SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

FRIDAY, NOVEMBER 18, 1904.

CONTENTS:

MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

THE SPHERE OF BACTERIOLOGY.*

IT is possibly a contemporary delusion that we are living in a period of unexampled mental activity. The life of the intrepid modern scholar affords opportunity for self-deception. If one becomes a member of a sufficient number of learned and quasi-learned societies, and attends committee meetings for an adequate variety of purposes, the impression of profitable intellectual endeavor may be prematurely acquired. There is much, however, to account for the prevailing sensation of breathless advance. The physiological and psychological accompaniments of a breakneck pace are not altogether lacking in the modern world, and there are bacteriologists in particular who will lend a credent ear to affirmations of the rapidity of scientific progress. However this may be, few can question that the development of the science of bacteriology has been marked by an unusual tempo. To those who have followed this development closely, discovery has trod upon the heels of discovery in bewildering succession. The scant thirty

* Read before the Section of Bacteriology, International Congress of Arts and Science, Universal Exposition, St. Louis.

years of its history have been crowded with feverish activities which have found their best justification in the results accomplished. At present the science touches nearly many human interests and sustains manifold and far-reaching relations to the whole body of natural knowledge. It is no matter for surprise that such should be the case with a science that owes its birth to a chemist, that concerns itself with microscopic organisms belonging both to the plant and animal kingdoms, and that extends its ramifying branches into the regions of medicine, hygiene and the industrial arts.

In several respects the history of bacteriology might be held to epitomize that of the other natural sciences or of the living organism itself. Advance in complexity of structure entails greater complexity of relations and adjustment; maturity has more extensive connotations than youth. Bacteriology is a relatively youthful branch of the stream of knowledge, but in late years it has perceptibly widened its banks. It has even encroached upon certain neighboring sciences. Modern physiography uses the term *piracy* to designate the capture by one stream of that portion of a watershed legitimately belonging to another stream. In the same way, one natural science, owing to peculiarities in its subject matter, in its evolutionary history or in the tools with which it works, may enter upon a piratical career and appropriate territory which for various reasons has remained unexploited by the science to which topographically it may seem to belong. This annexation of neighboring fields has been not uncommon among the natural sciences, and bacteriology has not shown itself free from the general tendency. A notorious instance of piratical conduct on the part of bacteriology is the virtual appropriation of the whole field of microbiology. Perhaps most familiar in this connection are the discoveries concerning the life histories of various microscopic animal parasites. The tracing out of the relations between parasites and hosts in Texas fever, malaria and dysentery has by no means been exclusively or even largely the work of zoologists. On the contrary, it is well known that much of the most important work in this direction has been carried out by bacteriologists and that the literature on these topics is chiefly to be found in the technical bacteriological journals. A recent instance of this tendency is the renewed study of the remarkable protozoa called trypanosomes, which has in large part been undertaken by bacteriologists and by bacteriological methods. Perhaps the most notable triumph yet accomplished in this field is the successful cultivation of these pathogenic protozoa outside of the animal body, a feat which has been achieved by one of the foremost of American bacteriologists. The exploitation of zoological territory by bacteriological workers is one of the many instances of successful borderland invasion and, like the Louisiana Purchase, illustrates the impotence of territorial lines to prevent natural expansion. Many reciprocal piratic inroads among the sciences are due to the acquisition by one science of new tools which, when workers become generally acquainted with their use, are found to be applicable to other problems in other fields. Bacteriological technique is one of these efficient tools the possession of which conduces to piracy; it can, however, never be forgotten that bacteriology itself owes its powerful equipment to a study of spontaneous generation which was undertaken primarily for the interest felt in its philosophical bearings.

Bacteriology stands in close relation to at least four other more or less defined fields of natural knowledge: to medicine, to hygiene, to various agricultural and industrial operations and pursuits and to biology

proper. Bacteriology, as has been often said, is the youngest of the biological sciences and perhaps for this reason has as yet contributed relatively little to the enrichment of the parent science. Morphologically the bacterial cell is so small and so simple as to offer many problems of surpassing interest but of great difficulty. The question as to whether a bacterium is a cell without a nucleus or a free nucleus without any cytoplasm or a cell constituted in the main like those of the higher forms of life has, to be sure, been practically settled in favor of the latter view. But there are other debated and debatable morphological questions to which up to the present no satisfactory answer has been given and to which our current microchemical methods are perhaps unlikely to afford any solution. On the physiological side, the achievements of bacteriology in behalf of general biology have as yet been far from commensurate with its potentiality. This may be partly because of its temporary engrossment in other seductive lines of research, partly because of the lack of workers adequately trained in bacteriological methods and at the same time possessed of an appreciation of purely biological data. It may be justly urged that a rich harvest of fundamental physiological facts waits here for the competent investigator.

There is no need to dwell in detail upon the manifold practical applications of bacteriology to the arts and industries. Particularly in agriculture and kindred occupations have the advances in bacteriology been immediately and intelligently utilized to bring forth in turn new facts and unveil new problems. The processes of cream-ripening and vinegar-making, the phenomena of nitrification, of denitrification and nitrogen-fixation, the modes of causation of certain diseases of domestic plants and animals, have all been elucidated in large measure by bacteriological workers. A new division of technological science, dealing with the bacteriology of the soil, of the dairy and of the barnyard, of the tan-pit and the canning factory, has already assumed economic and scientific importance.

It is often a temptation to distinguish radically between pure science and applied science and to look upon the latter as unworthy the attention of the philosophically minded. True science can admit of no such distinction. No thing in nature is alien to her. She can never forget that some of the most fruitful of scientific theories have been the outcome of the search for the utilitarian. Man's knowledge of the universe may be furthered in various ways. It is well known that the work of Pasteur was particularly characterized by applications to the problems of pure science of knowledge acquired in the study of the practical. One thing plays into the hands of another in wholly unexpected fashion. An attempt to improve the quality of beer gives birth to the germ theory of fermentation, and this in turn to the germ theory of disease; the chemistry of carbon compounds leads to the discovery of the aniline dyes, and these same aniline dyes have made possible the development of microchemical technique and thrown open spacious avenues for experiment and speculation; the attempt to obtain a standard for diphtheria antitoxin has resulted not only in the achievement of the immediate practical end, but in the discovery of unexpected theoretical considerations which have dominated the progress of an important branch of scientific medicine during the last five years. It will not be a hopeful sign for the advancement of science when the worker in pure science ceases to concern himself with the problems or avail himself of the facilities afforded by the more imminently utilitarian aspects of natural knowledge.

In the quarter century of its history

bacteriology has sustained close and mutually advantageous relations with the science of medicine. This has been the scene at once of its greatest endeavors and of its greatest triumphs. To recount these would be superfluous. There is hardly an hypothesis in scientific medicine that has not been freshened and modified, hardly a procedure in practice that has not been influenced by bacteriological conceptions. The experimental method in particular has been given new support and received brilliant justification. Experimental pathology and experimental pharmacology practically owe their existence to the methods and example of bacteriology. The security afforded by aseptic surgery has made possible physiological exploits that could not otherwise have been dreamed of, a pregnant illustration of the way in which applied science may directly further the advance of pure science. Conspicuous as these achievements of bacteriology have been, it can not be truly said that the field is exhausted. There is hardly an infectious disease of known or unknown origin that does not still harbor many obscurities. Some of the most difficult problems that medicine has to face are connected with the variation and adaptation of pathogenic bacteria. The phenomena of immunity, certainly among the most complicated and important that human ingenuity has ever set itself to unravel, still await their full description and interpretation. The study of the ultra-microscopic, or perhaps more correctly the filterable viruses, is being prosecuted with great energy and in a sanguine spirit. The extension of bacteriological method into the field of protozoon pathology has been already referred to and constitutes one of the latest and most hopeful developments in the study of the infectious diseases. Medicine, perhaps more than any other department of human knowledge, is most indebted to, and maintains the most intimate relations with, the science of bacteriology.

At the present time the relations of bacteriology to public hygiene and preventive medicine seem to me of particular importance, and it is upon this theme that I wish chiefly to dwell. Personal hygiene is not necessarily pertinent to this topic, but falls rather into the same province with the healing art. Matters of diet, of clothing, of exercise, of mental attitude affect the individual and contribute more or less largely to his welfare. But except in so far as the individual is always of moment to the community, they do not affect the larger problems of public hygiene. The pathological changes that take place in the tissues of the diseased organism and the methods that must be employed to combat the inroads of disease in the body of the individual patient must for a long time to come remain questions of supreme importance to the human race. But over and above the treatment and cure of the diseased individual, and the investigation of the processes that interfere with the proper physiological activities of the individual organism, rises the larger and more far-reaching question of the prevention of disease.

Racial and community hygiene are but just beginning to be recognized as fields for definite endeavor. The project may seem vast, but the end in view is undoubtedly the promised land. More and more will the problems of curing an individual patient of a specific malady become subordinated to the problem of protection. More and more will scientific medicine occupy itself with measures directed to the avoidance of disease rather than to its eradication.

Whatever else may be said of it, this is certainly the age of deliberate scrutiny of origins and destiny. Man no longer closes his eyes to the possibilities of future evolu-

tion or to those of racial amelioration. If we are to remain to a large extent under the sway of our environment, we can at least alter that environment advantageously at many points. We are no longer content to let things as we see them remain as they are. On the surface the wider relations of disease have often seemed of little significance as, before Darwin, the so-called fortuitous variations in plants and animals were considered as simple annoyances to the classifier; the causes of this variation were deemed hardly worth investigation. The rise and fall of plagues and pestilences have been readily attributed to the caprices of the *genius epidemicus*, and it has sometimes been thought idle to ascribe recurrent waves of infection to anything but 'the natural order.' Another phase, entered upon later and from which we have not yet entirely emerged, possesses its own peculiar perils. In meditating on the cosmos the agile mind is always tempted to fill in the gaps of knowledge with closely knit reasonings or fantastic imagery. The imaginative man of science still frequently finds himself beset with the temptation to erect an unverifiable hypothesis into a dogma and defend it against all comers. It is now fortunately a truism that a more humdrum and plodding course has proved of greater efficacy in advancing natural knowledge. Theories that stimulate to renewed observation and experiment have been of the greatest service, but unverifiable speculations have often been a barrier to further advancement. Metaphysics tempered with polemic is not science, whatever be its allurements.

If the attainment of a rational position in public hygiene, community hygiene or preventive medicine must then be regarded as the main objective point in the campaign against disease, it follows that the part played by bacteriology in this advance will be an important one. The relations of bacteriology to public hygiene are fundamental. The etiology of many of the most widespread and common diseases that afflict mankind is intelligible only through the medium of bacteriological data. The modes of ingress of the invading microorganisms, the manner of persistence of the microorganism in nature, the original source of the infectious material and all the varied possibilities of transmission and infection can be apprehended only through the prosecution of detailed bacteriological studies. It is only by this means that the weak point in the chain of causation can be detected and the integrity of the vicious circle attacked. Success will inevitably depend upon a thorough understanding of the circumstances governing and accompanying the initiation and consummation of the disease process. Yellow fever can not be suppressed by burning sulphur or by enforcing a shot-gun quarantine, the bubonic plague is not to be combated by denying its existence.

In the warfare against the infectious diseases a rational public hygiene is ready to avoid the mistake of beating the air. A preliminary survey of the possibilities reveals several distinct types of disease; those that are practically extinct or far on the road to extinction in civilized communities, those that remain stationary, or decline but slightly, and those that show a more or less consistent increase. The economy of energy would suggest that it is not a far-sighted policy for public hygiene to focus its endeavors exclusively upon those diseases that are yielding naturally before the march of civilization. The conditions under which civilized peoples live to-day are in themselves sufficient to render the foothold of many infectious diseases most precarious. What nation now fears that typhus fever will become a national scourge, or who looks to see the citizens of London driven into the fields by the Black

Death? It is of course true that the continuance of this immunity can be secured only by unremitting watchfulness, although so long as existing conditions of civilized life are maintained the recurrence of great epidemics will be relatively remote. The pestilences that once stalked boldly through the land slaying their ten thousands are now become as midnight prowlers seeking to slip in at some unguarded door within which lie the young and the ignorant. Already some once dreaded maladies have become so rare as to rank as medical curiosities, and their ultimate annihilation seems assured.

There are other diseases, however, that civilized life, or, at least, modern life, appears to leave substantially unchecked, and some that it even fosters. These may be considered as shining marks for the modern hygienist. The scale between hygienic gain and loss is always in unstable equilibrium. There is no such thing as consistent improvement all along the line. As Amiel wrote in his journal, 'in 1,000 things we advance, in 999 we fall behind; this is progress.' It is almost a biological axiom that progress in one particular entails loss in others. To maintain the efficiency of all parts of the complex of civilization calls for eternal vigilance. It may be that while we are waxing complacent over the fact that the opportunities for infection with certain parasites are diminishing and that other parasites are gradually losing what we vaguely denominate as their virulence, unforeseen and greater evils are raising their heads. The increasing exemption from certain diseases will itself lead to an increased prevalence of others as diversely vulnerable age-groups are formed. In general it will occur that the diseases peculiar to the advanced age-groups will increase as the diseases of childhood and youth succumb to hygienic measures. A different age-distribution of the population will bring in its train new problems of preventive medicine, which must be successfully solved if the issue is to be fairly met.

There are not lacking instances of a dawning consciousness on the part of mankind that the proper development of public hygiene involves a far more comprehensive view of its relations than has hitherto been taken. The study of tuberculosis is being approached by methods of unexampled broadness. We are just beginning to recognize the way in which the roots of this destructive malady are well-nigh inextricably interwoven with the whole social fabric. Bacteriological, architectural and economical data are all levied upon for contribution to our knowledge of what is universally recognized as one of the most important of all human diseases. Here, as elsewhere, the care and cure of the infected individual still looms large, but beyond and above this is beginning to be placed the prevention of infection, the drying up of the stream at its source. That for this heavy task public hygiene will require the aid of many workers in many different fields is abundantly evident. For all of them, however, bacteriology must furnish the only definite point of view. In the full consideration of the 'exciting causes' the tubercle bacillus can never be allowed to drop into the background. Given foul air, insufficient food, inhalation of dust, excessive and exhausting labor and the other deplorable accompaniments of modern industrialism, and it still must be constantly kept in mind that without the tubercle bacillus these predisposing causes would never result in a single case of tuberculosis. On the other hand, without these contributing factors, the tubercle bacillus would almost sink to the level of the negligible 'non-pathogenic organism.' Witness the impotence of the bacillus to produce infection or even maintain itself

in the tissues of those individuals able to live an outdoor life.

It is evident that in the case of tuberculosis the forces of civilization are on the whole working for its extinction rather than for its perpetuation. The available statistics demonstrate that before the modern movement for the suppression of the disease began, and, in fact, even before the discovery of the tubercle bacillus, consumption was already on the decline in widely separated parts of the world—in London, in Boston and in Chicago. It is, perhaps, significant that consumption is now one of the tenement house problems and that as such it occupies a strictly delimited field. As yet the campaign against tuberculosis has been a desultory one, waged by a few enthusiasts without adequate material or moral support on the part of the community at large, but signs are multiplying that this condition will be a transient phase. The comparative absence of intelligent, systematic endeavor for the suppression of disease is certainly a curious phenomenon in an age of otherwise extensive coordination and organized action. The executive talents and restless energy lavished on commercial, industrial and engineering projects may some day be turned to devising and carrying out hygienic measures. If it were necessary to find an argument in the economic value of human life it would be readily forthcoming. The recent movements for the study and suppression of tuberculosis mark one of the first attempts to apply bacteriological knowledge in a determined and radical way to a problem of public hygiene. As regards the ultimate extinction of tuberculosis, there may be more or less groping after ways and means, but there need be no misconception as to the scope of the problem.

There are other fields where a similar mode of procedure based on ascertained bacteriological facts and principles has been indicated and is being at least in part carried out. In typhoid fever the evidence from epidemiology has long pointed unmistakably to drinking water as being the chief vehicle of infection, and the first step towards suppression of this disease has been already taken in most civilized countries. The last half of the nineteenth century witnessed an improvement in the sanitary quality of public water-supplies which has diminished perceptibly the death rate from typhoid fever. This change has been in part effected by the introduction of water from unpolluted sources, in part by the installation of sand filters. To cite a few well-known cases. For five years before the introduction of a filtered water the annual typhoid fever death rate in Zurich, Switzerland, averaged 76; in the five years following the change it averaged 10. In Hamburg, Germany, for a corresponding period before filtration, the typhoid death rate was 47; after the change it fell to 7. In Lawrence, Massachusetts, under similar conditions the typhoid rate was reduced from 121 to 26, and in Albany, N. Y., from 104 to 38. A similar effect has been noticed where an impure water has been replaced by water from unpolluted sources. In Vienna, Austria, the abandonment of the River Danube as a source of supply in favor of a ground water diminished the typhoid fever death rate from over 100 to about 6. In the United States, the city of Lowell not long ago exchanged the polluted water of the Merrimac River for a ground water supply, with the result that the typhoid fever death rate was reduced from 97 to 21. In spite of the remarkable facts there has been a lethargic slowness in profiting by the lessons that they teach. Many communities have remained to this day unobservant and negligent, and, especially in the United States, the condition of the average public water supply

demands radical reform. A method that has not only reduced the deaths from typhoid fever by about 75 per cent., but has also reduced the number of cases proportionately, is worthy of universal adoption. If the fatality in all cases of typhoid fever was diminished, say, from 12 per 100 cases to 3, by the use of a new drug or an antitoxin the world would ring with the discovery. The introduction of a pure water supply has achieved an analogous reduction in the death rate and confers further the enormous benefit of preventing the occurrence of a similar proportion of cases. In the city of Albany, N. Y., the annual number of deaths from typhoid fever prior to the installation of a filter plant averaged 89 during a ten-year period; in 1902 there were but 18 deaths from this cause, representing a diminution not only of 71 deaths, but of over 700 cases.

Important as is the function of a pure water supply in preventing typhoid fever, it is now clear that public hygiene can not stop here. In some countries, as in Germany, for example, where the larger cities and towns are supplied in the main with water of a highly satisfactory character, there still remains a notable residue of cases of typhoid fever. These we know are due to contact infection, to contamination of raw foods, such as milk, oysters and the like, to the conveyance of the specific germ on the bodies of flies and to similar modes of dissemination. It is a fact full of significance that the existence of these various modes of spread is recognized, that they are held to be matters of public concern and that preventive measures are being instituted under expert bacteriological control for suppressing the existing sources of infection. One of the most difficult problems in this campaign lies in the prompt recognition and rigorous supervision of the mild and obscure cases. It may be comparatively simple to isolate and disinfect with thoroughness in the franker types of the disease, but it is not clear that the danger is most critical on this side. The application of searching and delicate bacteriological tests is often necessary to determine the suitable mode of action. The dependence of public hygiene upon bacteriological data and methods has rarely been better exemplified.

The vigorous warfare that is being waged against malaria in many tropical countries affords a further and striking illustration of the utilization of existing resources for the avoidance of specific infection. It is hardly necessary to reiterate the obvious truth that malaria constitutes the chief and, perhaps, the only serious obstacle to the colonization of the tropics by the white races. Political and economic questions of the gravest import to mankind are bound up with the fortunes of a protozoon and a mosquito. The complex life-cycle of the malarial parasite offers an unusual number of points of attack. As is well known, several distinct views are current as to the best way of interrupting the continuity of transfer between man and the mosquito. It is conceivable that by the destruction of the malarial parasite within the body of man the supply of parasites for the mosquito may be cut off and the circle broken at this point. If the mosquitoes are prevented from becoming infected, man is safe. It is claimed by the adherents of one school that this method has proved very effective in certain localities where it has been systematically employed. The extermination of the parasite in the blood of man by the administration of quinine certainly constitutes an important weapon in the armory of public hygiene, whether or not it prove to be the most efficient one or the most economical in execution. In this same category are to be put the attempts to prevent the infection of the mosquito by guarding malarial patients

against the bite of *Anopheles*. It is obvious that this plan may often be difficult of execution because of the impossibility of exercising efficient control over the movements of individuals suffering from latent or recurrent infection.

A second possibility consists in the general protection against mosquito bite of all persons dwelling in infected regions. The pestiferous insect may beat its wings in vain against the windows of a mosquito-proof dwelling; if it can not come near enough to the human being to inject the contents of its poisoned salivary gland, no single case of malaria will result. In parts of Italy, it is said, this mode of prevention has been practised with brilliant success in protecting railway employees, forced by the exigencies of their calling, to reside in highly malarious localities.

A third point of attack is presented in the possibility of destroying or at least arresting the propagation of the insect host of the malarial parasite. The extermination of a number of species belonging to a widely distributed and abundant insect genus may seem in itself a gigantic task to undertake. Remembering the ambiguous success that has attended the efforts of the human race to combat the ravages of certain insects injurious to agriculture, it is not easy to be sanguine concerning the speedy extinction of *Anopheles*. It is noteworthy that the most considerable triumphs attained along economic lines have been effected by the utilization of the natural enemies of the noxious forms. Efficient foes of *Anopheles* have so far not been discovered. There is no question, however, that in definite localities the number of individual mosquitoes belonging to malaria-bearing species may be enormously diminished by the destruction of the breeding-pools. The labors in this direction of English health officials in various parts of the world have been rewarded by a decisive decrease in the prevalence of malaria.

It will not escape remark that the effect of any one or of all of these protective measures is cumulative. A diminution in the number of mosquitoes, or in the number of persons harboring the malarial protozoon in their blood, or in the number of infected or non-infected individuals bitten by mosquitoes, will inevitably produce a lessening in the amount of malaria in a given region. This will in turn diminish the opportunities for mosquitoes to become infected and will at least put a check upon indefinite extension of the disease. It is significant that a high degree of success apparently attends the enthusiastic and persistent application of any one of the measures above instanced.

While malaria, typhoid fever and tuberculosis are to-day fairly in the field of view of public hygiene, such is not the case with a host of other maladies. A beginning is made here and there, but the vast majority of the diseases that affect mankind still lack an intelligent and organized opposition. This is partly because of insufficient knowledge. At the present time the apparent increase in pneumonia presents an imperative field for research. It seems unlikely that the available modes of attacking this disease are to be exhausted with attempts to improve individual prophylaxis. A clear understanding of the tangled web of statistical, climatic, racial, bacteriological and hygienic questions that environ this urgent problem of public hygiene is likely to come only through renewed investigation of the phenomena. If it is true, as some conjecture on what seems insufficient evidence, that the virulence of the pneumococcus is increasing, what is the bacteriological strategy suited to the emergency? Or if it turn out that an increase in the number of victims to pneumonia is largely made up of those who

have escaped an early death from tuberculosis, what procedure is indicated?

We can not always take refuge from the consequences of inaction under the plea of ignorance. There are few, if any, instances where public hygiene is utilizing to the full the knowledge that it might possess. Some responsibility rests upon those who are prosecuting bacteriological studies to see that the bearings of their investigations are not overlooked or neglected by those who are constituted the guardians of the public health. There is here no question of the sordid self-interest or commercial exploitation sometimes miscalled 'practical application.' In the long run the saving of life may play into the hands of the idealist. If John Keats had not died of consumption at the age of twenty-five the modern world would be a different place for many persons. It is not possible to estimate the loss to literature, science and art since the dawn of intellectual life which must be laid at the door of the infectious diseases. The relations of bacteriology to public hygiene, if properly appreciated and cultivated, will lead to an improvement in the conditions of life which will enhance both the ideal and material welfare of the race and will give greater assurance that each man shall complete his span of life and be able to do the work that is in him.

Edwin Oakes Jordan.
University of Chicago.

Evolution of Weevil-Resistance in Cotton.

The complexity of biological problems finds another excellent illustration in the evolutionary history of the relations between the cotton plant and the so-called Mexican boll-weevil. The present indications are that both the cotton and the weevil originated in Central America. The parasitism of the beetle is certainly very ancient, if, as seems to be the case, it has no other breeding-place than the young buds and fruits of the cotton plant. Of the severity of the parasitism there is ample evidence in Texas, the weevils being able to totally destroy the crop when the climatic conditions admit of their normal increase.

It was to have been expected, therefore, that in humid tropical localities where all seasons of the year are alike favorable the cotton would have been exterminated long since, or at least that its cultivation as a field crop would be utterly impracticable unless there were means of protection against the ravages of the insect. A definite intimation of the existence of protective adaptations was incidentally gained in eastern Guatemala in 1902 when no weevils were found in a field of the dwarf cotton cultivated by the Indians, although they were extremely abundant on a perennial 'tree' cotton a short distance away. The opportunity of making a detailed study of the subject during the second quarter of the present year has revealed an interesting series of protective adaptations resulting from the long evolutionary struggle for existence between the cotton and the weevil.

Reference has been made in another place* to the extensive system of extra-floral nectaries by which the cotton of eastern Guatemala has secured the active cooperation of the kelep or weevil-eating ant, but the Central American cottons and the Indians who have been cultivating them for thousands of years have developed many other expedients of structure, habits and culture which are of more or less assistance in resisting or avoiding the weevil.

The large leafy involucre of the cotton may have been at first a protective adaptation, though the weevils later learned to enter it easily. In some of the Guatemalan sorts the bracts are grown together at the base as though the evolution of a closed

* Report No. 78, U. S. Dept. Agric., p. 4, 1904.