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*PLANT PATHOLOGY: A RETROSPECT AND PROSPECT.**

THE study of plant diseases has made remarkable progress within the last two decades. This is commented upon at home and abroad. Perhaps in no field outside of organic chemistry or of animal pathology and bacteriology have the advances been greater. In casting about for a subject, it has seemed to the speaker therefore that perhaps he could not do better in the time allotted to the presidential address than to consider, first, the state of plant pathology prior to the year 1880; second, the progress which has been made from that time to the present; and, third, some of the problems which now confront the investigator. Nothing beyond a popular sketch is contemplated.

The twenty years preceding 1880 were years of stress and uncertainty in the biological world. Pasteur and Cohn had laid the foundations of modern bacteriology and the whole world was agog with interest over the new doctrines of fermentation and of disease. Sachs and de Bary had done equally magnificent work in plant morphology and physiology. But the great masters were not having everything their own way. Hallier and Billroth in Germany were upholding a crazy doctrine of

* Presidential address before the Society for Plant Morphology and Physiology, Fifth Annual Meeting, New York, January 1, 1902.

the polymorphism of species whereby an organism could change into, practically, whatever happened to grow in its vicinity; while Pouchet in France and Bastian in England were maintaining the spontaneous generation of minute organisms in sterile liquids with great vigor and a considerable following, if not with much logic. Everywhere the old, well-intrenched theories of disease were in conflict with the new. During the whole of this period the doctrines of Darwin were opposed and fought over with a pertinacity and a rancor scarcely to be appreciated by the younger men of this generation. Evolution has now become our watchword, but even yet we do not fully appreciate what it means, or at least we often speak and write as if we did not. It is too large a thought, and we are still entangled in the language of our ancestors. Especially do we not fully appreciate the molding influence of environment, *i. e.*, the plastic nature of the living organism under the action of changed conditions.

Prior to the year 1880, laboratory methods for the study of fungi and bacteria were not well developed. In the first place, there was no exact and convenient method for obtaining pure cultures and, in the second place, the microscope was still the principal instrument of research. The few experiment stations in this country and those in Europe were, for the most part, plodding along in a perfunctory way, without good equipments and with little money for botanical inquiry, and the study of plant diseases was scarcely thought of outside of a few university laboratories, and rarely in these with anything practical in mind for the benefit of agriculture. The main thing considered was the parasite rather than the host plant, and the technique for the study of both was of the simplest sort. We had no precise fixing and staining methods, no fine microtomes with their yards of serial sections, no synthetic culture media, no elaborate sterilizing ovens and brood chambers, and no apochromatic glass for lenses. 'Pure cultures' were practically unknown, and photography and photomicrography had not yet become arts of daily use in the laboratory.

Prior to 1880 we had indeed the brilliant researches of Louis Pasteur on a variety of subjects of wide interest to biologists, if not bearing directly on plant pathology. Berkeley had already done some good work on plant diseases in England, although most of his efforts had been devoted to systematic mycology. Tyndall in England had also done much to clear away the fog produced in the public mind by the adherents to the doctrine of spontaneous generation. Kühn, Sorauer, Frank and Hartig had begun their studies in Germany. But it was especially to de Bary, in Germany, that all eyes were turned as the great master mind. He had published a series of brilliant papers on the life history of various fungi, and was stimulating many of the younger men to undertake a higher type of research work than was then in vogue. Among these men, Woronin deserves especial mention. He published several fine papers in conjunction with de Bary and has continued the good work independently. In our own country, Dr. Farlow had published a number of interesting papers from the Bussey Institution on black knot and other diseases of plants, and there was some mycological work with an economic aspect going on under Dr. Burrill's direction at the University of Illinois, and under Dr. Bessey's direction at Ames, Iowa. In Europe and America, a number of younger men, who have since become widely known, were just beginning their work on diseases of plants.

Plant pathology was not an attractive profession in those days. When he first desired to make the diseases of plants, or mycology, as we called it, his chosen profession, the speaker well remembers casting his eye over the field very dubiously. There were no places for such workers, and, from the pecuniary side, it was a barren and unsatisfactory prospect. Nevertheless, the field was so inviting in other ways that it appeared to be worth while to run the chances. A meager livelihood in the pursuit of a most attractive line of work seemed preferable to a mint of money earned in an irksome profession, and so the die was cast.

How changed is the present outlook! At present, and for some time to come, the demand for well-trained plant pathologists (in this country, at least) is likely to be considerably in excess of the supply. By this I do not mean that there are not already enough, and more than enough, of second and third-rate workers; and I would not advise any one to enter the field who has not a marked talent for this line of inquiry, robust health, good training, and a determination to do superior work.

Of course, the magnificent development of bacteriology and animal pathology within the last twenty-five years has had its influence upon the study of plant pathology, as it has had upon all related sciences, but it does not seem to have exerted as great an influence or as immediate an influence as one would have supposed. In general, botanists were the ones upon whom the investigation of plant diseases naturally devolved, and most of them for some reason were very slow to make use of the exact methods of research which have led to such brilliant results in the study of human and animal diseases. However, as time has passed, more and more men have learned how to study plant diseases, and a considerable body of plant pathologists, although by no means all, are no longer open to the charge of not knowing how to pursue pathological researches.

Inasmuch as we have always had plant diseases with us, the query is sometimes raised why it is that the exact study of such diseases was postponed until the end of the nineteenth century. The primary reason, no doubt, is that exemplified over and over again in the history of the world, viz., that one branch of research must often wait for the development of some other branch. In this case, inquiry into the causes of many diseases had to wait for an exact method of isolation of the parasites and a knowledge of how to grow them in pure cultures. It now seems to us a very simple matter to separate one organism from another by means of poured gelatin or agar plate cultures. It seems, also, a very near discovery that discontinuous sterilization for a short time on three successive days should render a culture medium sterile, and that the simple intervention of a sterile cotton plug between this medium and the open air should suffice to strain out all the floating organisms of the air and keep the medium indefinitely sterile. That the study of the causes of certain diseases should have to wait many years until these simple facts had been demonstrated and a knowledge of them diffused among men is not less true than it is remarkable. The whole science of bacteriology and all the wonderful advances that have been made in the etiology of obscure diseases really date from the time when we were first able, with some degree of ease and exactness, to separate out one kind of organism from another and grow it indefinitely in pure cultures, all of which has come to pass since the year 1880. Only the crude beginnings of bacteriology were earlier than 1880. Prior to that time we had, it is true, the fractional and dilution methods of isolation, but these, although capable of yielding good results, are troublesome and have never appealed very strongly to the mass of workers.

In the time of which I speak, there were already many excellent helps in the way of treatises on fungi. We had, for instance, the splendid volumes of the 'Selecta Fungorum Carpologia' by the brothers Tulasne, and if we were not always sure of the Latin construction, we could at least read the magnificent copper plates which embellish these volumes. There were also books by Persoon, Corda, the Nees von Essenbecks, de Notaris, Rabenhorst, de Schweinitz, Fuckel, Bonorden and Montagne. There were numerous volumes by the Swedish mycologist Frieze. We had also Berkeley's 'Outlines,' Cook's 'Handbook of British Fungi,' and many scattered descriptions by Oudemans, Magnus, Schroeter, Winter, Berkeley, Cook, Ellis, de Thuemen, Rehm and others, in *Hedwigia* and other journals. The Italian Saccardo had not yet begun his monumental compilation of all known species of fungi, but he was printing the first parts of his 'Fungi Italici.' Several parts of Brefeld's 'Untersuchungen' also appeared prior to 1880, and there was an excellent 'Handbuch' of cryptogamic plants by Luerssen. There were also some good exsiccati, including, in this country, the first centuries by Ellis. De Bary's 'Comparative Morphology and Biology of the Fungi,' and the splendid cryptogamic 'Floras' by Winter, by Schroeter and by Oudemans had not yet appeared.

In the matter of plant diseases, we were much less well provided. In fact, there was scarcely anything in English in the nature of a general treatise. The nearest approach I can recall was a brief chapter on diseases caused by fungi in Berkeley's 'Outlines of British Fungology' (1860), and a little book by M. C. Cook entitled 'Rust, Smut, Mildew and Mould' (1865). A knowledge of foreign languages was even more essential in that day than it is now for the study of diseases of plants. Even in European tongues there were comparatively few useful general works on diseases of plants. We had, it is true, the rare, largely neglected, and generally negligible, crude, early works of Re, Unger, Meyen, Hamel and Hallier. There was also the first edition of Sorauer's 'Pflanzenkrankheiten' (1874), and Winter's little book of a dozen chapters, which appeared in 1878. This book, which described some of the commonest diseases of plants, is now quaint and old-fashioned reading, but it then seemed a model in its way. In 1878 there also appeared a little book by de Jubainville and Vesque on 'Les Maladies des plantes cultivées, des arbres fruitièrs et forestièrs, produites par le sol,—l'atmosphere,—les parasites végétaux, etc., d'après les travaux de Tulasne, de Bary, Berkeley, Hartig, Sorauer, etc.' There was also an earlier and very good book for its time by Kühn (1858).

A few diseases had been worked up quite carefully as to their etiology, and in the doing of this the way was blazed for the critical study of other and different diseases, and also, of course, for a great deal of inference and uncertain speculation. I refer to de Bary's classical work on the potato rot fungus (*Phytophthora infestans*), Farlow's work on the mildew of the grape (*Peronospora infestans*) and the black knot of the plum and cherry (*Plowrightia morbosa*), Woronin's work on the club root of the cabbage (*Plasmodiophora brassicæ*), de Bary's discoveries with reference to the heterocism of the grain rust (*Puccinia graminis*), Cornu's studies of the *Phylloxera* of the vine, Fischer von Waldheim's studies of certain of the grain smuts, and similar papers. The rusts and smuts, and the downy and powdery mildews, were the best-known parasites. Certain fungi then supposed to be pure saprophytes are now known to be active parasites, *e. g.*, certain members of the form-genus *Alternaria* and of the form-genus *Fusarium*.

Very little was known relative to the treatment of plant diseases beyond the fact that mildews in hothouses were supposed to be induced by draughts of cold air and to be partially preventable by the use of sulphur dust; that wheat smut appeared to be partially controllable by soaking the seed-wheat in a solution of copper sulphate, and that sulphur dust was a remedy for *Oidium* of the vine.

Little or nothing was known with regard to varietal or individual resistance of plants. In a general way, it had been observed by many that, under what seemed identical conditions, some plants sickened while others remained healthy, but it was quite generally believed that this was due to the fact that there had been no good opportunity for the fungus to infect the plant, rather than that the plant itself had any special power of resistance. This idea was yet unborn, or, at least, had not come to any prominence among pathologists.

Among the great mass of farmers and other growers of plants, the rusts, smuts, mildews, etc., were accepted as the will of God, or as a matter of course, and it never entered their heads that anything could be done to lessen the ravages of these troubles.

Nothing whatever was known about bacteria as the cause of plant diseases except to two or three workers who were just beginning their studies in this field. I refer especially to Burrill in America and Prillieux in France. It was also not generally recognized that algæ could cause disease in plants. Little or nothing was know about enzymes, ions, cell nuclei or symbiosis as important factors in plant life.

Let us now for a few minutes glance at what has been accomplished in the last twenty years. From being a mere rule of thumb, plant pathology has become a well-established branch of botanical science, the study of which has been pursued in many places with astonishing ardor and excellent results. Among others, the following authors have published general works on plant diseases within the period named: Sorauer, Frank, Hartig, W. G. Smith, Kirchner, Scribner, Ward, Comes, Prillieux, von Tubeuf, Massee. Sorauer, Frank, Hartig and Ward have published several different books on plant diseases. Books by Hartig and von Tubeuf have been translated into English, and Kirchner's book has recently been done into Italian. In some cases elaborate treatises have been written on the diseases of small groups of plants, *e. g.*, Viala's 'Diseases of the Vine' (three editions), and Erickson's 'Grain Rusts.' Sorauer and Kirchner have also both published atlases of plant diseases, illustrating the more common diseases with colored figures, which, however, in many cases, it must be confessed, could be improved upon. In this enumeration the extremely useful 'Host Index' by Farlow and Seymour should not be forgotten, nor Sturgis' compact 'Bibliography.'

In the publication of authoritative general treatises on plant diseases, the United States has not kept pace with Germany. Scribner's little book on 'Fungous Diseases of the Grape, etc.' (1890), is all that I can recall. That no book at all comparable with the handbooks of Sorauer, Frank, Kirchner or von Tubeuf has yet appeared in the United States is a matter for some wonder, considering the number of us who are affected with an itch for writing. It is also a matter for regret, considering the extent of our territory, the number of our plant diseases, and the character of our population. There is now a demand in this country for several good manuals of phytopathology, and these books are the more to be desired because European manuals only very imperfectly outline American conditions. Who will be the first to enter the field with something really excellent? Surely we ought to expect something rather better than the books I have named. A special exhortation to do well is hereby extended to the first man to occupy the field, since, if he sets the standard high, all the others must rise to his level, and the general gain will be great.

As an illustration of the growth in the United States of this branch of science, I may be permitted to cite the fact that when the speaker entered the United States Department of Agriculture at Washington in 1886, this line of work had only recently been separated from the ordinary botanical work of the department, which then consisted principally of answers to correspondents, and species descriptions of grasses. At that period, and for some time to come, we had no laboratory facilities and scarcely any place we could call our own. A little cubbyhole was apportioned off for the chief, Professor Scribner, and his assistant was allowed, by courtesy of Dr. Marx, the department artist, to occupy a desk in his room. We had very few books, and nothing in the way of apparatus beyond the simplest sort of microscopes. Now, under direction of this same United States Department of Agriculture, we have several more or less well-equipped laboratories in Washington, one in California, one in Florida and one in the Middle West at St. Louis. The number of men employed, including those who are working with us in the closely related and frequently overlapping fields of plant physiology and plant breeding, and exclusive of clerks, typewriters, artists and laborers, is twenty-six. The amount of money appropriated by Congress for this line of work in 1887 was $5,000; the sum named as necessary in the estimates of the Secretary of Agriculture for the coming year is $118,000.

As to places for the study of plant diseases, we now have in this country about fifty experiment stations where such diseases are studied or may be studied, and perhaps half as many colleges and universities, where more or less attention is given to the subject. No great university has yet done itself the honor to establish a distinct chair of plant pathology, but the subject is such a large and important one that this must unquestionably follow within a few years. More attention should, I think, be given to the proper teaching of this subject in colleges and universities. While perhaps the study of plant diseases has had a larger development in this country than anywhere abroad, owing to the fostering care of the National Government, there are nevertheless many places in other parts of the world where such diseases are now studied. I might mention the dozen or more experiment stations in Italy, in nearly all of which something has been done on this subject; the numerous places in Germany, in universities and agricultural colleges, and now recently in the laboratory of the Imperial Government Board of Health, under the able leadership of Dr. von Tubeuf; similar places are now provided in France, England, Russia, The Netherlands, Sweden and other European countries, for the study of plant diseases. There is also considerable activity in Japan, in Australia, in Java and in various other parts of the world.

The result of this is that a large body of young men has undertaken the study of this class of diseases, and the literature of the subject is now extensive. It is also, unfortunately, so scattered through journals, transactions, agricultural papers, etc., that one must read very widely if he would undertake to keep pace with the advances which are being made. This, of course, has its great disadvantages, and one sometimes wishes that the Latin tongue had been retained as the universal language of science, or that some one language could be agreed upon in which the abstracts of all scientific papers should be published as a prerequisite to international recognition, or at the very least, that the authors of all important papers would follow the good example set by some of the Japanese and Russian writers. These men publish with their papers a summary in some other language. Such summaries need not be long. They should be, preferably, in English, German or French, since these are the leading scientific languages of the world, so far as quality and bulk of publication are concerned.

Of special journals devoted to plant pathology there were none twenty years ago; now there are five or six. Very many of the general journals of botany also now publish long papers on diseases of plants.

The time is too brief to cite all of the interesting special papers which have appeared during the last twenty years, even if it were desirable. I may, however, mention the following as interesting examples of what has been done at home and abroad. First, perhaps, in importance comes de Bary's pioneer paper on *Sclerotinia* and sclerotinial diseases. Hartig has published numerous very interesting papers on the diseases of trees and of timber. Woronin published a beautiful paper on *Tubercinia trientalis* and several equally interesting ones on sclerotinial diseases. Sadabeck and Johanson have added much to our knowledge of the *Taphrinas*. Frank has published several interesting communications on a *Gnomonia* disease of the cherry, in which he not only points out the cause of the disease, but also a remedy for the same. Burrill and those who followed him have worked out conclusively the etiology of pear blight. Savastano, Cavara and others have done the same for the olive knot. Many other diseases have also been shown to be due to specific bacteria, one of the best recent papers being by Jones, of Vermont, on a soft rot of the carrot and other plants. Brefeld has shown for many of the smuts that they can vegetate for long periods in forms resembling yeasts. In a magnificent paper on corn smut the same author has shown clearly that, unlike most smuts, the pustules appear in about fourteen days from the time of infection, and that only young, actively growing tissues can be infected. Ward in a remarkably fine paper showed a certain lily disease to be due to *Botrytis*. Woods has brought a whole class of diseases into prominence by demonstrating the spot disease of carnations to be due to insect punctures. Various workers have shown that insects and mollusks are frequently the indirect cause of disease by carrying bacteria and the spores of parasitic fungi from diseased to healthy plants. Galloway demonstrated the early blight of potatoes to be due to an *Alternaria*. Peglion in Italy proved a destructive spot disease of muskmelon to be due to another *Alternaria*. Dorsett has demonstrated that a third species causes the vexatious spot disease of violet leaves. Barclay, Plowright, Schroeter, Winter, Magnus, Klebahn, Dietel, von Tubeuf, Farlow, Thaxter, Carleton and Arthur have all contributed to our knowledge of those perplexing rusts which grow alternately on widely different plants. Erickson has demonstrated the existence on related plants of morphologically similar rusts which are incapable of cross-inoculation. Thaxter has shown that the potato scab is due to a minute fungus, *Oospora scabies*. Laurent has published two very interesting papers on the causes of immunity, one dealing with bacterial potato rots and the other with the distribution of the mistletoe in Belgium. W. G. Smith has published interesting papers on the histology of galls due to *Taphrina* and other fungi. Cornu published an interesting paper on the grape mildew (*Peronospora*). Nawaschin has increased our knowledge of the parasite which causes club root in cabbage. Went and Beyerinck have published a number of very suggestive papers on enzymes. As already stated, this list is not designed to be complete. It might be greatly extended.

A great advance has also been made in treatments for the prevention of disease. In France, Millardet saw that the mildew did not attack certain grape vines which had been sprinkled with a mixture of bluestone and lime to prevent thefts of the grape bunches. He had the alertness of mind to recognize that here was the germ of an important method of treatment, and, with the help of Gayon, promptly elaborated it for the prevention of mildew of the grape. Following fast on the heels of this discovery was its application in France, Italy and the United States for the prevention of other fungus diseases. By the General Government, under the energetic direction of Scribner, and subsequently of Galloway, and a little later by many experiment station workers and farmers, this and similar methods of treatment were applied successfully in the United States for the prevention of the black rot of the grape, leaf spot of the pear, apple scab, and a number of other serious diseases of plants. At one time this treatment was hailed as a general panacea for all plant diseases. In Denmark, Jensen discovered that smut of various grains could be prevented by soaking the seed in hot water for a few minutes. These experiments were subsequently repeated, expanded and confirmed in this country by Kellerman and Swingle. Thaxter and Sturgis demonstrated that onion smut was only communicable during the seedling stage of growth and that, if plants were grown for a few weeks in healthy soil, they might be transplanted to fields badly infested with this smut without danger of infection. Bolley showed that the potato scab was frequently disseminated by seed potatoes, and in such cases could be controlled very satisfactorily by soaking the infected seed potatoes in a solution of corrosive sublimate. This treament is, however, not successful in case the fungus is already present in the soil. Coquilette, the entomologist, demonstrated that certain scales infesting orange trees in California could be controlled by fumigating with hydrocyanic acid gas, and Woods and Dorsett in Washington subsequently extended this treatment and applied it on a large scale, most successfully, for the freeing of hot-house plants from scale insects and aphides. This treatment has subsequently been pretty generally applied in the United States for the fumigation of nursery stock. Riley and others conceived the idea that the best method of controlling certain scales would be by multiplying their insect parasites, and the threatened destruction of the orange orchards of California by the cottony cushion scale was avoided in this way, viz., by the introduction of a lady-beetle from Australia. Giard, Snow, Forbes and others have experimented with certain fungous parasites of crop-destroying insects, hoping to spread epidemics among them, but thus far with only partial success. The dreaded San José scale can now be held in check in this country by insecticidal sprays. Potter, Halsted and others have shown that club root of cabbage may be partially prevented by heavy liming of soils. Millardet, as a result of thousands of crosses of *Vitis vinifera* with hardy American species, has obtained wine grapes resistant to *Phylloxera*. Pierce, by similar methods, has obtained a raisin grape resistant to coulure. Quite recently the Dutch in Java have largely circumvented the Sereh disease of sugar cane by bringing healthy cuttings from the hills. Cobb pointed out a way to avoid the gumming of sugar cane, a serious disease in Australia, viz., by the selection of healthy cuttings. This practice, he informs me, has greatly reduced the amount of gummed cane in New South Wales. Orton has recently found evidence that the wilt of cotton and of cowpeas can probably be prevented by the selection of resistant individuals. Pierce and others have shown that curled leaf of the peach can be prevented by fungicidal sprays. The saving from curl in one year on one variety in one peach orchard in California was $12,700 and the estimated saving to the whole state was $400,000. Waite blazed the way for a whole series of observations on self-sterility of orchard fruits by demonstrating that a supposed pear disease infesting a great orchard in Virginia was nothing else than sterility of the flowers to their own pollen, and could be overcome by planting in the orchard an occasional pear tree of a different variety blooming at the same time or by grafting in such variety. Galloway and Dorsett have shown that the leaf spot of violets may be overcome by the selection of resistant individuals. Jones has been remarkably successsful in protecting potatoes from leaf blight by use of copper fungicides. Nearly every experiment station man has been able to chronicle some interesting treatment or important discovery.

If we consider the sentiment of the community at large respecting this kind of scientific work, the change has been equally great. From being merely ‘bug hunters’ and ‘queer fellows,’ the entomologist and mycologist have become people of importance. Farmers, fruit growers, gardeners and hothouse men are no longer skeptical or indifferent, but are eager to get the last word and quick to apply each new discovery. A recognition of the importance of plant pathology is also gradually extending to State legislatures and national bodies of legislation, and the time is not far off when appropriations for the study of plant diseases will be as prompt and liberal, in this country at least, as they are now for any line of work which is fully recognized by the men who legislate as important for the general welfare of the country and beyond the possibilities of private inquiry. Diseases which annually deplete the large civilized countries of hundreds of thousands of dollars, *e. g.*, cotton blights, grain rusts, potato rots, and which not infrequently assume an epidemic form and sweep out entire industries, *e. g.*, coffee disease of Ceylon, sugar-cane disease of Java, peach yellows of the United States, Anaheim vine disease, are certainly legitimate objects of governmental inquiry. I need not argue this point.

Some words, finally, as to the future. The prophet is always at the mercy of events. Nevertheless I shall venture a few predictions. First of all, we may predict for plant pathology in the United States during the next fifty years a wonderful development, since it appeals very strongly to the genius of our people. This being taken for granted, how shall that development be best facilitated? The facts which lie on the surface of things, as regards both the causes of disease and the treatment of the same, have now been pretty well picked up. In my judgment, the treatment of diseases by spraying with copper fungicides has reached its climax and is now on the wane. We shall have to devise other methods for dealing with many plant diseases. Plant breeding is one of the most hopeful. It is a slow process, and the man in the field will sometimes become impatient unless he is a philosopher as well as a farmer. Field hygiene is also a matter of prime importance. Suitable rotation of crops must be practiced, and as far as possible diseased material, and the carriers of such material, must be destroyed. I lay much stress upon the last statement. Insects in particular are responsible for much more than the direct damage they cause.

The men who enter this field from now on must have a better training and a more versatile one than those who have cultivated it in time past, and the emphasis should be placed on laboratory work and laboratory training. It goes without saying that the man who would become a useful pathologist must have considerable familiarity with the literature of his subject. In other words, he must know how to use literature, and must be a linguist, or able to command linguists. He ought also to have a very considerable amount of technical training in physics and chemistry and should know something of zoology. In the way of preliminary training, eight years of university work, or its equivalent, is not too much, and a very considerable part of at least four years of this time the student should spend on organic chemistry. He must not expect to accomplish very much as a pathologist unless he has also become familiar with a very considerable body of knowledge respecting the behavior of plants under normal conditions. In other words, to be a good pathologist he must be a good physiologist, and to be a good physiologist he must first be a good chemist and physicist, for at bottom physiology rests on chemistry and physics, and the advances in this line during the next fifty years will undoubtedly be made by men who approach the problems of biology from the standpoint of physiological chemistry. Given all this, and still the man will not be eminently successful unless he is a born experimenter; I mean by this one capable of reasoning closely, and of devising ingenious methods of extorting from nature her well hidden secrets. This is, of course, asking a good deal of one man, and is more, perhaps, than can be expected of most men. Very likely a solution of the question will be found in many cases by a union of forces. No man is likely to solve these problems who approaches them from the purely chemical standpoint. Something more is required. The pathologist should be the guiding mind, but he must associate with himself a competent physiologist and one or more skilled chemists having some flexibility of mind and a decided inclination to study living things rather than dead things. The old routine ash analyses of the chemist are of no help to us. We wish to know the proximate rather than the ultimate elements of the plants we are studying, and to know how these vary in quantity and kind under changed conditions. In other words, what we wish to know is not how much carbon, hydrogen, oxygen, nitrogen, potash, phosphoric acid, etc., the plant contains, as determined by ash analyses, but in what form it exists in the living plant. We wish to know the kind and quantity of each of the organic acids, and how they vary in amount from time to time under changing conditions. We wish to know all about the sugars, the fats, the tannins, the proteids, the amids, the glucosides, the enzymes, etc., changes in all of which play an important part in nutrition and in predisposition to disease. How are these substances increased, diminished or changed by changing external conditions, either natural or of man's devising, *e. g.*, by foods added to the soil, by fungicides sprayed upon the foliage, by heat, or cold, sunshine or cloudy weather, drought or excessive precipitation? We desire to study the chemical-physiological requirements of the parasites in the same minute way. Then we shall be able to put the two kinds of evidence together and begin reasoning.

Two or three congenial men, having each his special training in the lines indicated, would be able to accomplish much more in solving the difficult problems which confront us than any single man. But I cannot divorce myself from the thought that the pathologist should himself be a chemist and a physiologist. There must certainly be a deeper study of the intimate nature of the plant in health and disease if we are to determine just what constitutes immunity in many given cases and just what is the best method of checking the prevalence of many of our most vexatious diseases. I may refer, for example, to the difficulties which lie in the way of understanding the action of even so well studied and simple a thing as Bordeaux mixture. In recent years we have heard a good deal about injuries due to the Bordeaux mixture, especially on the peach and plum. Why are these trees more susceptible than the apple and the pear or the grape? Why does Bordeaux mixture appear to be more injurious one season than another season, or in the hands of one man than in the hands of another man? Only an intimate knowledge of the nature of this substance and of the chemical physiology of the plants themselves can furnish an answer to these questions.* I may refer also to a whole group of diseases, the etiology of which mere field study and the ordinary laboratory methods do not appear to be competent to unravel; for example, the California (Anaheim) vine disease, the wilt of the orange, the sereh disease of the sugar cane, gum diseases, the yellows and rosette of the peach, the winter blight of the tomato, the internal brown spotting of potato tubers, etc. We may confidently expect that these obscure diseases will yield up their full etiology to careful study at some time in the future, but it will have to be a more thorough and exhaustive study than any that has yet been given to it and by men better trained for the solution of the special problems involved. A good beginning on this class of diseases has been made by Beyerinck and Woods in the study of the Mosaic disease of tobacco.

In the time which has passed, much attention has been given to the parasite and comparatively little to the host plant. The plant has seemed to many in the nature of a passive agent. This is far from being the true state of the case. In time to come I would not have the parasite studied less (it must be inquired of with still greater care, especially as to what are its limits in the use of foods, and in the toleration of non-foods), but I think that the host must also, certainly, be studied more diligently if the wonderful progress in plant pathology during the last two decades is to continue. To my mind, the problem of problems in pathology, both animal and vegetable, during the next fifty years will be the varying nature of the host plant or host animal as related to the parasite. This is the burning question. Why is it that some individuals are so very susceptible to disease and others so resistant? Why is it that the same organism is more susceptible at one age, or at one time or season, than at another? These are questions intimately connected with structure and with changes in secretion and excretion, *i. e.*, with the complex chemistry and physics of the individual body, and we shall never be able to solve the difficult problems of plant immunity and put our knowledge into practice for the prevention of diseases until we have a much more intimate acqaintance with the plant cell as a chemical laboratory, or as a physio-chemical laboratory, if you prefer that term. When we are able to point out clearly just what the chemical and physical changes have been

* Since this was written considerable light has been thrown on the subject by Mr. J. F. Clark (*Bot. Gaz.*, January, 1902, p. 26).

which lead up to susceptibility to a given disease, then we shall have gone a very long way toward pointing out to the practical man the methods by which he will be able to avoid bringing about those specific changes which end in disease. It is certainly entirely within the bounds of the possible to know definitely just what particular changes lead to disease, *i. e.*, tend to invite a given parasite, or a given degeneration, and, knowing these, to put the plant or animal under such conditions as to food, light, air, etc., as will lead to the development of counter changes tending to ward off disease. A beginning has already been made, but much remains to be done, and a more inviting field of research does not anywhere lie open to the young and earnest experimenter.

The so-called ' practical man ' has gone about as far as he can go and must have help from the technical and laboratory man. Personally, the speaker has no sympathy with that line of thinking that would hold the pathologist to the narrowest kind of experimental or field work, or which requires him to make bricks without straw. Of course, I mean bulletins without new discoveries to put in them. Nothing is gained by repeated threshing of old straw, and time, the most precious of all things, is lost. Haphazard experimenting is not science. Every decade will not be fortunate enough to stumble on a Bordeaux mixture. The trained pathologist should be given plenty of time and the largest liberty, and allowed to work out his own salvation as best he can. This he must do very largely by experimental devices, and he certainly will never be able to get very far without a thorough technical training and use of the exact methods of the laboratory, or, as I have already pointed out, without chemical knowledge and much assistance from the chemist and physicist. I would not disparage field work. It is right as far as it goes, and I think every pathologist ought to have a thorough acquaintance with diseases as they occur in the field; but a man may work all his life in the field and never get beyond a rule of thumb, if he does not also have that technical training which is usually acquired only in the laboratory. The pathologist must be able to see all that the practical man sees, and a great deal more. In other words he must not only see that things go on in a certain way in the field, but he must also be able to probe beneath the surface and determine why. It is then, often, not difficult for him to make nature conform to some other and better plan whereby harvests are saved and the hungry are fed.

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*THE BIOLOGICAL BASIS OF LEGISLATION GOVERNING THE LOBSTER INDUSTRY.**

CAUSES OF THE DECLINE.

THE causes of the growing scarcity and the yearly diminishing average size of the lobsters caught are: (1) *The natural demand,* arising from an increasing population. This increased demand has not been met by a correspondingly increased source of supply. (2) *The existing laws,* for the reason that the destruction of adults has been permitted. The present laws, with their practical difficulties of enforcement, have had an adequate trial. The decline of the lobster industry demonstrates that these laws have proved inefficient for increasing or even for maintaining the supply. The chief defect of the present laws seems to lie in permitting the destruction of adults.

SUGGESTIONS FOR REMEDIAL LEGISLATION.

Of the suggestions for legislation to check this decline, seven, either singly or in

* Abstract of a 'Report' to the Massachusetts Commissioners of Fisheries and Game, and published in their 'Annual Report' for 1901 (Public Document No. 25).