass blowing are very simple. Only skill in the worker is necessary to produce the most diverse shapes from the molten material. In order to attain this skill, years of training for hand and eye are necessary. The calling of the glass-blower, so to speak, is an inheritance from antiquity. The sons grow up to the father's trade and devote themselves from early youth to the acquisition of the all-important feeling and skill.

[1]Hydrozoa are stationary, jelly-like animals which attach themselves to fixed or floating objects and feed on the marine organisms which come within reach of their waving tentacles. Many of these creatures are microscopic and many live attached to one another in colonies. Many of these latter may be seen in the wharf-pile group at the American Museum.

[2]Radiolaria are tiny, one-celled animals which possess the faculty of extracting silica from sea water and forming with its skeptical structures to protect their soft, jelly-like body. They are found in both fresh and salt water, particularly the latter, and are usually microscopic, but giants among them may attain the size of a pin's head. There may be very many in a single drop of sea water, especially in the warmer seas, and they exhibit great variety of form.

Scientific Cider Making

An effort is being made to extend the scope of the cider making industry in France, which, although very important in the regions where the industry is carried out, is much more limited to those regions than it should be. For this reason there has been remarked a considerable effort during these recent years to increase the use of cider for use in daily consumption in households to replace the beverages for table use. Already there have been obtained appreciable results toward this end in the way of improving the methods of cider making under the influence of scientific discovery, and on this account there will be a much better chance of having the use of cider extended beyond the actual regions where it is produced. But there still remains much to be done as concerns the uniformity of the products as well as their long-keeping qualities. In a paper presented to the Amiens Industrial Society, Prof. Crochetelle, director of the Agronomic Institution of the Somme department, brought out the present status of the problem in a very clear manner, and he looks at the problem in what would seem the rational way, that is, from the consumer's side. In the same way as prevails for wine, it seems necessary to obtain several different kinds of cider, first an ordinary or cheap quality especially as a table drink, then a better grade which is sold in sealed bottles, and again a cider *de luxe*, which is sparkling to a high degree, and is intended to replace the cheap wines of the Champagne class. But for all these uses it is required to produce a cider of soft and good keeping quality which does not acidify and thus give a sour taste, and does not become hard when its fermentation is finished at the end of winter. In fact, it is during the warm season that the consumption of cider is especially high, and it is also at that time that it should also show its best tasting qualities. It is possible to attenuate and also to retard the hardening of cider by taking precautions to have the greatest cleanliness during the cider making, and it is also required to draw off frequently at the beginning of spring. As the softness and sparkle of the cider is due to the sugar it contains, it would seem a good plan to add sugar in the right amounts and at proper intervals during the year so as to have the cider always in good condition to be delivered for consumption, but as there are not yet enough data on this point, it is evidently premature to leave the already well known methods.

Speaking of the best cider treating methods in use, the author places the sulphating process in the first line, this being very successful in wine treatment, and metabisulphite of potassium is employed here. However, on the contrary to what holds good for wine, it appears that the cider thus treated takes on a disagreeable sulphur taste, and also has a bad effect on the stomach. But nothing of the kind is observed for wine, except sometimes where it is given a too strong treatment with this chemical, and again the treatment with liquid sulphurous acid never hurts wine, and its use is found harmless on the human system as was shown after a series of scientific tests made by doctors and other experts at Bordeaux. No doubt, in the case of cider the matter is one of proper proportions, and this valuable substance should certainly be used if possible. Prof. Perrier of the Rennes University finds it an excellent plan to wash the apples and all the cider making utensils with an eight per cent formol solution, and this effectively destroys all the ferments. On this plan, and taking care to keep the cider in well closed barrels, the author was able to keep cider at a density of 1.056 for a year, and when bottled, this cider had not yet begun to ferment at the end of two years. The amount of formol found in the cider is well below the safe limits. In place of using formol, Prof. Gimel recommends the use of hypochlorite of calcium to destroy the ferments, but it remains to prove that this substance is harmless for such use. Messrs. Gimel and Alliot are now carrying on experiments with permanganate of potassium for the treatment of cider, which are not yet terminated, but which appear to be quite favorable. Again, Prof. Warcollier makes use of a strictly scientific method which consists in removing the ferment substances as soon as they are deposited, or he renders them inactive by precipitating the albuminoid substances. A slight heating followed by a sudden cooling is found to place the ferments under unfavorable conditions by paralyzing their action. These different methods are all in the laboratory stage. Prof. Crochetelle thinks that a great progress in the present direction can be secured by the use of a refrigerating process. Taking the cider at the precise stage of fermentation which leaves a sufficient amount of sugar for the cider to remain sweet, he then cools down to about the freezing point so that all fermentation is rendered impossible. The cider can be kept at this temperature as long as desired, and when it is needed for consumption from time to time, it can be allowed to come back to the ordinary temperature, whereupon the fermentation starts up again and the result will be a sweet cider of apparently recent production. From the above considerations it will be seen that the preservation of sweet cider is a technical problem of great complexity, and one that gives rise to numerous solutions. Some of these solutions are already on the way of being realized, and when the proper methods are once established and become generally adopted, this will mean a great outlook in the near future for the cider industry.

The Raw Materials Used By the Rubber Manufacturers*

And Various Processes Employed

By B. D. Porritt, M.Sc., F.I.C.

THE many varied applications which have been found for rubber in the arts may be attributed in the first place to the remarkable alteration in its physical properties which occurs when this substance is mixed with sulphur and heated, and secondly to the further modifications which can be effected by the incorporation of various mineral and organic substances. The first process is known as "vulcanization" and the second as "compounding."

Were it not for the discovery and development of these processes the rubber industry would never have reached its present importance, and, instead of uses innumerable, the technical application of rubber would probably have been limited to the manufacture of waterproof garments and similar goods.

First of all, rubber itself, and the changes it undergoes when treated with sulphur and vulcanizing agents, may be considered, and subsequently some of the other ingredients which are added by the manufacturer in order further to modify the physical and other properties of his products will be dealt with briefly.

Raw rubber is often far from a clean substance when it reaches the manufacturer, and usually requires washing and drying prior to use. The moisture and impurities removed by this process have been known on occasion to amount to as much as 60 per cent for some dirty varieties of wild African rubber, but the average for the supplies of uncultivated raw material would be nearer half this figure.

Owing to the rapid development of the plantation industry many inferior types of wild rubber have dropped out of the market, and in place of the almost endless variety available some eight years ago, the manufacturer of to-day is mainly concerned with the various grades of wild Para and cultivated *Hevea* rubber, for which the combined washing and drying losses are about 20 per cent and 1 per cent, respectively.

This change in the supply of the primary raw material obviously represents a very important simplification for the rubber manufacturer, both from the point of view of purchasing and uniformity of factory running.

Even after washing and drying, good quality rubber is not a chemically pure substance, since it still contains, besides caoutchouc, a small quantity of resin, some nitrogenous and other organic substances, together with a small amount of mineral matter. For instance, an average sample of plantation sheet, after washing and air drying for four weeks, will contain about 94.5 per cent of caoutchouc, the difference being made up by about 0.25 per cent of moisture, 0.25 per cent of ash, 2.5 per cent resins, and about 2.5 per cent insoluble nitrogenous and other organic impurities.

In addition to the variations which exist in the amounts of the non-caoutchouc constituents present, it is found that the caoutchouc in different rubbers is itself not always identical in physical properties, and in dealing with different varieties of rubber considerable variation will be found in the resistance to oxidation, the temperature of softening, the viscosity of solutions, and the amount of mechanical working required in preparing the material for factory use. Such variations must be attributed to the fact that caoutchouc is a colloid.

Exposure to light, mechanical working, heating, etc., considerably modify the properties of raw rubber without any corresponding chemical change being detectable,[1] and, owing to the inapplicability of any of the usual tests which serve as criteria of purity for crystalline organic compounds, it is impossible to determine whether chemically purified caoutchouc is a simple substance or a mixture. It is interesting to notice in this connection that almost every worker in this field has experienced difficulty in preparing purified material free from oxygen, and that Caspari,[2] by means of petroleum ether, has separated the caoutchouc from wild and cultivated *Hevea* into two varieties, differing in their physical properties and behavior toward solvents.

Those unfamiliar with the rubber industry might be inclined to ask why the manufacturer is satisfied generally merely to remove the gross mechanical impurities without further chemical purification. The removal of the resins and nitrogenous constituents representing the chief impurities would, however, be an exceedingly difficult operation on the technical scale, and would in addition result in an inferior product. The former constituent is found to enhance greatly the resistance of the caoutchouc to oxidation, to which under certain conditions it is somewhat prone,[3] and moreover appears to play a considerable part in the process of vulcanization, litharge in its absence being inoperative as an accelerator. It has for some time been known that the nitrogenous constituents also facilitate vulcanization, but these substances have recently attracted increased attention as a result of some investigation carried out by the Laboratory of the Agricultural Department of the Federated Malay States,[4] which would indicate that the variation in the rate of vulcanization, which constitutes the chief defect of the plantation rubber, is probably to be attributed to irregular changes which take place in these proteid constituents in consequence of variations in the process of separating and drying the coagulum from the latex. The fact, however, remains that rubber, and plantation rubber in particular, cannot be regarded as fulfilling at present one of the essentials of an ideal raw material in that it is not uniform in quality. Variation in vulcanization properties, which is the chief defect, will inevitably result in variations in strength under the conditions of uniform treatment necessary during the manufacture of rubber goods on a large scale, when it is evidently impracticable to modify the conditions of vulcanization to suit each individual consignment of rubber. Technical experience would indicate, moreover, that the cultivated product is somewhat inferior to Para rubber for the preparation of solutions, and also in its resistance to the repeated application of stresses such as are experienced by articles such as catapult cord. Investigations which have as object the production of a uniform plantation product are beset with both scientific and geographical difficulties, due to the complexity of the problems involved and the wide separation of the producer and consumer. Recent publications, however, manifest substantial progress toward this goal. They testify, moreover, that those responsible for the future of one of our youngest and most successful commercial enterprises, which in the course of a few years has made the British Empire the largest rubber producer in the world, are fully alive to the necessity for continuous progress and the need for scientific research.[5]

At the same time co-ordination between the several agencies responsible for research in this field, with the elimination of jealousy and overlapping, is evidently desirable if rapid progress is to be made in the production of the uniform plantation product so important in the interests of the consumer.

The remarkable changes which are effected in the properties of rubber by the addition of sulphur and heating can now be considered.

If two mixtures, the one containing about 95 per cent of rubber and 5 per cent of sulphur, the other 65 per cent and 35 per cent, respectively, are heated in steam, the former for about 2½ to 3 hours at fifty-pound pressure and the latter for a considerably longer period at a higher pressure, striking changes will be found to have taken place in their physical qualities, and they will besides present a marked contrast in appearance. The sample with the low sulphur content on comparison with the untreated material will be found to be little altered in appearance, but enormously improved in strength and resilience.

Further, it will have become insoluble at ordinary temperatures in the usual solvents for rubber, and a proportion of the added sulphur will be found to have become firmly combined with the caoutchouc. The second sample will have been transformed into a hard, jet black material, totally different in its properties from the original yellow plastic mixture of rubber and sulphur.

These examples illustrate the two distinct branches of rubber manufacture—"soft rubber" and "hard rubber." The latter is known also as "vulcanite" or "ebonite," and the process by which these changes are effected is termed "vulcanization" or "curing." The formation of "hard rubber" can be explained by the assumption that an addition compound $(C_5H_8S)x$ is formed by the unsaturated caoutchouc and the sulphur. This empirical formula corresponds to a combined sulphur content of 32 per cent, which is in accordance with observed facts. Whether other molecular changes accompany this reaction it is impossible to determine in the absence of information regarding the molecular weights and constitutions of the initial and final products.

The nature of "soft cured" rubber is less readily explained, and in spite of a considerable amount of research work during recent years, it is still a subject of discussion.

Satisfactory vulcanization may be effected by the combination of from 1.5 to 4.5 per cent of sulphur, depending on the nature of the other ingredients present; these figures do not correspond with the formation of any definite caoutchouc-sulphur compound, though it cannot be assumed that the sulphur has combined uniformly, and possibly there may be present varying quantities of a definite caoutchouc-sulphur compound or compounds dissolved in unchanged caoutchouc. If vulcanized rubber consists of such a mixture its resolution into the several constituents has not as yet been effected. It would seem probable that, in addition to the combination of sulphur, some polymerization change may take place in the caoutchouc with the formation of a substance of higher molecular aggregation insoluble in solvents.

The polymerizing action of sodium on isoprene and butadiene is interesting in this connection; but it is noteworthy that vulcanized rubber "depolymerized" during the process of "reclaiming" does not become soluble once more in solvents.

The remarkable effect produced by this small addition of sulphur was discovered by Goodyear in 1839. It is therefore surprising to find that, in 1916, sulphur is still almost exclusively employed for the purpose of vulcanization.

No satisfactory explanation has as yet been advanced to account for this property, possessed apparently by sulphur alone of the elements, or for the fact that this action can be accelerated by the presence of litharge and basic substances, and that, in the absence of litharge, a certain amount of pressure seems necessary for the action to take place satisfactorily.

At various times compounds, such as hypochlorites, iodine and polysulphides, have been proposed as vulcanizing agents, but have found at the most only limited technical application.

According to the latest suggestion of this kind a large number of aromatic nitro-compounds are efficient substitutes for sulphur that is in the process of vulcanization.[6]

It has been found that dinitrobenzene, one of the substances named, is quite inoperative as a vulcanizing agent,[7] and simultaneous work in this laboratory[8] employing pure 1-methyl 2.4.6-trinitrobenzene confirms the foregoing observation; this latter substance acts neither as a vulcanizer nor an accelerator, but rather as an oxidizing agent, the rubber being markedly deteriorated on heating when appreciable quantities of the nitro-compound are admixed.

Apart from sulphur one substance only, and that a sulphur compound, has found general application for the purpose of vulcanization, the use of sulphur monochloride at ordinary temperatures for this purpose having been patented by Parkes in 1846. The vulcanization of rubber may, therefore, be effected by one of two general methods—the "hot cure" process, in which sulphur and heat are the agents, and the "cold cure" process just mentioned.

There are three modifications of the former method in general use.

(1) The "steam heat" process can be used for textile and other goods on which the rubber coating is comparatively thin, the material being suitably protected from the deposition of moisture and subjected to the action of steam under pressure. The tendency of the uncombined sulphur to effloresce or "bloom up" on the surface renders this process inapplicable when brightly colored goods are desired. A modification of this method has been described recently in which the heating is

Journal of Chemical Industry.

[1] Harries, *Annalen,* 1911, 383, 157.

[2] Caspari, this J., 1913, 104.

[3] Peachey, this J., 1912, 1103.

[4] Eaton and Grantham, this J., 1915, 898.

[5] For contrary opinion see H. E. Armstrong, this J., 1916, 501.

[6] Ostromyslenski, this J., 1916, 59.

[7] Stevens, *Le Caoutchouc et la Gutta Percha,* 1916, 8880.

[8] The author in conjunction with Mr. W. G. Martin.

carried out in an indifferent gas under pressure.[9]

(2) The "dry heat" process also employed for lightly rubbered articles, especially shoes, differs from the previous instance in vulcanization being effected at ordinary pressure in large hot-air chambers heated by steam pipes. The presence of litharge in addition to sulphur is essential to the success of this process and, owing to the consequent formation of lead sulphide, articles vulcanized in this way are always black. The open heating, however, results in the volatilization of the greater part of the free sulphur, so that a permanent dead black finish is secured.

(3) The "press cure" process is employed for heavy articles, such as buffers and motor tires, which are vulcanized in molds placed in heated hydraulic presses.

The "cold cure" process is rapid and results in a material possessing a soft velvety finish. It permits the production of brilliantly pigmented articles which will not "bloom" but which are generally somewhat deficient in permanence. This method, which is suitable only for lightly coated goods, can be carried out either by dipping in a dilute solution of sulphur chloride in carbon bisulphide or by exposure to the vapor in a large chamber. Whichever method is used, an after-treatment with ammonia must follow to neutralize any acid formed by the action of moisture on the excess sulphur chloride.

Incorrect vulcanization probably is responsible for as much trouble in the factory as is caused by inferior or defective raw materials. Not only will it result in defective physical qualities, but the material will be liable to oxidize or "perish" in the course of a few weeks, if the treatment has been unduly severe.

The conditions and duration of heating to insure satisfactory vulcanization will depend upon the nature of the ingredients and the proportion of each in the mixing. It is therefore of the utmost importance that the rubber manufacturer should employ uniform raw materials, and should submit all factory mixings to careful physical tests in the laboratory in order to determine the correct conditions of vulcanization, judged by strength and durability, before undertaking the manufacture of goods for sale.

The many other fillers employed by manufacturers, apart from rubber and sulphur, remain for brief consideration. These sometimes are spoken of as "drugs" in the trade. This metaphor is very appropriate since they are materials which, while valuable in skilled hands, may become deleterious when misapplied. It has been said:[10] "If it had never occurred to any one to mix extraneous substances with rubber, it is safe to say that the industry as we know it would be inconceivable; rubber manufacture would have expanded perhaps in volume, but hardly in scope, beyond its boundaries of pre-vulcanization times. In unvulcanized rubber we have one material, in soft cured rubber a second, and in ebonite a third; but by admitting compounding ingredients we gain innumerable new materials. Moreover, the lowering of prices thus achieved has done much to widen the market for rubber goods."

In making such additions, the manufacturer may have any of the following objects in view: (1) Mechanical properties, such as stiffness, toughness, etc. (2) Chemical or physical properties, for example, indifference to acids and dielectric resistance. (3) Color. (4) Duration of vulcanization. (5) Cost. These "compounding" ingredients may be divided into two classes, organic substances such as reclaimed rubber, rubber substitute and bitumen; and mineral compounds, for example, zinc oxide, barytes and whiting.

It is unnecessary to consider exhaustively the merits and defects of the many different fillers employed by rubber manufacturers, and it will suffice to refer to some of the more important. It might be mentioned in passing, however, that compounds of copper appear to exert a highly prejudicial influence on the durability of rubber goods, and must be avoided carefully for this reason.[11] A "pure" vulcanized rubber, on account of its extensibility and softness, would be unsuitable for many purposes involving abrasion or compression. It is therefore necessary to incorporate a suitable proportion of mineral matter when rubber is needed for mechanical uses, and zinc oxide and magnesia are the fillers generally favored by manufacturers for this purpose. The conditions to be satisfied by an eraser are in direct contrast to the foregoing requirements, and, instead of being tough and resistant to abrasion, the material must be flexible and friable. These qualities can be secured by the employment of a large proportion of "white rubber substitute," prepared by acting on rape oil with sulphur monochloride. This, when the goods are dark in color, can be replaced by a "brown substitute" resulting from the action of sulphur on vegetable oil at a high temperature.

The choice of pigments for the production of colored articles depends to a considerable extent on the method of vulcanization selected.

When vulcanization by heat is necessary the number of pigments which are at the same time cheap and permanent is somewhat limited, the ones generally used being antimony sulphide, yellow arsenic sulphide, zinc chromate, green oxide of chromium, ultramarine, and lamp-black. The cold cure process permits a selection being made from a much wider range of colors, including many brilliant permanent dyes and lake pigments.

The question of accelerators for the hot vulcanization process may now be considered. These are important for three reasons. In the first place, their use insures a larger output from the vulcanizing plant, or permits the employment of lower temperatures; secondly, they provide a means whereby the correct vulcanization conditions of two different mixings used in conjunction may be made identical, as, for example, the tube and cover of a hose, and finally by their use the addition of sulphur may be somewhat reduced with a view to minimizing "blooming." Litharge is the most effective of these substances, but lime, magnesia, and certain basic organic compounds[12] possess the same property in a lesser degree, and can be employed when color or other considerations render the use of litharge inadmissible.

The production of satisfactory rubber goods at moderate prices for the many purposes which do not require high mechanical strength has been greatly assisted by the discovery and development of the acid and alkali processes for reclaiming waste rubber. By means of reduction to a fine state of division and chemical treatment followed by washing, it is found possible to remove the textile impurities generally present in rubber waste. The cleaned material can subsequently be restored to a plastic condition by heating in steam under pressure, and the product may, after drying, be employed either partially or wholly to replace rubber in mixings, which can be vulcanized in the usual manner.

It is noteworthy that up to the present all the various processes having as their object the removal of combined sulphur and the regeneration of the caoutchouc in a soluble form have met with no success, since the combined sulphur appears to be retained tenaciously. Reclaimed rubber, therefore, prepared from vulcanized waste, will be insoluble in rubber solvents, and will contain unchanged the greater proportion of the original fillers, since the methods of preparation have as object merely the restoration of plasticity.

This necessarily superficial sketch of the materials used by the rubber manufacturer would be incomplete without reference to the large amounts of textiles which are used in conjunction with rubber in such articles as motor and cycle tires, hose, waterproofs and the like. Such fabrics, usually cotton, must possess the requisite strength, be unaffected by vulcanization, and be free from any dressing likely to affect the durability of the rubber.

From what has gone before it will be clear that the successful manufacture of rubber goods depends on the observance of three conditions, namely, uniform supplies, suitable mixings, and correct vulcanization. Failure on the part of the manufacturer to comply with any of these essentials is certain to result sooner or later in serious trouble, which may be either immediate or appear after the goods have been distributed to the consumer.

An efficient chemical and physical laboratory must therefore be regarded as an essential in a rubber works. The preparation of suitable mixings and the physical testing necessary to ascertain the correct conditions of vulcanization will demand a special section in the department equipped with a miniature factory milling and vulcanizing plant, together with all the necessary testing machines for rubber and textiles.

The chemical uniformity of the supplies of raw materials and the investigation of problems in the factory requiring scientific assistance may be left for attention to the chemical section of the works laboratory.

It will remain nevertheless for the research chemist to raise the manufacture of rubber from a somewhat empirical operation, however well controlled it may be by physical and chemical tests, to one which is based on scientific principles. The problems presented by colloid chemistry are difficult of solution and the progress is slow; but until the constitution of rubber and the mechanism of the vulcanization process are more clearly understood the rubber industry cannot be said to be on a sound scientific basis.

[9] *India Rubber World*, 1916, 333.
[10] Caspari, "India Rubber Laboratory Practice," p. 37.
[11] Thomson and Lewis, this J., 1891, 712.
Dewar, this J., 1891, 71.
[12] Ditmar, *Le Caoutchouc et la Gutta-Percha*, 1915, p. 8681.

Rhododendrons and Lime

In a note in *Nature* of February 17, 1916 (volume xcvi., page 684), reference was made to Mr. Forrest's discovery of rhododendrons growing on limestone rocks in Northwest Yunnan. In this connection Lady Wheeler-Cuffe, writing from Maymyo, Upper Burma, informs the editor that she found "a beautiful bluish-white rhododendron growing actually wedged into a bare limestone crag on the very summit of Sindaung (6,022 feet), in the southern Shan States, a few years ago." Mr. Forrest also states definitely that he found rhododendrons with their roots actually spreading in the crevices of the limestone rock.

From the evidence of Mr. Forrest and Lady Wheeler-Cuffe it would appear that these particular rhododendrons must come in contact with a large quantity of lime, but, unfortunately, we have no definite information as to the particular character of the limestone rocks on which they have been found.

In the European Alps the two endemic species of rhododendron, *R. ferrugineum* and *R. hirsutum*, are recognized as being chalk-avoiding and chalk-loving, respectively. *R. ferrugineum* is found in damp, deep-layered soil rich in humus, and it will only grow in a limestone region when there is an overlying layer of humus. *R. hirsutum*, on the other hand, is a limestone rock plant, found in dry, open situations, and when the two species are found in the same locality, *R. hirsutum* grows only on the rocks, while *R. ferrugineum* occurs in the pockets of humus.

Several of the new Chinese rhododendrons which were collected on limestone are now being experimentally cultivated in this country on various lime-containing soils. Some of the species (see Grove in *Gardeners' Chronicle*, January 29, 1916, page 65) appear to thrive under these conditions very well, while to others the lime has proved fatal, but the experiments have not been in progress for a sufficiently long time for a definite verdict as to the behavior of these limestone rhododendrons under cultivation to be given.

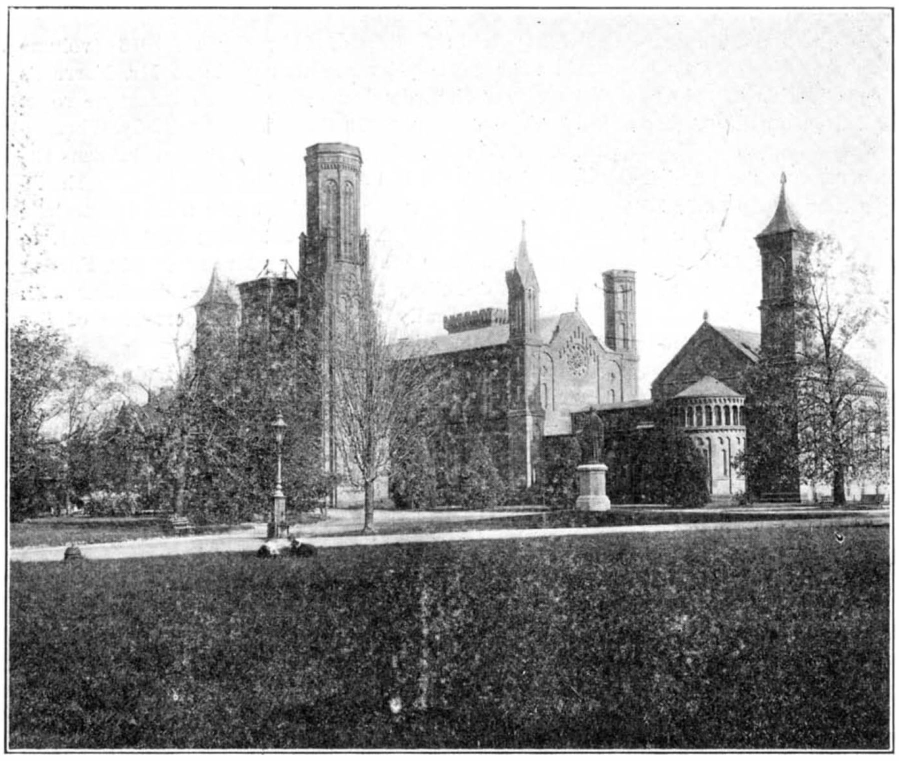
The abhorrence of lime by the humus-loving rhododendrons appears to be intimately connected with the mycorrhiza, the symbiotic fungus which lives in association with the roots of the rhododendron and heath family (Ericaceæ), and performs the functions of the root hairs in absorbing water from the soil; and it may be that the mycorrhizal fungi associated with the humus-loving forms of rhododendron are physiologically, if not specifically, distinct from those of the lime-loving species.

It has recently been shown by Rayner, Jones and Tayleur (*New Phytologist*, volume x., 1911, pages 227-240) that the common ling, *Calluna vulgaris*, though it is sometimes found on chalk downs, is really growing in pockets of loamy soil rich in mineral constituents but poor in lime. It is also worthy of note that in the "limestone pavement" district of Westmoreland ling grows vigorously in the very thin layers of earth which lie directly on the limestone rock. An analysis of the surface soil, however, reveals an almost complete absence of lime, and so lime-free is this layer that it is actually necessary to add lime thereto in the course of ordinary agricultural operations.

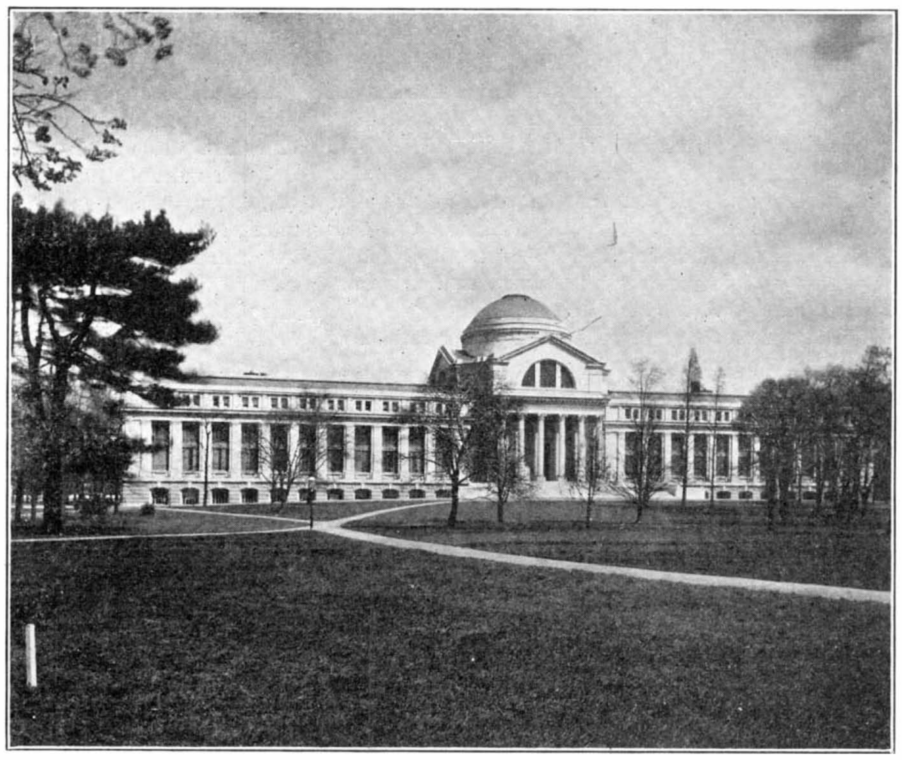
Cultures made by C. A. Weber and Graebner (see Graebner, "Lehrbuch der Allgemeinen Pflanzenphysiographie," 1910, page 236) have shown that the lime-avoiding Ericaceæ and other plants they examined suffer from lime only when this is associated with a large amount of soluble salts, and that root formation fails when nutritive salts are in abundance in the presence of lime. Rhododendrons, however, do not appear to have been among the plants examined.

In connection with their behavior toward lime-containing soils, plants may be roughly divided into two groups: of those which avoid lime, the heath family affords one of the most striking examples, but, contrary to expectation, certain members of the family, as, for instance, *R. hirsutum*, are characteristic plants of limestone districts.

It seems probable from the evidence now before us that some of Forrest's newly discovered Chinese rhododendrons, as also the one found by Lady Wheeler-Cuffe, must be reckoned as lime-loving species, but in all these cases the interesting question as to the quantity of lime absorbed by the plants growing on limestone rock still awaits an answer. Under natural conditions these lime-loving rhododendrons are flourishing on what we should consider a very sterile medium, and it may be that the poor growth which such plants exhibit when grown in lime-containing soil in our gardens is due to the superabundance of soluble nutritive salts, which may cause the lime to react unfavorably on the mycorrhiza of the roots, and that, under certain chemical conditions, the lime may have a definitely toxic influence.—*A. W. H., in Nature.*



Old building of the Smithsonian Institution.



South front of new Smithsonian building.

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A Remarkable Establishment for the Promotion of Knowledge

THE Smithsonian Institution at Washington, D. C., is a unique establishment for the furtherance of knowledge; its object is to carry on and aid general scientific investigations, whether they be geological, biological or anthropological—the study of the earth, its life or man himself—and to disseminate the same throughout the world by means of its various series of publications.

The institution was founded at Washington city in 1846, under the terms of the will of James Smithson, an Englishman, who bequeathed his fortune "to the United States of America, to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men."

Smithson, himself a scientist of note, a graduate of Oxford University, and a Fellow of the Royal Society, maintained that "Every man is a valuable member of society who by his observations, researches and experiments, procures knowledge for men," and it was not unnatural that he should leave behind him funds for the purpose of carrying out his ideals.

He died in Genoa, Italy, in 1829, three years after making his will.

Following many delays and much deliberation, Congress accepted the bequest and enacted a law organizing the institution in 1846. It is national in its scope and governmental in its affiliations, its statutory members being the President, the Vice-President and the Chief Justice of the United States, together with the President's Cabinet. Its governing body, known as the Board of Regents, includes the Vice-President and the Chief Justice as *ex-officio* members, three members of the Senate, three members of the House of Representatives, and six citizens of the United States appointed by joint resolution of Congress. The secretary of the Institution, elected by the Board of Regents, is the executive officer and director of its operations.

The Institution proper is maintained by the income of a permanent fund comprising the original Smithson bequest and legacy of $541,000, the accumulated interest on which, with other gifts and bequests, has brought the total fund to a little more than $1,000,000. The Regents are empowered to accept gifts in furtherance of the purposes of the Institution, without special Congressional action, and to administer trusts in accord therewith. In this connection many important researches and explorations have been aided by special trusts provided by patrons of the Institution.

Several bureaus or branches, developed through its early activities, are administered by the Institution with the aid of Congressional appropriations amounting to about $600,000 annually. These comprise the United States National Museum, including the National Gallery of Art, the International Exchange Service, the Bureau of American Ethnology, the National Zoölogical Park, the Astrophysical Observatory, and the United States Regional Bureau of the International Catalogue of Scientific Literature.

While the Smithsonian is not an educational institution in the nature of a university with a corps of professors and a student body, its educational functions are of the highest rank, for its scientific staff and its many collaborators are constantly engaged in investigations, in which students of all branches of science participate, and the Museum collections, the animals in the Zoological Park, as well as the library, and the various publications, are constant sources of information to specialists and students.

For the increase of knowledge the Institution aids investigators by limited grants for research and exploration. It advises the Government in many matters of scientific importance and coöperates with all the Governmental departments, and numerous scientific and historical organizations. Through assistance rendered by special bequests and funds it has advanced science in connection with atmospheric air, and aviation. In general, its activities embrace all branches of natural science, fine arts, and industrial arts; its scope being world-wide. Since its establishment it has participated in astronomical, meteorological, geographical, anthropological, biological and geological expeditions in nearly every portion of the world, resulting in vast increase in knowledge and in the acquisition of a great amount of valuable material for the National Museum.

For the diffusion of knowledge there are issued several series of publications, constituting original contributions to knowledge, accounts of explorations and investigations, and papers recording annual progress in the field of science, all of which are distributed gratuitously to important libraries.

The Institution coöperates with the Library of Congress in maintaining a library which numbers about half a million titles, including mainly transactions of learned societies, scientific periodicals and publications of academies and universities throughout the world.

Three buildings located in the Mall between the Capitol and the Washington Monument, in what is known as the Smithsonian Park, house the offices, laboratories, and exhibition rooms of the Institution and its branches. They comprise the Smithsonian, completed in 1855, with its administrative office, the Bureau of American Ethnology, the Bureau Library, the National Herbarium, and the exhibits of the section of graphic arts; the National Museum building, built in 1881, containing the Museum offices, and the exhibits and collections pertaining to American history and technology, and the new natural history building of the National Museum, completed in 1911, where are to be seen the exhibits of natural history and the National Gallery of Art.

The Washington laboratory and the office of the Astrophysical Observatory are located in the rear of the Smithsonian Building.

The Zoölogical Park, with about 1,400 mammals, birds and reptiles, is located in the Rock Creek Park, in the northwest section of the city.

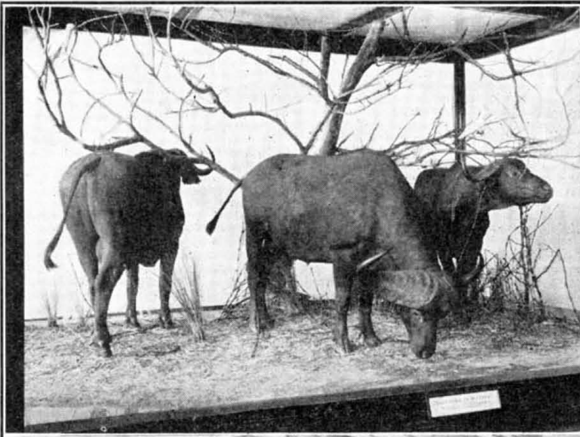
The first building erected for the accommodation of the Institution was completed in 1855, and subsequently additions to it have been built, together with a second structure, and both of these are now devoted in greater part to the arts and industries and American history. The new building, of which an excellent photograph is shown above, was commenced in 1904 and finished in 1911, furnishing much needed space for housing and displaying the wonderful collections of the Institution, gathered from every part of the world, as well as for the carrying on of the widely diversified work of the establishment. This building is 561 feet long, with a depth of 313 feet, and is four stories high. The outer walls are all of marble, and the interior is provided with every convenience for its uses.

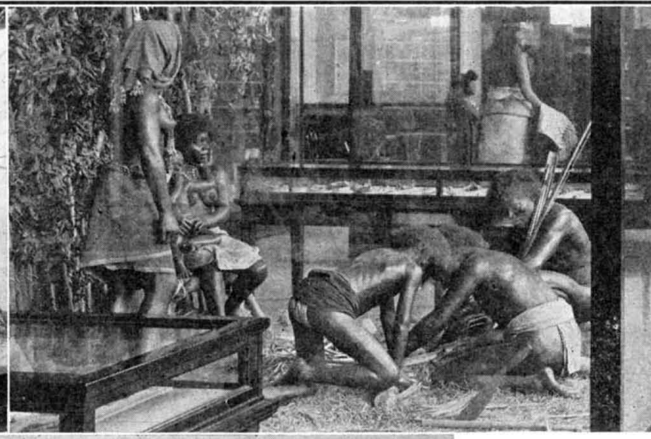
A complete enumeration of the many branches of science and learning, and of the numerous lines of activity included in the regular work of the Museum, is too great to be undertaken here, but are fully covered by the excellent reports of the Institution, and the results of its many undertakings will be found in the many valuable papers that are frequently issued.

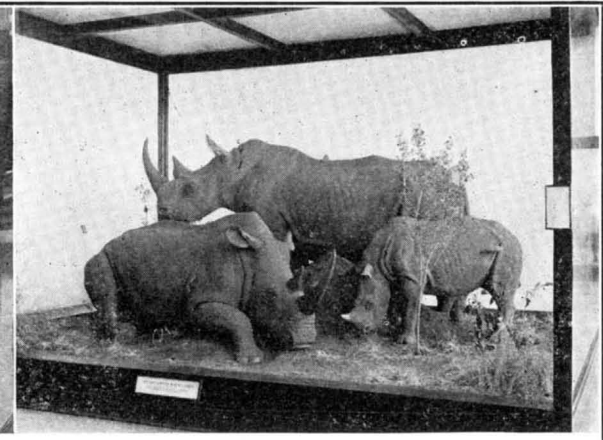
For the facts and photographs above we are indebted to Dr. Richard Rathbun, assistant secretary of the Smithsonian Institution, in charge of the United States National Museum.

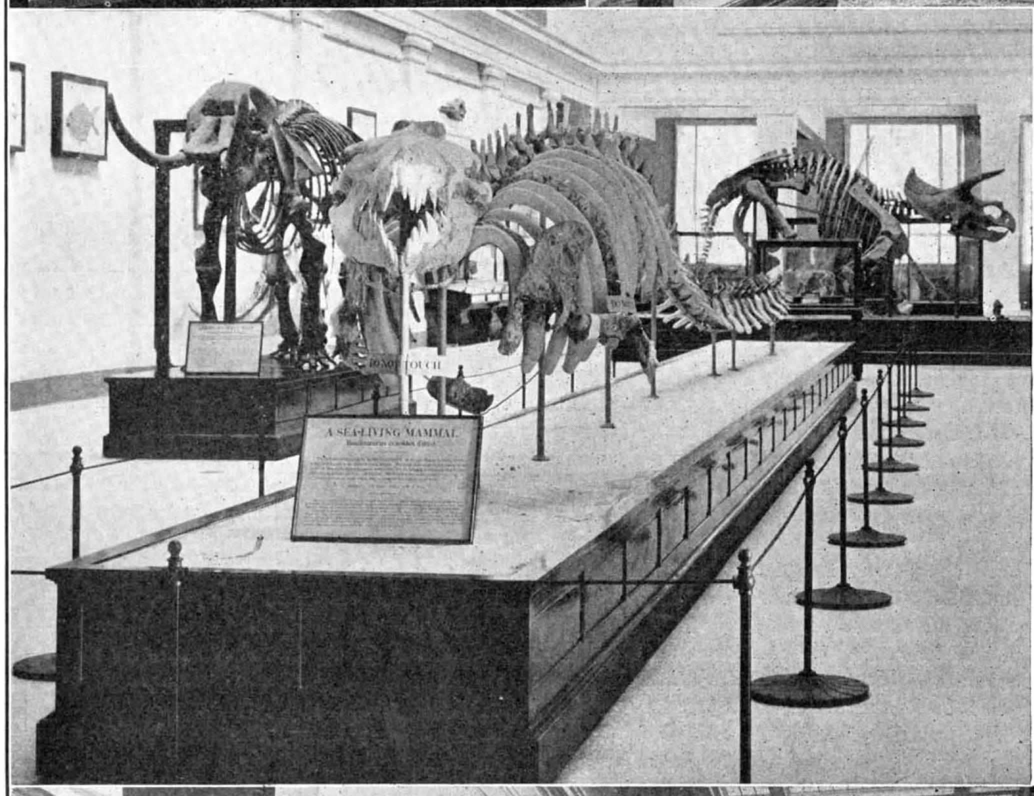
Erratic Migrations of Fish

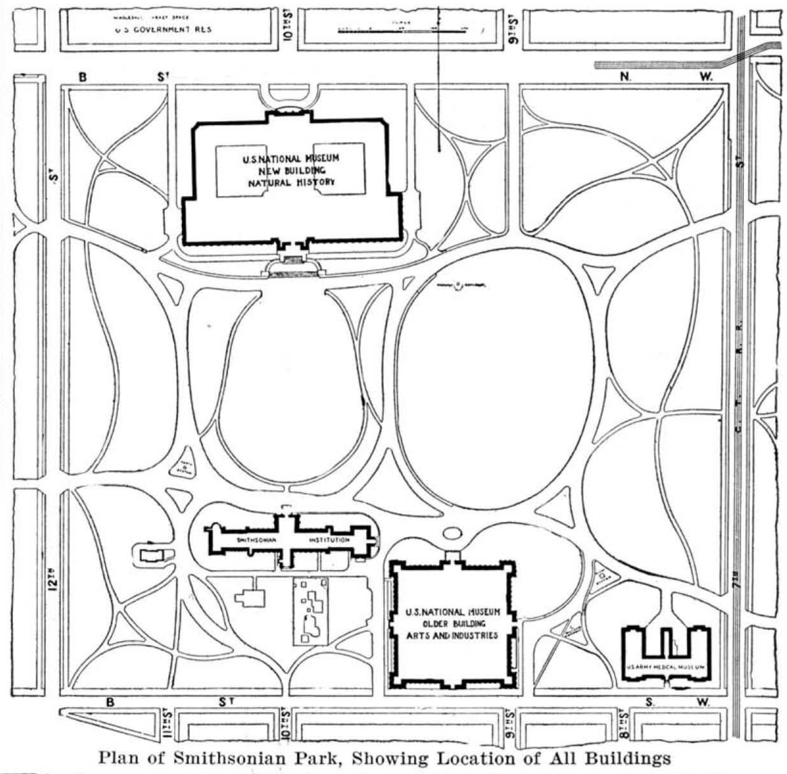
PROF. ROULE of the Paris Natural History Institution (Jardin des Plantes) has been occupied of late with the problem of fish migrations. The most familiar migration is the one which occurs during the period of egg-laying, and on this occasion the sexually mature individuals travel from soft or brackish water to enter sea water, in which the egg laying and the hatching of the minnows is accomplished. What is noticeable about these migrations is that they only occur among the sexually mature individuals or at least those approaching that stage, and besides they take place at a determined period and in one direction. But aside from these genetic migrations of a periodic and constant nature, Prof. Roule remarks what he calls "erratic migrations" in the case of certain fish, and these include individuals of all sizes, whether mature or not, besides being made in variable directions and at periods of the year which do not correspond in the least to the hatching season. As he states in the proceedings of the Biological Society, certain fish in the Thau Lake which lies near the Mediterranean, are noticed to migrate during the cold season, but here they do not proceed as usual toward the sea, as occurs during the hatching season, but mount toward the spring of the Vise River, which flows into the lake, this being a warm-water spring. A distinction is therefore to be made between the genetic migrations which seem to be mainly caused by a search for a medium which is richer in oxygen, and the erratic migrations that appear to be determined by a search for a warmer water.



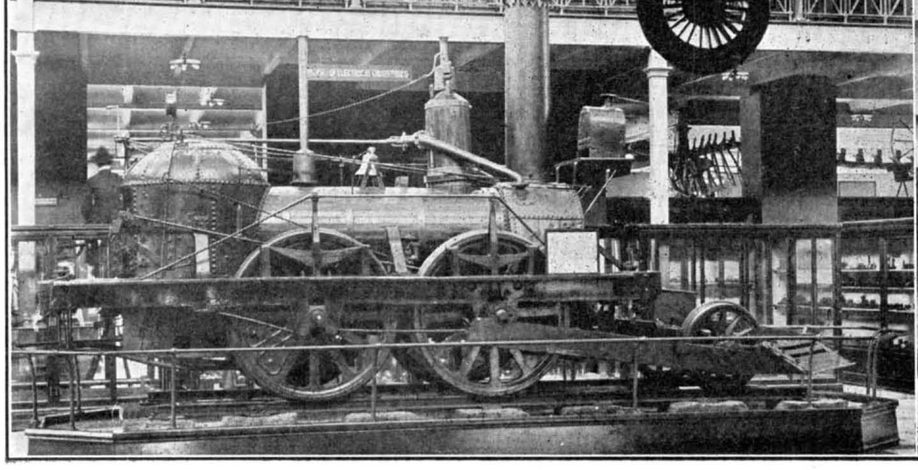


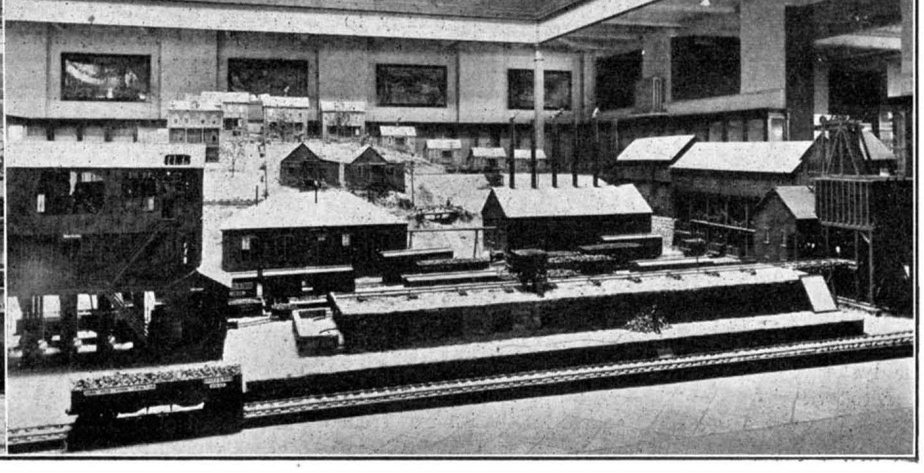






Plan of Smithsonian Park, Showing Location of All Buildings





Views in the Smithsonian Institution, indicating some of its many activities in the promotion of knowledge.

The Use of Ozone*

Some of Its Applications in Chemical Research and the Industries

OZONE is a powerful oxidizing agent which exists in small quantities in nature, but can be produced artificially to an extent only limited by space and money. So far as the British Empire is concerned ozone may generally be said to be known to chemists but not recognized. It is the Cinderella of the chemical profession and trade, who (with few exceptions) have been content to ignore it as a practical commercial oxidizing agent and to regard its suggested applications as the proposals of cranks. The causes for this attitude are not far to seek; in the first place one must take into account the economic status of the British analytical or industrial chemist as it has existed up to the time of the war; in the second place, very few chemists know much or have been able to acquire information about the electrical production of ozone, its estimation or its practical uses. Much has been written in the daily press regarding the status of chemists and their training, and although these are questions outside the sphere of this article, they have an important bearing on the subject from the utilitarian and national points of view.

To our shame it must be said that while most of the research work in connection with the practical application of ozone in chemical industries has been done by a British firm, as usual it is the German chemists and manufacturers (often synonymous terms) who have had the enterprise to make practical use of ozone, and by so-called "secret" processes to flood the markets of the world with certain articles of a better quality than could be obtained in this country. The attitude of the manufacturer here has often been too much in the direction of shying at the capital outlay for an ozone plant without considering how quickly this may be redeemed by the saving effected in the process. Propositions involving the repayment in two years of the capital sunk have been "turned down" as too expensive, whereas to the men of business they would be termed highly profitable investments. In other cases the status of the works chemist has proved an insuperable barrier to the introduction of any new process by an outside firm. Probably these are some of the things that the war will change, and there are already signs of awakening interest in improved processes in general and in ozone in particular. The object of this article, therefore, is to stimulate this interest by a general survey of the applications of ozone to the chemical industry, and to describe some of the ozone research apparatus and industrial plants which have been evolved as the result of many years' experience.

APPLICATIONS OF OZONE.

Although all chemical applications of ozone are in the nature of oxidation they may be classified for convenience as follows:

(1) Manufacture of chemical preparations by ozone.
(2) Treatment of oils, fats, and waxes, and similar substances by ozone.
  (*a*) Bleaching.
  (*b*) Deodorizing.
  (*c*) Refining.
  (*d*) Technical oxidizing.

In addition to these there are other applications which, although oxidation processes, are actually employed in the course of manufacture of goods. These processes include drying of linoleum, fishing nets, waterproof materials, printed matter, varnished or painted articles, etc., bleaching of textiles, maturation of timber, tobacco, wine and spirits, curing of leather, bleaching of sugar and molasses, etc.

Although of interest to chemists, and especially to works chemists, these treatments cannot be discussed within the scope of this article, as they each necessitate apparatus of a special nature, differing considerably from the plants which will be afterwards described, and which have been standardized for the strictly chemical applications of ozone.

(1) MANUFACTURE OF CHEMICAL PREPARATIONS BY OZONE.

Ozone can frequently replace other oxidizing agents with advantage, giving better, cheaper and quicker results in the manufacture of many of the more expensive chemicals, such as certain synthetic perfumes and aniline dyes and disinfectants. Among these processes may be noted the preparation of vanillin from isoeugenol, heliotropine from isosafrol, artificial hawthorn from anethol, the oxidation of camphene to camphor, the production of indigo from indol, and the manufacture of iodoform from alcohol and iodide of potassium. Ozone has recently also proved to be of value in the oxidation of impurities in tar oil, the conversion of ferrous into ferric salts, and the production of ozonized gasoline for internal combustion engines.

Another field, to which attention may be directed at the present moment, is the use of ozone in dyeing, for fully developing certain colors and producing or modifying others.

A great deal more work still requires to be done in these directions by practical chemists who have the time or by chemical manufacturers who will place at the disposal of their chemists research apparatus such as are described later. It is only by taking up an investigation of this kind (which has been proved in the laboratory) and working it out systematically on a larger scale that practical commercial results can be obtained and present processes superseded by better ones.

(2) TREATMENT OF OILS, FATS, AND WAXES, AND SIMILAR SUBSTANCES BY OZONE.

The processes involved in bleaching, deodorizing, refining and technical oxidizing are allied to one another, and in fact in many cases two or even three of the processes may be effected by a single treatment. They all more or less rely for their success on the powerful oxidizing influence possessed by ozone.

The object of bleaching is of course to remove natural coloring matter, such as the green vegetable color (chlorophyll) and the reddish brown color of palm oil, or of colors due to age or impurities, such as the dark color of greases, without injuring or altering the composition or nature of the substance bleached.

Liquids may be bleached by various physical methods, such as the use of coagulants, charcoal or fuller's earth, but chemical processes alone have to be employed for the bleaching of solid substances. These processes may be divided broadly into two classes: (1) Reduction and (2) Oxidation. The former is entirely an artificial process, and requires the use of such reagents as hydrogen, sulphur dioxide, sulphurous acid (produced by burning sulphur), hydrosulphites, or sulphoxalates. The latter process, on the other hand, is constantly taking place in nature, the oxidizing agent being the oxygen in the atmosphere, the action of which is accelerated by sunlight and by moisture, e. g., dew.

Many chemicals have been proposed and used for assisting this natural oxidation, such as potassium bichromate, potassium permanganate, manganese dioxide, bleaching powder, persulphates, perborates, sodium peroxide, hydrogen peroxide and various organic peroxides. Most of these are open to objection for certain purposes. Thus for the bleaching of food stuffs it is obvious that no poisonous material should be used; in the bleaching of textiles by means of bleaching powder the chlorine liberated tends to weaken the fibers; sodium peroxide is liable to explode when in contact with organic matter. In addition most of these "per" salts are very expensive.

(a) *Bleaching.*—The use of ozone overcomes these difficulties with most substances, and in addition the resultant bleach is much more likely to be permanent than that obtained by reduction, since the natural tendency is for the body to become oxidized on exposure to air. Substances which bleach most readily and efficiently with ozone are most

Edible fats and oils,
Soap-making materials,
Industrial oils,
Waxes.

The first include margarine and nut-butter and various animal and vegetable fats, such as tallow, lard, palm oil, cocoanut and palm kernel oils, and "stearines," cacao butter and other so-called chocolate fats—e. g., Borneo tallow, Illipe fat, Dika fat, etc.

The fact that these are intended for internal consumption precludes the use of practically all the usual chemical bleaching agents, as not only is there, of course, great objection to the use of anything of a poisonous nature for the purpose, but also because some processes, particularly those involving the use of mineral acids, tend to spoil the flavor of the oil. Ozone, however, is free from both of these objections, and, indeed, in some cases rather improves the flavor by the removal of impurities, so that it can be very advantageously used for bleaching.

The same remarks apply to salad oils, olive oils, arachis oils and monkey nut oil, cotton-seed oil, soya bean oil, turnip-seed oil and rape oil, etc., all of which may be more or less satisfactorily bleached by the use of ozone.

As regards soap-making materials, ozone is a very useful bleaching agent in this industry, doing all that the ordinary oxidation methods will accomplish, but more quickly and effectively and at less cost. The better qualities of palm oil, for example, can be bleached perfectly at a cost of about 2s. 6d. per ton, while the so-called unbleachable palm oils, such as Congo or Salt Pond, are very considerably improved in color. Tallow, bone fat and greases are also very readily bleached by treatment with ozone. Another method of utilizing the bleaching effects of ozone in the soap works is to ozonize the contents of the pan or kettle during the primary saponification or pasting stage, whereby the saponification process is said to be accelerated.

Industrial oils—that is oils used for paints and varnishes—readily combine with ozone on account of the larger amount of unsaturated bodies which oils of this class, such as linseed oil, contain. In addition to being bleached by the oxidation of the coloring matter, which is an advantage in connection with the mixing of light colors in the paint and varnish industry, they further absorb a considerable quantity of ozone, which should accelerate the subsequent drying of the paint.

Many waxes can readily be bleached with ozone. Beeswax, which is probably the most important of the waxes, can be much more rapidly bleached by ozone than by the ordinary method of air bleaching. Other waxes for which the ozone treatment is suitable are Carnuba, Insect or Chinese, and Japan waxes.

(b) *Deodorizing.*—The offensive odor which many substances possess is due in most cases to organic matter in a state of decomposition with which they are always more or less associated. This is best illustrated in the case of sewage greases, fish meal, tallows, bone fats, and such like materials. These substances, if left exposed to the ordinary air, develop nauseous qualities, although one would imagine that the oxidizing properties of the atmosphere would at least stay further development. On the other hand, if treated with ozone they are at once deodorized by reason of the existing organic impurities being oxidized and the cause of putrefaction destroyed. Such substances as oleine and stearine owe their disagreeable odor to chemical causes, but ozone completely deodorizes these also. The use of ozone is also found to deodorize cocoanut oils considerably.

(c) *Refining.*—Refining of various substances is necessary for the purpose of preparation for articles of consumption. By refining is implied the removal of the disagreeable natural flavor or taste which is inherent in some of these substances, which may be said to include practically all the edible fats and oils referred to under "(a) Bleaching."

(d) *Technical Oxidizing.*—This term is used to discriminate between the several meanings of the word "oxidizing" and the thickening or drying process as applied to the industrial drying oils, such as linseed oil. While this renders them unsuitable for soap making, it possesses great advantages in the paint and varnish industry, the drying properties of the oils being increased and accelerated, so that there should be considerable scope for the use of ozone in the production of quick drying paints and varnishes, such as are required by coachbuilders, shipbuilders, and other trades, and the preparation of linseed oil as used in the linoleum and waterproofing trades.

As has already been stated, two or three of these processes will sometimes be effected with a single treatment. For instance, edible oils will be bleached and refined at the same time; fats will be bleached and deodorized; oils may be bleached only or bleached and thickened.

INDUSTRIAL OZONE PLANTS.

The method of treatment is almost identical, whether for bleaching, deodorizing, refining or oxidizing, and the plant used is practically the same, with only slight modifications to suit particular circumstances. The process is very simple, and consists essentially in forcing ozonized air through the substance, which is contained in a suitable pan or vessel. Various conditions are used to suit various substances or objects to be achieved. According to the nature of the substance the concentration or strength of the ozonized air must be varied, also the quantity of air per unit of material, and the time during which it is subjected to treatment.

*The Chemical News.

The conditions of temperature, etc., have also to be considered, but the process, generally speaking, is in almost all respects identical.

Quite apart from the natural advantages which such a system of treatment has over ordinary chemical processes for such materials as are required for human consumption, this method of bleaching, etc., by ozone possesses actual commercial value and undoubted merit. In most cases the cost is considerably less, while in others the length of time now occupied may be very considerably shortened. In many other cases the results obtained cannot be achieved by any other means.

The plant consists essentially of an electrically driven blower, a refrigerating plant for cooling and drying the air to be ozonized, a battery of ozone generators, and the vessel in which the material is treated. The blower has a capacity varying with the speed at which it is driven and the resistance of the column of material in the treating vessel.

The air now passes into the cooler of the refrigerating apparatus. This apparatus is worked on the direct expansion system; the temperature of the air issuing from the refrigerating apparatus is about 0 deg. Cent. The object of this cooling of the air is, first, to dry the air by deposition, and, secondly, to cool it, in order to keep the electrodes of the ozonizers cool and thus increase their efficiency.

The air now enters the bank of ozonizers through a series of pipes, which are arranged in order to give an equal volume of air to each ozonizer. The high-tension current is supplied by transformers, whose secondary voltage varies from about 7,000 to 9,000 volts. This secondary voltage is capable of regulation by means of the primary winding of the transformer. The switchboard is arranged so that the energy consumed by each ozonizer can be measured and complete regulation and control obtained. The ozonized air is distributed by means of a series of pipes, which force it through the material at the bottom of the treatment vessel. A plant of this kind will bleach one ton of beeswax at an expense of approximately 120 kilowatt hours. The same plant can be used for bleaching various other materials, such as palm oil, tallow, etc., and the amount of power taken per ton of these materials varies also. For instance, for bleaching palm oil the power taken is much less than for bleaching beeswax and amounts approximately to 50 kilowatt hours per ton.

Comparing the relative advantages of this method of bleaching beeswax with the chemical method ordinarily adopted, it will be seen that, quite apart from other advantages, the cost is relatively very small, and shows a large advantage in favor of ozone. The method chiefly used up to the present for bleaching wax is known as the bichromate method, and consists in heating the beeswax for several hours in contact with bichromate of potash and sulphuric acid, the approximate quantities used being for each ton of beeswax 5 hundredweight of sulphuric acid and 1½ hundredweight of bichromate of potash. The cost of these chemicals alone amounts normally to about £3 15s., as compared with the cost of 120 kilowatt hours—or, say, an average of about 5s.—in this country. To this sum of 5s. must be added a small amount representing the interest and upkeep on the ozone bleaching plant, but even with this addition the total cost of the process represents a large advantage in favor of bleaching by ozone.

There are still other advantages. In the chemical method of bleaching there is a considerable loss of material, due to the chemical action and to what is technically known as "charring." This loss in the case of ozone is practically negligible.

Another advantage is that the wax bleached by ozone remains pure and uncontaminated, whereas very special means are needed in order to free the wax from the mixture of chemicals when that method is used.

Similar arguments may be adduced in favor of the treatment of other substances by the ozone method as described.

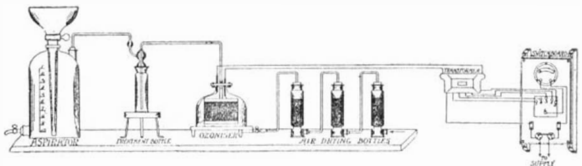
As already stated, the plants, of which the foregoing is a general description, have been standardized for the strictly chemical applications of ozone as already defined. For other applications, such as the manufacture of chemical preparations, the industrial plants might differ in various respects, depending entirely on the nature of the substance and the details of the process. The latter has to be worked out in the laboratory, and for this purpose the chemist requires a suitable set of apparatus. He may, first, require merely to ascertain whether ozone will do what he desires, and afterwards, if his results are promising, he will require to make quantitative experiments involving an estimation of the quantity of ozone used to achieve his end. On the basis of such experiments the chemist may be able to form the necessary conclusions as to whether ozone will be a more economical reagent for his purpose than the oxidizing substances that he has hitherto used.

RESEARCH APPARATUS.

The standardization of research apparatus for the laboratory is a great convenience to the chemist who wishes to make investigations with ozonized air under his own superintendence and control. Such outfits cannot, however, be built up from the apparatus found among an ordinary laboratory equipment, as they include parts which cannot be used for any other purpose. Standardized outfits which will cover the whole range of possible laboratory or research work are, however, available. The most important item of these outfits is the ozone generator with the high tension transformer for furnishing the necessary high voltage, and, in addition, where a continuous current only is available, a rotary converter.

A small switchboard is always advisable, mounted with the necessary controlling and regulating apparatus, and an ammeter or a wattmeter is useful, although not absolutely necessary for small experiments. The outfits should include the necessary aspirator or pump for drawing or pushing the ozonized air through the material to be experimented with, treatment and air drying vessels, etc., but in some cases these bottles, vessels, etc., and the connection tubes and corks may be omitted if the user is already in possession of such accessories.

The diagrammatic illustration shows a small outfit consisting of air-drying bottles, ozonizer, treatment bottle, aspirator, transformer and switchboard. The ozone generator is of the small size with bell glass. The aspirator is of 9 to 10 liters capacity, and the maximum rate of the outfit is about 10 liters in five minutes. The aspirator must therefore be refilled after each 10-liter run, so that the experiment in some cases cannot be worked continuously.



Where continuous working is required and only qualitative results desired a Bunsen tap pump may be substituted for the aspirator, but where quantitative results and continuous running are required a small suction air pump and electric motor can be substituted for the aspirator, by which the rate may be increased up to about 30 liters per minute. In this case, as the aspirator is not used, an air meter is employed, with a maximum reading of 40 liters per minute.

A larger outfit includes the aluminium ozone generator, electrically driven air pump and an air meter, and the apparatus as described for the previous outfit, but all slightly larger, and an absorption bottle is included for the absorption of any other gases, in order to leave the ozonized air absolutely pure. This outfit has a capacity of about 60 liters per minute.

A still larger outfit is recommended for work on a more extended scale. Its capacity—namely, 120 liters per minute—is double the size of the previous outfit, and it is in fact a miniature industrial installation adapted to the laboratory. The ozonized air, instead of being drawn through the liquid to be treated, is forced under considerable pressure through small injectors, which have the effect of bringing the ozone into intimate contact with the whole of the substance to be treated, so that a better result is obtained in a shorter time, and therefore with a smaller expenditure of ozone. Moreover, certain treatments can be performed which by any other means would be impossible.

The set comprises an air cleaning and drying apparatus, an electrically driven air pump, air meter, air cooling apparatus, ozone generator, spraying injectors, treatment vessel, transformer and switchboard. The air cooling apparatus is not essential except for very exceptional circumstances or in hot climates, and could be dispensed with altogether if the new type of ozone generator is used. The air cleaner and dryer is of advantage, because it enables a considerable increase of yield to be obtained, while the possibility of the formation of the oxides of nitrogen at very high concentrations is eliminated.

In conclusion it may be pointed out that while the foregoing remarks give a fairly wide indication of the field in which ozone has been proved to play an efficient part, and also of one method of applying the industrial treatment, there is still a very large unexplored tract for the chemist to investigate, particularly among the complicated benzine and other organic compounds and derivations of coal tar, etc. In this connection it may be hinted that ozone in some cases acts something like a catalyst in the presence of another oxidizer, in promoting oxidation, which in its absence does not take place. By this is implied that with certain substances the theoretical quantity of ozone required to perform the process of oxidation may appear to be so large as to preclude its employment on economic grounds, whereas actually the presence of a relatively small quantity of ozone will induce oxidation by another oxidizing reagent to the extent of as much as twenty times more than without ozone.

Progressive Oxidation of Cold Storage Butter

The air contained in various samples of cold storage butter was extracted and the carbon dioxide and oxygen contents determined, and at the same time the chemical characters of the extracted butter fats were in many cases also determined. The butter samples were placed in special tubes (9 × 1¾ inches) with widened necks to carry a rubber bung fitted with a glass stop-cock, and the space between the butter and the bung was filled with pure paraffin oil. The air contained in a pasteurized sweet cream butter containing bacteria and prepared from cream of acidity 0.11 per cent (as lactic acid), underwent little or no change during six months at 0 deg. Fahr. (—18 deg. Cent.), nor did the buttermilk made from the same cream. The composition of the air in the butter changed considerably when the temperature was 32 deg. Fahr. (0 deg. Cent.), the oxygen diminishing and the carbon dioxide increasing progressively, and at room temperature this change was more marked. The air enclosed in butter made from sweet cream of acidity 0.25 per cent, and churned immediately after the addition of 15 per cent of a commercial starter, remained unchanged for seven months at 0 deg. Fahr., but that from similar butter prepared with the addition of lactic acid suffered a progressive loss of both oxygen and carbon dioxide, the decreases being accentuated at 32 deg. Fahr., and the taste becoming unpleasant after three months. Buttermilk, from butter prepared similarly, lost all its enclosed oxygen in twenty-six days when it was exposed to a very large and confined surface of air; the carbon dioxide rose from 2.37 per cent to 34 per cent in the same time, but thereafter began to diminish. To investigate the oxidation of pure butter fat, the latter was separated and washed practically free from non-fatty constituents, and then stored for several months at 0 deg. Fahr. The samples showed no deterioration even after eighteen months, and the chemical analyses, performed after four months, showed that no oxidation had occurred. The confined air, however, showed a slight progressive increase of carbon dioxide, which bore no relation to the oxygen content. Stored at 32 deg. Fahr., and exposed to a large surface of air, the fat underwent a slight oxidation. To ascertain if the changes in whole butter were due to its non-fatty constituents, samples made from pasteurized cream and ripened with a pure culture were (*a*) washed until the wash water was just clear, (*b*) more thoroughly washed, and (*c*) left unwashed. The keeping qualities at 0 deg. Fahr. of the two former were the same, as were also the chemical characters of the butter fats, and hence no chemical changes had occurred. The carbon dioxide enclosed in (*a*) decreased greatly in the second to third month, and then the decreased percentage remained fairly constant; that in (*b*) rose to a maximum after three months and then remained constant. In both samples, the oxygen content was different at each stage but it diminished regularly in both. Sample (*c*) was prepared similarly, but from a different lot of cream, and it contained more buttermilk. Although the fat did not change during storage at 0 deg. Fahr. for six months, the confined air became very different from that in (*a*) and (*b*): the carbon dioxide was at a maximum after three months, when a characteristic "off flavor" developed, and after eight months the oxygen content was reduced nearly to zero. The general conclusions arrived at were: Undesirable flavors in cold storage butter are not due to oxidation of fat, but to a chemical change in one or more of the non-fatty ingredients; the extent of the change is proportional to the acidity of the cream from which the butter was made; the amount of confined carbon dioxide is probably related to the quantity of buttermilk present, and this amount may increase to a maximum and then decrease progressively.—*Note in Journal Soc. Chem. Ind. from an article by D. C. Dyer in J. Agric. Res.*

Storing Powdered Coal

In some places where experiments have been made in using powdered coal for fuel, troubles have been encountered from the powder caking or packing in storage, but it has been found that if it is permitted to cool off, after the drying and pulverizing process and before it is put in storage, large quantities can be kept in a satisfactory condition.

The New Science of Nematology

That Deals With Minute Animals That Pervade the Universe

By Annis Salsbury

A NEW science has just made its bow to the public. It is called nematology and it has to do with thousands of millions of minute animals called nematodes. Fifty varieties are found in man himself. Enormous numbers exist all about on land or sea. A thimbleful of mud from the bottom of river or ocean may contain hundreds of specimens. Nematodes from a ten acre field, if arranged single file, would form a procession long enough to reach around the world. If all the matter in the universe except the nematodes were swept away, the world would still be dimly recognizable, and if as disembodied spirits human beings could investigate it, they would find its mountains, hills, valleys, rivers, lakes and oceans represented by a film of nematodes. Towns would be decipherable by the massing of the nematodes whose habitat had been in man, and trees would stand in ghostly rows, marking former streets and highways.

This academic science has recently been swung into the limelight through the sensational discovery of nematodes in filter bed sands. It has been demonstrated absolutely that a score or more of species and thousands of millions of individuals inhabit the sands of city filtration plants, and calculation has laid bare the fact that every glass of water drunk in many a city, which uses a slow filter system, percolates over the bodies of at least a thousand nematodes.

While it is not particularly pleasing to think that the waste of these myriad organisms passes into city drinking water, scientists are not yet agreed that it is harmful. It is highly probable that the physiological effect produced by a change of drinking water when the usual chemical and bacteriological tests show but slight differences, may be due to the presence of nematode excreta, and it is scarcely doubted that the local flavor of city drinking water is affected by its nematode content.

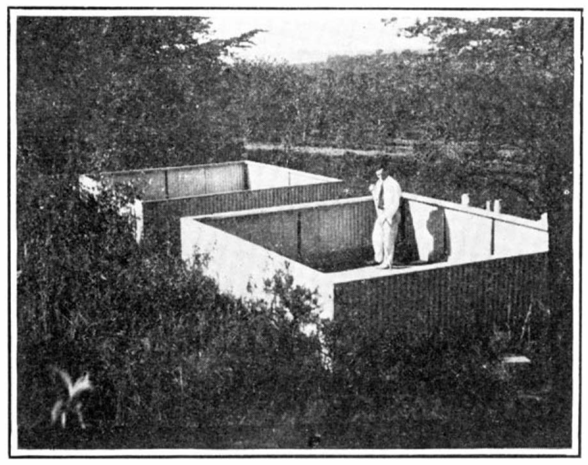
Excreta has its own peculiar character, and that of any given species must be different from that of any other. Though differences between excreta might be slight in organisms that are similar to each other, the differences among organisms of different filter beds are great enough to cause material differences not only in the insoluble parts but in the soluble parts as well. Such soluble parts as pass into the drinking water must play their rôle in imparting to the water its flavor and other qualities.

The excreta of Mononchus developed in one environment vary markedly from the excreta of Dorylimus, the product of different soil and rock habitat. Just as the rose exhales one sort of fragrance and the violet another, so water which contains the soluble organic matter from the nematode Mononchus has a different flavor from water whose taste is due to the excreta of a different species of nema. It is hardly too finespun to say that the future will see connoisseurs of drinking water like the present day tasters of wine and tea, and that along with chemical and bacteriological tests, which are now so efficiently made of filter water, there will be an attempt to determine the nature of the minute quantities of soluble organic substances in water, which it seems probable are the source of the difference of flavor of different city waters.

"It is beyond the imagination of the scientist of to-day to vision the relation between this micro-organism and other soil constituents," asserts Dr. N. A. Cobb, who knows more about nematodes than any man living, having collected them from every corner of the earth, and who conducts his experiments in a laboratory in the Department of Agriculture in Washington city. "There are hundreds of thousands of undiscovered species of nemas whose part in the economy of the soil is scarcely sensed.

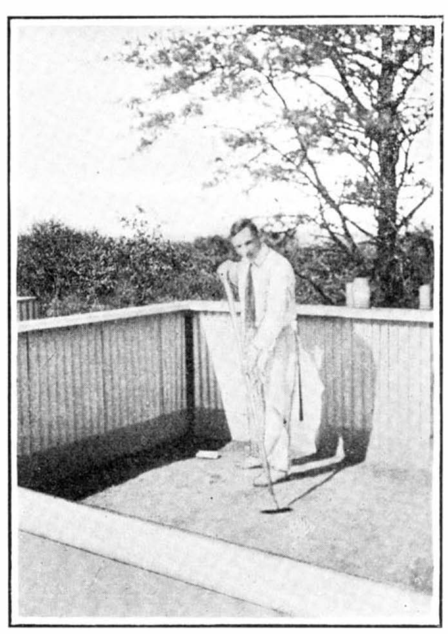
"Hundreds of investigators will have lived and died before any great impression is made upon this huge group, and it is early to prognosticate in any definite way what the future holds in the way of applying these myriad organisms to practical uses of mankind. Yet even the slight inroad which we have made into this new science hints at great possibilities.

"Parasitic nematodes are responsible for millions of dollars' worth of crop damage yearly," continued Dr. Cobb. "The onion and other bulbous crops of Europe are attacked by a nematode which frequently destroys the entire crop. Nine tenths of the crops growing in the United States, if not actually destroyed by this plant pest, are materially impaired. It is believed that the mutilation of root fibers true of a large number of our cultivated crops is due to a parasitic nema.



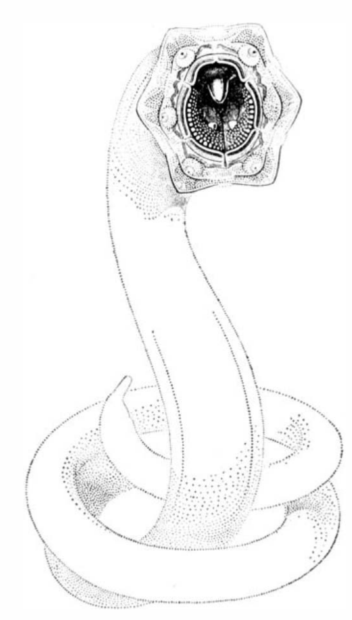
Nematode proof plots at Arlington Farm, Va., designed to test the effect on nematode population inside by keeping down the growth of vegetation.

Where a root is destroyed the plant throws out another root higher up on the same axis and in this way continues to derive its nourishment from the soil. If the plant were freed from the necessity of constantly supplying new roots in place of those killed off, the aerial part of the plant would undoubtedly flourish with greater vigor.



Working over the plots to keep them free from vegetation.

"It has been demonstrated that deleterious insects can be fought with insects, and though we know but little of how the life forces of nemas interplay with those of surrounding organisms, I believe that it is quite possible that we may achieve as brilliant and successful results in using nematodes in this way as entomologists have the insect.



A predaceous nematode. Mononchus brachyuris, showing front view of mouth opening and teeth.

"We have another interesting possibility along the line of nematode and soil relationship in a variety of species, one of which I have called Diplogaster aerivora, meaning air-eater. This nematode literally swallows and ingests air, nitrogen, oxygen, argon and all. I am not laying any claim as to what this micro-organism can do in the way of increasing soil fertility. We know that it only lives for a day and that its mausoleum is the soil.

"It is known that certain organisms, commonly considered to be vegetable in their nature, are capable in some way of converting atmospheric nitrogen into a form available as food. The fact that organisms can convert the nitrogen of the air into valuable nitrogen compounds is more and more occupying the attention of agricultural scientists everywhere, as the process is one of enormous economic importance owing to the fact that nitrogenous food is the most valuable kind, and is steadily rising in price. To what extent other organisms than bacteria have the power to fix atmospheric nitrogen is a question of timely interest in the face of observations of the life and habits of Diplogaster.

"Cases are on record, and they are increasing in number, in which it has been observed that if the soil be thoroughly sterilized, and afterward inoculated with micro-organisms which are known to be necessary to the health of growing plants, plants reared in it flourish remarkably. Surely Diplogaster would be counted among these useful micro-organisms, and for the future agriculturist Jack's beanstalk may become a reality."

We do not know how many of the predaceous genera may be utilized in destroying the plant parasites of their own kind. The prospect is highly promising. We have already discovered that Mononch papillatus feeds upon Tylenchulus, which preys upon the citrus groves of California, and that Mononch brachyuris devours the gall worm which is responsible for a large proportion of the damage done to crops by parasitic nematodes. In this connection it is significant to know that the latter is one of the most abundant species of nema found in filter bed sands at certain periods. It occurs in countless millions in the filter beds of the waterworks of a number of American cities, and thus provides a culture from which to obtain material for inoculation in case it is found practicable to combat the gall worm in this way.

A newly discovered activity of an age-old nema promises to have important bearing upon soil fertility. Rhabditis, a genus of soil inhabiting nema, is largely instrumental in the production of humus. Armed with powerful lip muscles, and secreting a substance which aids in breaking down animal and vegetable tissue, Rhabditis works its way into dead organic matter not yet penetrated by bacterial agents of decay. Feeding upon microbes and spores of fungi, this soil nema leaves in its wake bacteria infested excreta which is not slow in germinating and getting started the process of decomposition, in whatever medium it happens to be.

How to use this nematode so that it may be applied practically to the production of humus has not yet been worked out. Its inoculation in organic matter, ploughed under for conversion into humus, may prove of great importance to the farmer. It must necessarily play an important part in the new view of the soil which emphasizes making use of the myriad organisms whose habitat is within the earth in developing conditions favorable to plant growth.

Nematodes do not closely resemble any other organism. While they constitute a group more widely spread than almost any other, and are numbered by countless millions, their relationship to the rest of the organic world must remain more or less of a riddle. They bite, puncture, gnaw, suck and dig as do insects, but they do all these things with organs of an entirely different character. They see, feel, taste and smell. No one has proved that nematodes hear, though organs on either side of the head whose function has not yet been determined may be organs of hearing. When a nematode

is possessed of definite jaws, these are usually three in number, instead of two as in most other animal groups, and act radially somewhat as do the jaws of a lathe chuck. The jaws are moved by relatively powerful muscles, and often are armed with ferocious teeth which can be used in a very effective way.

Sometimes the mouth is armed with a sting or spear with which to puncture the tissues of the victim, preparatory to sucking away its vital fluids. In such cases, behind the spear, and constituting a portion of the gullet, there is a relatively powerful pump or sucking bulb. The nematode applies its lips to the object to be punctured, exerts suction by means of its muscular pump, thus attaching its lips firmly, and then thrusts its spear through the mouth opening so as to puncture or batter down the tissue containing its food or through which it wishes to pass.

The Iotas, which inhabit the meadows and swamps, are remarkable because of the peculiar mechanism which furnishes propulsion as well as aids in procuring nourishment. They are covered with projecting retrorse scales or prickles, so that it is with difficulty that they move in any other direction than forward. Every movement of their bodies drives them in a more or less forthright way through the soil. Coming against the root of a plant, their muscular movements push the head firmly against the surface of the root, so that the spear with which the mouth is armed when thrust forth acts from a well-supported base, namely the friction of the surface of the body against the surrounding soil material.

The Mononchus, upon which great hope is placed as a natural destroyer of the gall worm, is one of the most powerful of nemas. It has six powerful lips and a remarkably supple neck, which enables it to dart its head suddenly here and there and to seize its prey even though the latter be also active. The onchi or teeth act as fangs and are used in opposition to the lips in seizing and holding the prey. Denticulate areas, or rasps, are used in conjunction with the strong dorsal tooth in fixing its quarry. The Mononch glides up to its victim and makes its onslaught by a quick snap of the head, throwing its jaws suddenly wide open, and grappling its prey by means of the inner armature of the lips.

While the modern science of nematology is merely in its infancy, knowledge of nematodes dates back to antiquity. It was known in Biblical times as a fiery serpent, incrusting itself in a man's ankle and remaining there until the ancient leech, by a rude system of skewer and lever, drew the worm out. At one time there was a widely prevalent worm theory of disease as popular as the germ theory of the present day. It had for its basis the fact that worms are obviously associated with numerous and varied forms of disease.

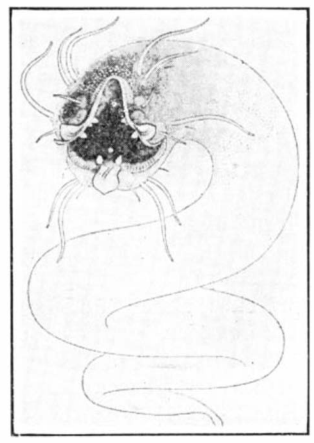
In modern times the knowledge of parasitic species of nematodes which cause disease has become much greater. The dreaded hook worm is a nematode, and so is that scourge of the tropics, the guinea worm. Trichina, costing civilized nations hundreds of thousands of dollars yearly for the inspection of pork, is a nematode. If raw or insufficiently cooked trichina-infested pork be eaten by human beings, the result is a serious, oftentimes fatal, sickness called trichinosis, epidemics of which have claimed victims by the hundred.

Nematodes have recently been suspected, with good show of reason, of being carriers of cancer. The list of more or less serious human nematode diseases and ailments might be increased until practically half a hundred had been enumerated.

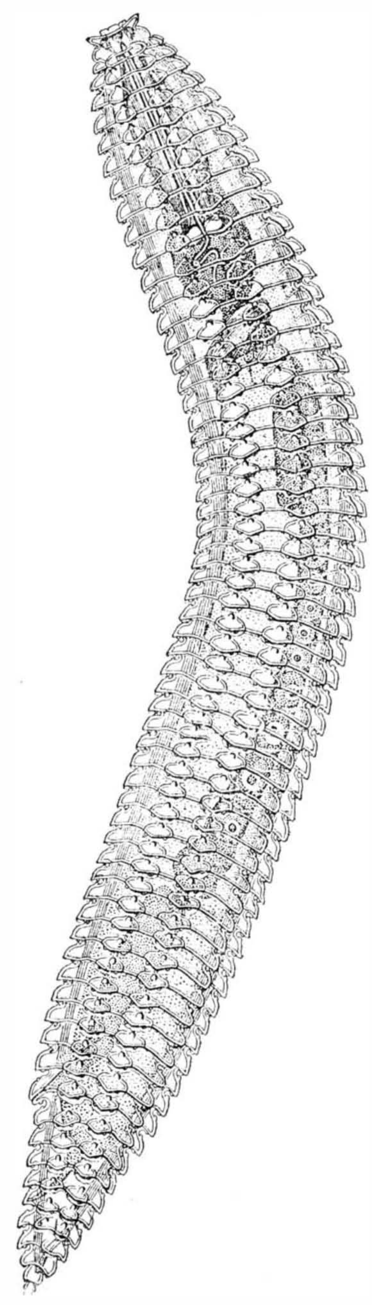
Of curious interest along the line of parasitic nema is a recent discovery made by B. H. Ransom, in the Bureau of Plant Industry, of the existence of a larval stage of nematode in the house fly. There was no evidence favoring the hypothesis that this larval stage in adult form was a free-living nematode, and the natural inference was that it belonged to some variety of parasitic nematode. Horse manure is a favorite breeding place of the house fly. The stomachs of two horses were examined shortly after death and disclosed the adult form of the nematode which had been found in larval stage in the house fly.

The present day familiarity with the characteristics and habits of the free-living nematode is acclaimed the height of microscopic attainment. Scarcely second to its economic value is the part played by this small but complex organism in biological study. It presents a wonderful complexity of organization combined with such transparency that very little is hidden from view. Digestive system, nervous system, all are to be seen with most instructive wealth of detail and in full action in the living animal.

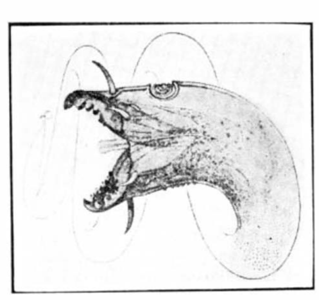
Every individual has more or less familiarity with just common worms, but the present generation, if all that nematology holds in prospect is realized, is laboring in Egyptian night as far as any real comprehension of our wormy environment is concerned. While the visible world has been pretty well explored, there is still the realm of the invisible, which holds marvels never dreamed of in our philosophy, and it remains the onerous yet exciting task for the devotee of the new science to reveal to the public the wonders to be found in the realm of the nemas.



Front view of a nematode monster, which feeds upon others of its kind.



One of the scaly little monsters, frequenting the soils of our meadows and swamps. These are known as Iotas. They are covered with retrorse scales, or bristles, so that it is practically impossible for them to move in any other direction than forward. Near the head the remarkably large and powerful spear can be seen through the skin. When, in order to make punctures, this spear is thrust out, the nematode is not pushed backward, because of the friction which its scales offer to surrounding soil particles. There are many kinds of Iotas, and all of them appear to be injurious.



The shark nematode, selachineura, which preys upon other nematodes.

Ventilation and Chills

The question of ventilation is treated very differently in different countries. We in England are, or pretend to be, inured to chills and not very apprehensive of draughts, and think that this is a manly attitude. But on the Continent people often insist upon shutting railway-carriage windows when the Briton bares his brow to the wintry blast with complete (or pretended) indifference. Hence certain quarrels we have witnessed. Which is the right attitude?

Our theory appears to be based upon the view that we do not get chills when walking in the open air, and indeed feel the benefit of such exercise. But a person who is sitting in a draughty room or railway carriage is not taking the exercise which warms him against the cold of the atmosphere when he is walking. During a long railway journey we may become thoroughly chilled and open to the attacks of the numerous germs which are living upon our skin, throat, nose, or elsewhere, waiting for an opportunity to enter the deeper blood or tissues, or of other germs which may be hiding in the carriage cushions. The cold air may perhaps impede the attacks of the latter germs, but will tend, by chilling the patient, to encourage the former ones. On the whole, then, the case for sitting in draughts may be questioned; and there are numbers of subsidiary factors which are usually ignored—such as excessive meat-eating, alcohol, previous illness, and so on. Our theory that a close room means much poisoning with exhaled matter has been rather exploded by the work of Prof. Leonard Hill and others. It may be that the danger of being thoroughly chilled is much worse than the danger of infection by germs floating in the air of a close room. At all events, many people declare that they get colds by sitting in draughty places, while others say they get them by going to crowded assemblies in ill-ventilated halls.

Our mode of life is based upon our theories. Our sash windows are probably the most irrational things in creation. They appear to have been first invented in Holland, and brought over to England toward the close of the seventeenth century, in place of the rational French windows. It must have been a curious person who invented the former, which are often dangerous owing to the breaking of the cords, while a draught is always pouring in between the two sashes. What their advantage is, no one can understand, and we are glad to see that they are now being replaced again in new houses by the French windows. On the other hand, French windows, as will be easily seen anywhere on the Continent or in Egypt or elsewhere, may be closed to exclude either draught or noise. Moreover, seldom if ever do we have double windows such as are used throughout Northern Europe.

Our open fires do not warm the rooms, while they flood the atmosphere with particles of carbon, and are the most wasteful method of producing artificial heat. On several occasions the writer has left England in the depth of Winter for Russia, Germany or Sweden, and has never been cold until he returned here. On one occasion a Canadian told him that England is the coldest country that he was ever in; and most foreigners make the same exclamation. In Russia the double windows are kept closed nearly throughout the Winter; the house is ventilated by proper arrangements of pure heated air brought up from the basement, with a great saving in cost and with the effect of enabling all the inmates to keep warm all day and night. In fact, in the middle of a Russian Winter people wear only thin under-vests and sleep at night with a single blanket; while we shiver and shake before smoky fires and dress in thick semi-arctic clothing, besides having the privilege of wasting a large part of our income on coal. To be brief, Swedes, Germans, Russians and Canadians laugh at our arrangements. The writer has inquired whether colds are very frequent in Northern Europe and has generally been told that such is not the case, but that colds begin only in the Spring when the windows are first opened. As an experiment he once spent five days in Stockholm in December with windows closed (and remained perfectly well), but one comparatively warm night opened the window and heaped blankets on his bed as in England. The next evening a bad cold commenced.

Englishmen complain that rooms in Northern Europe are stuffy, but this may possibly be a mere auto-suggestion. Personally, the writer prefers the Continental system—one is warm all the time in the house, and when one goes out one can brave the outside cold in a thick coat without having been previously thoroughly chilled in the house.—*Science Progress.*

The Honey Ants*

Notes on an Insect of Curious Habits, Found in Mexico and Southwestern United States

By Percy Leonard

Ever since Llave first described a Mexican honey ant in 1832, these insects have been more or less before the public notice, and yet there are many obscure points to be cleared up in respect to their habits.

The following notes are a contribution to the subject, and are based upon nearly a year's observations of these ants, both in the wild state and in captivity.

In opening up a nest of honey ants we are liable to meet with six distinct phases. First, and most numerous, are the workers, the undeveloped females, which occur in three sizes, the majors, the minors, and the minims, and the so-called "queens," who exercise no regal power, but are simply the egg producers and mothers of the community. They have deprived themselves of their wings and inhabit the darkest recesses of the nest. Next come the virgin females, adorned with gauzy wings of great beauty, and lastly, the almost brainless males, likewise provided with wings.

Besides these, we find the repletes, which are not, however, a distinct phase, but are simply workers (usually majors), whose crops are so distended with honey as to justify their generic name, Myrmecocystus, i. e., ant bladders. These ants have evolved their distinctive habit with reference to climatic conditions. In the Californian springtime the hills are covered with flowers and flowering shrubs. The juicy shoots of many plants are also infested with aphides, which excrete the "honey dew." These insects use only a part of the sweet sap sucked from the growing shoots, the surplus being excreted, and the foraging ants lap it up from the surface of the leaves, or directly from the excretory orifice of the aphides. The quantity of syrup thus produced is extraordinary. As an extreme case we may mention an aphis living on the sugar maple which excretes forty-eight drops in twenty-four hours.[1]

During the season of plenty a certain number of the workers, usually majors, are set aside to store up the supplies collected by their foraging sisters. They hang motionless from the vaulted ceilings of the underground chambers, and are always ready either to relieve a returning collector of the contents of her crop or to regurgitate a drop or two to feed a hungry member of the community. The swallowed honey is not "consumed," but simply stored. It remains in the crop, and is returned to the mouth in the same condition as when first swallowed. A minute quantity is, of course, passed on to the stomach proper for the sustenance of the individual, but the crop contents are available for the use of the community "on demand."

The tendency to active exertion, common to ants, is held in abeyance, and the patient replete resigns herself to the monotonous occupation of serving as a simple container for the fluid wealth of the community.

During the dry season the whole community depends upon the honey stored in the repletes supplemented by dead bees, wire worms, and other insects. The replete, when appealed to by the antennæ of another ant, opens her mandibles to their fullest extent, and the recipient sucks up the honey with mandibles almost shut. In two or three minutes the meal is over, and it is usual for the party served to lick the replete all over and massage the abdomen, as she is powerless to perform her own toilet. The crop, which expands to fill almost the entire gastric cavity, has no glands discharging into it, and as its walls are composed of non-absorbent chitine,[2] it is, to all intents and purposes, as cleanly a container for fluids as a glass bottle.

MYRMECOCYSTUS MEXICANUS MOJAVE.

Early in March, 1910, some boys of the school at Point Loma, San Diego, brought me some honey ants. Their gasters looked like partly deflated bladders, or half-dried raisins. This was because their honey contents had been almost exhausted by the winter consumption of the nest, and the spring blossoms having not yet opened, no fresh supplies were available.

It is a golden moment in the myrmecologist's career when, with a few blows of a mattock on the hard, tough sandstone sub-soil, he lays open the honey vaults. In the bright sunshine the repletes glitter like jewels. They look like highly-polished amber beads, clear and translucent, as they hang from the domed ceilings. So firmly do they cling that only one or two are dislodged by the shock of the mattock. Many of the workers huddled together, like frightened sheep, in one of the chambers, and made no effort to defend their citadel, but doubtless they were paralyzed by the sudden glare. All the chambers and passages were spotlessly clean and absolutely free from smell. Although they look quite helpless, the heavily laden repletes are perfectly well able to regain their position in the dome when shaken to the floor. William M. Wheeler comments on the need of keeping the nest dry to prevent the crumbling of the walls and to prevent the growth of the molds on the repletes.[3] My observations, continued daily for nearly a year, have convinced me that they actually prefer a moist soil. I have found many chambers of repletes about four inches below the surface of the flower beds in a garden which was repeatedly irrigated during the summer months. A wild nest under observation was situated at the bottom of a steep bank, where it received not only its own rainfall, but the surface water shed by the adjoining slope. The soil crumbles very readily when moist, and how the nest escaped disaster is not very apparent; nevertheless, it appears to be a strong and populous formicary.

At first it seems almost incredible that these ants, whose mandibles cannot pierce a plum skin or the rind of a pear,[4] should be able to drive tunnels in the hard sandstone subsoil. The sandstone, however, must appear to the ants as Lilliputian masonry, the stone being represented by the sand grain, the mortar by the yellow clay which binds them together. It is not a question of cutting through the tiny blocks of silica, it is only necessary to moisten the clay matrix with saliva and remove the loosened grain. Lafcadio Hearn's statement that ants can bore tunnels in the solid rock is therefore seen to be misleading. William M. Wheeler states his belief that the relatively large nest opening is an adaptation for increasing the ventilation.[5] My own view, based upon observation, continued for many months, is that the large entrance is required for the removal of nodules of iron encountered while excavating. During the hot weather of July and August the entrance was almost entirely blocked up with little clods; but when the first autumnal rain fell, softening the soil and favoring excavation, the hole was enlarged to a size somewhat greater than that of a ten-cent piece (which measures eighteen millimeters in diameter). Six or eight workers unite their efforts to drag out a nodule. Each grasps it on its equatorial line with her mandibles, and their bodies radiate outward from this center like the spokes of a wheel. Those in front drag, while those behind push, and, after very heavy exertions, the heavy burden is deposited outside the entrance. To allow egress for a team of eight workers surrounding a nodule necessitates a commodious gangway. The constant stream of ants circulating through the galleries is probably sufficient to prevent the accumulation of stagnant air. The nursery chambers are invariably situated in the upper portion of the nest, and one may sometimes see a worker carrying a cocoon outside the nest, as if to give it an airing.

One usually associates ants with dry weather and sunshine, but these ants come out only at night. A thick fog drifts in from the ocean spangling the scanty grass blades with glittering drops. The landscape is shrouded in darkness; but the little circle, illuminated by the lantern, is a scene of bustling activity. A constant stream of amber-colored ants pours out of the entrance hole, each carrying a small pellet of sand-grains in her mandibles. Some leave their burden just outside, others laboriously plod as far as three or four feet before they drop their load and hurry back for another. The underground workings are being extended almost every day in the year. I have seen the ants at work at 9 P. M. in the pouring rain and at a temperature as low as 44 deg. Fahr. They do not leave their holes until about half an hour after sunset. Thus they escape the birds and the lizards, their only enemies being the night-prowling toads and ant lions.[6] If we smear a little honey on a piece of glass it is quickly surrounded by forty to fifty ants, who climb upon each others' backs to reach the tempting fluid. In two or three minutes they are loaded to the limit of their capacity, and then they stagger off toward home. They are perfectly ready to regurgitate when appealed to on their way home by a hungry comrade. The ant's antennæ, in which the "contact-odor" sense resides, are constantly being cleaned to free them from dust, which must dull their sensibility. The eggs and larvæ are continually being licked over, probably as a sanitary precaution to prevent the growth of molds, to which they are very subject in the damp recesses of the nest.

As evidence of individuality in character I give the following anecdotes.

An ant had fallen into the moat surrounding my artificial nest and was rescued in a moribund condition, and laid upon the surface of the island. Two of the workers came up, inspected the sufferer and passed by without the slightest effort to help. Presently a minor worker arrived and showed the liveliest concern.

For many minutes she vigorously kneaded the patient's gaster, and worked the stiff legs until at last the half-drowned ant revived.

On another occasion, after a team of six workers had deposited a nodule outside the nest opening, one major stayed behind and by strenuous exertion dragged the load one third of an inch further away. Its exact location was a matter of absolute unimportance; but the major's notions of exactitude had to be satisfied.

For more than nine months I was unable to get the least indication as to the source of their honey. Occasionally foraging ants would drag a dead bee or other insect into the nest; but I could never find any foragers returning with distended crops.

On March 16th, 1911, however, it seemed as if the whole population was on the move, and streaming up and down the trunk of a neighboring pepper tree (Schinus molle). An examination of the tree by daylight showed a quantity of blossoms, but I could find only one or two scale insects. My captive ants greedily lapped up the nectar from these flowers. I have found these ants "milking" the aphides upon roses and carnations at night. It is probable that almost all the wild flowers are visited by the foraging ants. I know they get nectar from the "rattlesnake weed" (Euphorbia sectioba), the honey plant (Echium simplex, a cultivated flower), and the blossoms of that fragrant wild shrub, Ceanothus cuneatus. As evidence of the stay-at-home habits of these ants, I can certify that a honey plant was in full bloom twenty-seven feet away from their nest, and yet it was three weeks before the foragers discovered it.

The honey stored in a replete of average size I found to weigh 0.1885 of a gramme, and if we take McCook's figure of 600 repletes in a nest of the horti-deorum variety[7] to be approximately true of M. M. Mojave, this would give us 113.10 grammes, or a grand total of about a quarter of a pound of honey. Small though it may appear to us, I fancy that the knowledge of a share in this provision imparts a certain dignity to every individual member of the nest.

These ants do not display such a wolfish eagerness to acquire chance scraps of food, as is shown by other species, who live from hand to mouth. To show the inoffensive character of the ants under consideration, I may mention that once a troop of little black ants (Dorymyrmex pyramicus var. niger) gathered round to lap up some honey which I had put at the nest entrance, but there was no resentment expressed toward them.

When watching the nest at night one may sometimes see crickets hop about among the ants who cover the ground outside the entrance; but no notice is taken of these intruders, and they hop away in a leisurely manner. Once I saw a tiny cricket emerge from the nest among the moving throng of ants, and markedly differentiated from his companions by his sudden, jerky action of progression. He skirmished about for a minute or two and then retreated down the hole. Evidently he was one of the "pets" of the nest.

Among the solitary insects, such as the flies, the moths and beetles, only a very small percentage of their numerous offspring ever reach maturity, owing to parental neglect. Among ants, under favorable conditions, the infant mortality is practically *nil*, so that if every female produced eggs the population would very soon outrun the means of subsistence. It has been very plausibly suggested that the ants regulate the supply of "queens" by rearing a selected number of female

*A paper read before the San Diego Society of Natural History.

[1] "Ants: Structure, Development and Habits" (page 341).

[2] "Ants: Structure, Development and Habits" (page 33).

[3] "Honey Ants, With a Revision of the American Myrmecocysti" (page 380).

[4] "Ants: Structure, Development and Habits" (page 177).

[5] "Ants: Structure, Development and Habits" (page 375).

[6] Since writing my nest was raided by driver ants (Eciton sumichrasti) on June 12th, 1911. The invaders poured into the nest and emerged carrying larvæ. They were repulsed by spraying them with kerosine oil. "The ant's most dangerous enemies are other ants, just as man's most dangerous enemies are other men."—*Forel.*

[7] "Nature's Craftsmen" (page 104).

larvæ on a full diet, while the great majority of them are so insufficiently nourished that their reproductive organs never develop. The feminine trait of taking delight in nursing the larvæ survives, however, in its full strength in these stunted females, and they devote themselves passionately to the care of the little, white, semi-translucent grubs, which resemble a crook-necked squash in general form. I think I have never looked into my artificial nest at any time during the day or night without seeing the nursing ants employed in caring for the larvæ.

On October 28th, 1910, I caught a worker near my wild nest who was carrying about a cocoon in her mandibles. I placed her upon the island nest, where a quantity of other workers were wandering about, not yet having begun to excavate tunnels. There arose immediately a tremendous competition to nurse the cocoon. The lucky possessor was constantly surrounded by eager applicants for the privilege. Sometimes they showed their impatience by stamping violently on the ground or jerking their bodies forward in their uncontrollable desire to caress the helpless pupa. A few days afterward the covering was stripped off, and the pale, unfinished infant was carried to and fro without a moment's peace, as one ant after another acquired possession of it. Every worker wanted to be good to it, and in the end it died, killed by kindness. If the care of the luckless pupa had been entrusted to one nurse all would have gone well, but by a perversion of the nursing instinct a tragedy resulted.

On October 16th, 1910, after the first real rain of the winter season, I noticed a number of ants peeping out of their hole in great excitement. To produce the effect of nightfall I inverted a box over the entrance. On raising the box after a few minutes I saw the ground alive with ants and among them a virgin queen, which I secured. This is the first capture of this phase of M. M. Mojave. The general coloring and markings remind one of a wasp. Although many nests have been searched, only two queens of this species have been found.

During the hot spell of weather at the end of August, 1910, the ants stayed underground. The entrance was almost closed with little clods of earth, which seems to show that the extraordinarily large nest opening is needed not so much for ventilation as to afford egress for ants removing nodules.

For some time I had noticed ants come out of the nest carrying what seemed to be the corpses of ants in their mandibles. I casually noted that they dropped their burdens and returned to the nest. Later on, I discovered that these burdens were live ants, and that when deposited, both parties plodded away in opposite directions without showing the slightest trace of emotion. Other observers who have witnessed similar occurrences have thought them to be a kind of play; but what I saw was much too solemn to be called a frolic. I would suggest that the ants carried out were "callows," that is ants newly emerged from the chrysalis, and that after being allowed to harden their shells for some days in the shelter of the nest they were thus formally introduced to the world as a hint that they might now undertake the regular work of the nest.

Professor Wheeler has established the fact that it is only "callows" which are capable of becoming repletes. Once an ant gets thoroughly matured and hardened it appears to lose the elasticity required in order to allow of the enormous distention of the crop which characterizes the replete. An ant in process of becoming distended to the proportions of a replete can never be confounded with a replete who has fed away her store and is slowly collapsing to her normal condition. In the former case the gaster is tense and more or less spherical, in the latter the skin is corrugataed into folds and the segments stand out as ridges.

MYRMECOCYSTUS MEXICANUS.

These ants have never been found in the United States until 1910, and our discovery of a nest on Point Loma was the third reported occurrence of this species in the year.

On November 6th I dug up a nest in a soil composed of disintegrated shale. They are hardly distinguishable to the casual observer from the preceding species, except by a slightly darker color.

There were many semi-repletes moving about the galleries, and about eight laying females.

When opened up the resulting hole was only three feet deep and two feet in diameter—evidently a new nest. The laying females, in pleasing contrast to the queens in a beehive, are very friendly, and spend hours with their heads together, caressing one another with their antennæ. On January 30th, 1911, I found a solitary female in a little hole in a bank. The excavation could not have been more than a day or two old. Had she been undisturbed, in due time a new colony would have been produced by her unaided efforts.

Shortly after I had established an island nest in a basin and had moistened the earth, a minor worker was struck with the idea of sinking a shaft. Accordingly she scratched away at the soil, using her fore legs just like a terrier Her energy was so infectious that a major joined her, and presently a minim was drawn into the undertaking. Ants digging in pure sand are obliged to remove it grain by grain, but the slightest admixture of clay permits the formation of pellets, thus enormously economizing labor. The loose dirt is first scraped into a heap under the ant. The gaster is then curved forward and downward as in the act of stinging,[8] and the front pair of legs is used to pat the earth against the opposing lower surface of the gaster. The loose soil granules are thus packed into a solid pellet, which is seized in the mandibles and carried out. When digging a gallery against the inner wall of a glass tumbler the digging consists for the most part in tugging at the sand grains and detaching them by main force. The gallery is afterward enlarged to give passage room for the females. One of the nests under observation had its entrance against the edge of a level slab of smooth concrete, so that the circular area over which the ants deposited their excavated soil was divided into two parts; one extended over a flower bed, the other over a surface of cement.

Every day the concrete slab is swept, so that on any given morning the loose earth is exactly half of the total amount brought up during the preceding night. On January 24th, 1911, the radius of the circle of debris was 7 feet 4 inches. The night had been calm, so that in sweeping up the deposit I am sure that I collected no wind-borne particles. The weight was 23.6489 grammes, and by doubling this figure we get the total output of loose dirt for the night. When poured into a cubic inch measure it almost exactly filled it. Under favorable conditions, therefore, these ants can excavate nearly two cubic inches in a night. During a colder night, a few days previous, the radius of the circle was only 4 feet 8 inches. Quite early in the evening some ants will be seen traveling to the very circumference of the circle, passing by bare spaces where we might imagine they would be perfectly justified in getting rid of their load.

Professor Wheeler, in speaking of repletes, remarks that they "are, of course, imprisoned for life;" but I have found my ants gradually resume their original figure when their contents are exhausted. In the nest I excavated November 6th, 1910, there were two or three dozen semi-replete majors whose gasters were no larger than those of the fertile female's, and who could walk about quite freely. Others had apparently been entirely emptied, owing to the lapse of time since the spring honey harvest, and their gastric segments were in a distressing condition of misfit. They did not overlap smoothly, but were warped and twisted out of shape. But another course is open to a replete who finds her honey content diminishing. *She may swallow air*, and thus maintain her size. This is done by both M. M. Mojave and the present species. In my artificial nest I found a full-sized major replete three quarters full of honey and with an air bubble occupying the upper region of the crop. I stinted supplies of honey to bring about diminution of her stock, and as she fed away her store the air bubble increased, until it filled three quarters of her capacity, while the remaining quarter of honey lay in the lower part of the crop.

I now frequently found her lying on the floor of the little grotto where she lived, with six or eight workers gathered around to be fed. The reason for her recumbent posture is at once apparent. So long as she was hanging from the ceiling, the air bubble occupied the upper portion of the crop, and her efforts to regurgitate honey could only result in an escape of the imprisoned air; but if she lay upon her side, or ventral surface, on the principle of the spirit level the air rose to the highest point of the gastric wall, and then any contraction of the proventriculus, or pumping stomach, forced the honey out at the mouth. Contrary to the observations of McCook on the hortideorum variety, I have found that these ants very economically lap up the honey content of dead repletes, after depositing the heads and thoraces in the moat round their nest. It was very amusing to watch the workers of this species feeding their larvæ with eggs. The nurse holds the egg in her jaws and squeezes it into the mouth of the helpless baby, who shows great eagerness to be fed. After the larva has got what it can, the nurse cleans out the shell, and regurgitates the remnant into the larva's mouth. Frequently the nurse sticks an egg on to the back of the larva's neck by saliva, so as to have it ready for the next feeding time.

[8] N. B.—No ant of the Subfamily Camponitinæ, to which the genus Myrmecocystus belongs, possesses any sting. They have a large poison bag, the contents of which are used to spray their enemies and their prey.

Although these ants have no stings, they can spray some poisonous fluid into the wounds made by their mandibles, from a gland situated in the tip of the gaster. Two caterpillars, an inch and a half long and a quarter of an inch in diameter, succumbed to the spray in a few minutes, and were dragged down into the nest for food. It is quite common to find dead insects, termites, flies, etc., lying among the larvæ, and in wild nests and among captive communities it is usual for two or three repletes to hang from the ceilings of the nursery chambers. Sometimes the larger larvæ remain for a long time with their heads thrust into the thoraces of dead flies, devouring the muscular tissues.

The high development of ants is shown by the long period of helpless infancy and absolute dependence upon the care of the nursing workers. Although they lie upon the bare earth of their caves, they are protected from actual contact with the soil by stiff bristles which are set in their soft skin, and which allow of a free circulation of air all round them. Living as they do in damp subterranean caverns, they are peculiarly liable to be attacked by various molds, and it is for this reason that the nurses are indefatigable in licking their charges to remove the spores from which these vegetable parasites take their rise. Larvæ isolated from the attentions of the workers very quickly succumb to these exhausting growths. It is probably due to the need of a certain amount of ventilation that the larvæ are usually found in the upper chambers, thus presenting a parallel with the case of the short-tailed field vole (Microtus agretis) of England. The ordinary retreat of these rodents is a burrow situated far below the surface; but their young are reared in a nest of split grass, built upon the very surface of the ground. They are exposed to innumerable dangers, of course; but a litter of six or eight young mice would probably be suffocated if confined in a deeply situated nursery.

As showing the preference of these ants for moist surroundings, I may mention that for some months I kept a colony upon a porous earthenware saucer inverted in a basin of water and completely covered by a mound of clay and sand. When I eventually broke up the formicary, I found that the chambers and galleries had all been hollowed out in the soil immediately above the damp earthenware surface, the saucer itself forming the floor. The higher and drier portion of the mound had not been inhabited at all.

PRENOLEPIS IMPARIS

is found here in great abundance, and is common from the Atlantic to the Pacific. We will content ourselves, therefore, with merely recording its occurrence. It ascends the blue gum (Eucalyptus globulus), and may be found by the dozen resting half hidden among the fragrant anthers.

MYRMECOCYSTUS MELLIGER FOREL.

The typical form has not yet been found here, but a variety which appears to be intermediate between varieties testaceus and semirufus has been identified by Professor Wheeler.

MYRMECOCYSTUS MELLIGER LOMAENSIS.

Another variety or sub-species has been found here, only previously reported from Riverside and Whittier by Mr. Quayle.

This ant is strictly diurnal in its habits, and has been seen feeding upon the white flowers of Mesembryanthemum æquilaterale.

In an artificial nest these ants were fed with a drop of bee's honey in a leaf. Instead of greedily lapping it up, as the first two species here treated of would have done, they became violently agitated. They flung themselves upon the honey and sprayed it with their poison, snapping at it furiously with their mandibles, and it was some time before they realized that it was good for food. Is it possible that, being diurnal in their habits, they have a perennial feud with honey bees when they compete with them for the contents of the nectaries of flowers, and that the smell of the honey forcibly suggested bees to their minds, and provoked the customary hostilities? Whereas the honey bees require a hollow tree and household furniture in the shape of waxen cells for rearing brood or storing honey, the ants can carry on their lives with nothing more than food and a few cubic feet of soil. They use no implements, utensils, nor bedding, and the sole garment they require is the swaddling gown of woven silk that wraps them in the pupal state. Ants have no personal ambition. The only end they have in view is to cover the earth with colonies of their own particular species, and, urged by this remote, impersonal desire, they spend their lives in ceaseless toil. The instinct which impels the ants' unselfish labor is probably as irresistible as that which forces human beings to pursue their personal advantage. The personality of ants appears to be dissolved, and every individual seems to act as if it was the agent for that nameless,

universal will that urges on the slow advance of cosmic evolution. Without compulsion or direction their social life is carried on in perfect harmony. Each ant is a law to herself; but as the aim of all is identical, a spirit of perfect harmony prevails. The ants have shown the possibility of a perfect communal life, and have proved that individuals can be incited to the maximum of effort with the minimum of personal advantage, and that the little states, based on unselfish sisterhood, are supremely fitted to survive in the struggle for existence.[9]

Why Flat Surfaces Adhere

By H. T. Wright., A.R.C.Sc.(Lond) A.M.I.Mech.E.

GAGES having such surfaces—optical surfaces really—are much used in the best class machine work at the present day, and especially for the testing of limit gages. The Newall end measuring blocks are guaranteed to be lapped parallel with errors not exceeding 0.0001 inch. Gages which are even better suited for experimental work on adhesion are being manufactured in large quantities by Johansson, of Eskilstuna, Sweden, although the manufacturing methods are not generally known.

These gages are guaranteed true to 0.00001 inch, and are made in sets, the individual gages varying from 0.1001 inch to 0.1009 inch by 0.0001 inch; 0.101 inch to 0.149 inch by 0.001 inch; 0.05 inch to 1.0 inch by 0.05 inch; and from 1 inch to 4 inches by 1 inch. These gages will wring under suitable conditions, and a number of gages so arranged will give a length so nearly equal to the nominal length that the error cannot be detected in an ordinary measuring machine. The results of experiments on specially made gages and on those referred to above prove that the adherence is due principally to the surface tension of the liquid film between the faces.

For instance, if gages heated in an oven are allowed to cool in an enclosure free from water vapor, they will not adhere, but will fall apart under their own weight. Also, if gages are wrung together under normal conditions and are then placed in a vacuum, the force necessary to separate them is less than the theoretical amount, due to atmospheric pressure.*

This may be due to the fact that some air finds its way in between the more separated parts of the surfaces. The force due to atmospheric pressure also increases with a thicker film, and this may be due to the fact that there is less distortion of the blocks in the process of wringing, and that the air is more impeded.

By assuming a continuous film it follows that:

$$d = 2. \frac{a.t}{P}$$

where d = distance between the faces,
a = Area of face,
t = Surface tension of liquid,
and P = Force of attraction between the faces.

If we use a liquid with a known surface tension, and the experimental value of P, we can calculate d. Experiments on paraffin have given a calculated value of d which approximates to 1/200000th inch. From this we see that gages having four sets of faces wrung together would have an aggregate length which would exceed the nominal length by 1/50000th inch, an amount which could be easily detected and measured. As no such variation in length can be determined, it follows that the calculated value of d is far too large. The true explanation is probably to be found in the value of a used in the formula. It is doubtful whether the liquid film covers the surfaces—and the opinion now generally held is that the film covers part of the surface in concentric rings, starting at the points of nearest approach. Thus any reduction in a would give a corresponding reduction in d. Reference has been made to the fact that gages left wrung together for a considerable period require to be struck smartly to bring about separation. This is due to slight corrosion, which may lead to rusting of the surfaces. Incidentally this proves the existence of a liquid film between the surfaces. The results obtained by various experimenters may be stated briefly as follows:

1. Volatile liquids give no adhesion.
2. Viscous liquids produce very little effect.
3. Condensed water vapor gives better results than light oils, and light oils give better results than heavy oils.
4. Approximately, from 70 per cent to 80 per cent of the adhesion is due to surface tension, and the remainder to atmospheric pressure.
5. The force due to atmospheric pressure is greater with heavy oils than with light oils.
6. With well cleaned surfaces—free from film—no adhesion can be obtained.
7. Molecular attraction is negligible.—*English Mechanic.*

[9]This paper would be incomplete without an expression of grateful acknowledgment to Professor William Morton Wheeler for his kindness in identifying the various species of ants to which reference has been made. Without this help in naming specimens, and the assistance derived from this correspondence, the production of the paper would have been indefinitely delayed. It may be of interest to note that I have in my possession specimens of replete Honey Ants collected at Coronado, San Diego, in 1890, by Dr. F. E. Blaisdell, formerly a member of the San Diego Society of Natural History. They evidently belong to the species Myrmecocystus Mexicanus, but whether to the pure type, or to one of the sub-species or varieties, it is impossible to determine, owing to their defective state of preservation.

*Results of experiments are given by H. M. Budgett, B.A. *Proceedings Royal Society.*

Correspondence

[*The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.*]

An Unusual Experience With Ignes Fatui

TO THE EDITOR:

The ignis fatuus, or will-o'-the-wisp as it is often popularly called, is a well-known phenomenon supposedly due to the spontaneous combustion of gas arising from decaying vegetable or animal matter. For this reason it appears most commonly over marshy places. It appears as a faint, colorless flame flitting about in the air slightly above the surface of the ground. The rarity of the phenomenon and the usually lonely setting have caused it to be looked upon with superstitious awe. Its origin is plausible enough, but inasmuch as the writer has met with no persons who have witnessed such an extensive display of this phenomenon as he was fortunate enough to encounter, it appears of interest to describe this experience briefly.

During one winter the writer was tramping about in southern Nevada on a prospecting expedition and met with this experience late in January. The region is devoid of vegetation except for scanty bushes of sagebrush, greasewood and a few grotesque cacti. About ten days preceding this night a snow had fallen high in the mountains, accompanied by rain on the lower desert areas or "dry lakes," as the regions between the mountain ranges are called. This water settled in spots on the flat desert areas and varied in depth from one to several inches where the ignes fatui were encountered. The writer obtained the information at a distant mining camp that this was the first time water had stood in that desert for years. On this night the writer was tramping from Goodsprings, Nevada, to Ivanpah, California, and at 2 A. M. encountered a water-covered area. The flitting lights did not begin to appear until after some progress had been made through the water. The night was very dark and suddenly one of these lights appeared to float in the air about five feet above the ground. However, owing to no knowledge regarding its size, it could readily be imagined to be the light from a cabin window at some distance but for the fact that there was no habitation within twenty miles of the spot. Suddenly this light ceased to float complacently and sailed swiftly away to the left for some distance, then stopped. It was easy to imagine that it was waiting and coaxing—living true to its name in attempting to lure benighted travelers to destruction." Soon others appeared, some floating apparently stationary, others shooting here and there. Little wonder that the peasantry of ancient times viewed this phenomenon with superstitious awe!

When the display was at its height hundreds of individual lights were visible simultaneously. The display was continuous during the hour or more that the water-covered area was being traversed. It possibly continued for days. At first it appeared to be very chaotic, but after observing it for a time, during which the writer continued walking, the individual lights seemed to progress rather jerkily or spasmodically in the same general direction. This led to a theory formulated at that time which may or may not be tenable.

The desert air was very quiet, as was often the case at night, as indicated by the slow drift of smoke from the campfire. It is easy to imagine that a great number of minute generators of gas in such a case as this, which appeared to be extraordinarily favorable for such a display of ignes fatui. A thread of gas might arise from each of these generators and slowly drift away in a crooked path as determined by the slow drift of air currents. How this gas ignites will not be considered, but the grotesque antics of the individual lights can be readily explained in this manner. An individual light appeared to float stationary when the direction of the thread of gas was directly away from the observer. When the direction of the thread was at any other angle it was easy to account for the varying speeds with which the light apparently traveled. Thus by imagining an irregular path the grotesque antics of individual lights can be accounted for. The lights were quite faint and of no definite shape except that they appeared as spots of finite sizes, so that it was impossible to gage their distances.

The writer has never read of such a multitude of ignes fatui having been witnessed at one time, and oddly enough has never encountered a person who has seen even a single one. This would indicate that the phenomenon is rare and that this experience was quite unusual. Although the writer recognized the phenomenon as the ignis features, it is needless to state that the lonely setting, the vocal accompaniment of coyotes, and the knowledge that the nearest human beings were twenty miles away, aroused emotions which contributed much to the experience which can be readily imagined.

M. LUCKIESH.

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Table of Contents