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BIOGRAPHICAL MEMOIR

OF

ERWIN FRINK SMITH

1854–1927

BY

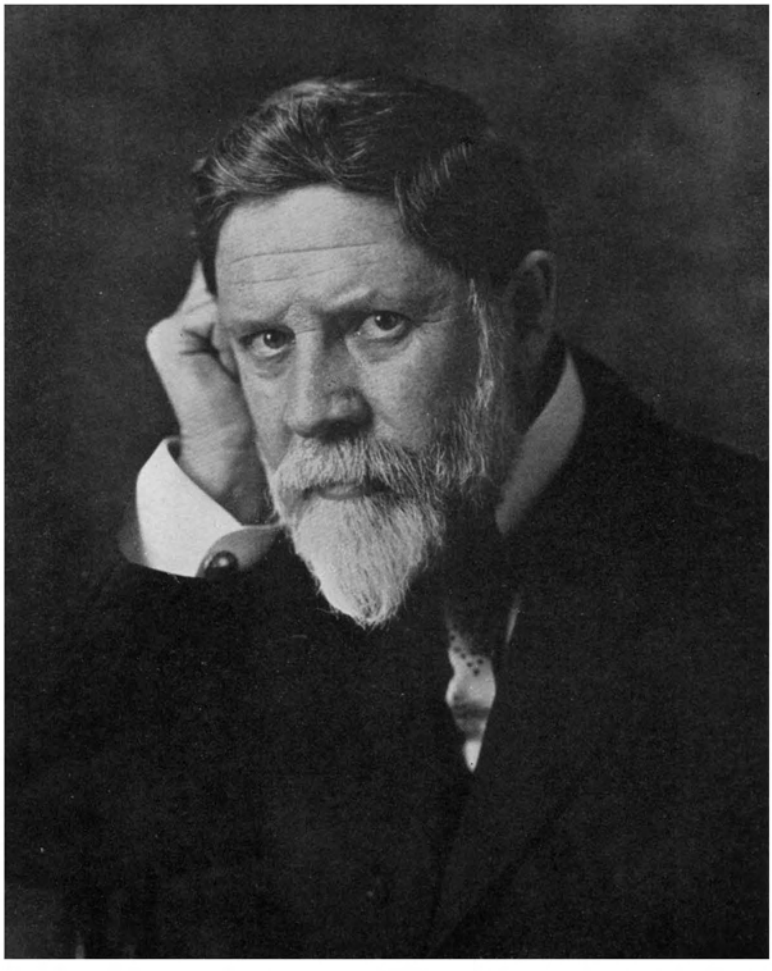
L. R. JONES

With synopsis of researches by

ERWIN F. SMITH

and bibliography by

FREDERICK V. RAND



Erwin F. Smith

ERWIN FRINK SMITH

1854–1927

BY L. R. JONES[1]

The personal qualities that endeared Erwin F. Smith to the friends and scientific associates of his mature years were evident from his early youth. Among these were a lovable disposition, passion for study, quick idealism, intense devotion to the task in hand, and unalterable integrity. He was born in the little village of Gilberts Mills, New York, on January 21, 1854. His parents, R. K. Smith and Louisa (Frink) Smith, migrated in his early childhood to a farm home in Hubbardston in southern Michigan. Unfortunately we are able to add but little concerning his earlier ancestral history. His family were of Anglo-Saxon stock, some of the lines going back among the earliest of the New England settlers. They were pioneers and frontiersmen, who helped to settle half a dozen towns in eastern Massachusetts and then moved on into Connecticut, afterwards into central New York, and still later into southern and central Michigan and farther west. His immediate forebears on both sides lived in central New York in small farming communities, and his family had settled in Gilberts Mills shortly before he was born. Their social life centered around the church and school, and there was a strong element of piety in his home life. There was much hard work to be done, but his was a happy boyhood, with all the interests and activities connected with farming, to which he early added an interest in books, nature, science, medicine, art, and music. That Smith himself recog-

[1] Thanks are due for kindly advice and aid in the preparation of this memoir to numerous friends and scientific associates of Doctor Smith. Especial mention should be made of Mrs. Erwin F. Smith for access to unpublished early writings, now deposited in the library of the U. S. Department of Agriculture, and of Dr. Liberty Hyde Bailey, whose friendship with Smith dated from their early associations as amateur botanists in Michigan. Dr. Frederick V. Rand and Miss Florence Hedges, long-time members of Doctor Smith's research group, aided concerning many details. Doctor Rand prepared the manuscript for the bibliography in consultation with Miss Claribel R. Barnett and other staff members of the Library of the Department of Agriculture.

nized his own indebtedness to worthy forebears is shown in brief suggestion at the close of his "Synopsis." There he lists two significant traits, most helpful in his scientific work, as "matters of inheritance." These were "persistence along a previously determined line of work" with a "fondness for all forms of art and a desire for perfection." Evidence for both of these traits is to be found throughout his educational development. Partly from financial necessity, partly because of shy individualism, his formal schooling was inconsequential through the Ionia (Michigan) High School from which he graduated at the unusually mature age of twenty-six. His studies were even less regular at the Michigan Agricultural College, where he spent some time while employed with the State Board of Health at Lansing. With little more formality he then enrolled at the University of Michigan and was granted the bachelor's degree in June, 1886, and three years later the doctor's degree. This latter was based on Smith's work on peach yellows, a serious orchard disease to be discussed later. At the close of the examination for the doctorate Professor Volney Spalding, his major counselor during these four years, expressed regret that the University could offer no higher token of its esteem for Smith's scholarly researches. This is but one of many testimonials that, throughout these unconventional relations in lower schools, college and university alike, he was recognized as having unusual intellectual interests and scholarly abilities. Fortunately, at all stages he also met with liberal-minded teachers and wise advisers, who gave encouragement and aid in his irregular educational programs and related problems.

From such personal associations with teachers and other friends he early developed a keen interest, continued through life, in language and literature. Similar stimulating relations on the scientific side began with Charles F. Wheeler, the druggist of his home town. Wheeler was a keen, scholarly man and the leading amateur botanist of Michigan. Through his kindly interest in this eagerly inquisitive country boy, Smith was early tutored in French and was introduced almost simultaneously to the fascinations of chemistry and botany. One result was that he early set up some simple chemical apparatus in his home.

More significant, however, was the close association of Wheeler and Smith throughout many years of intensive work in taxonomic botany. Beginning with exhaustive local explorations, these developed into a state-wide study of the Michigan flora and matured in their noteworthy hand-book, "The Flora of Michigan." This was published in 1881, the year after Smith graduated from high school. The influence of this early botanical work in association with so able and enthusiastic a taxonomist as Wheeler was evident in much of Smith's later work. It outweighed that of any formal course of study in biology.

Smith's associated school programs were at once so unusual and significant as to deserve more intimate glimpses. While his early botanical work with Wheeler was in progress he taught for some time in district schools. In 1876, when twenty-two years old, he entered the Ionia High School. Here he found two exceptionally good teachers. The first of these was the principal, A. R. DeWolf, a recent graduate of the University of Michigan. Smith's personality and genius immediately impressed DeWolf who has, in a recent letter, described their early relations as follows:

"Wearing a full beard . . . he entered school the second week of the fall term . . . At the close of the day . . . he introduced himself . . . outlined his circumstances . . . obstacles . . . Mentioned work, upon which engaged [Flora of Michigan] . . . could not be quite regular in attendance . . . but would exercise additional diligence in preparation. His unusual intelligence, courteous bearing and evident acquirements were such that I fell in love with him and . . . gave full permission to come and go as the spirit moved . . . he dropped everything, filled his collecting can with food and went into the woods in search for uncommon and new species. For days he was lost to everything else. Before I knew him he had acquired a fine knowledge of the French language . . . [Wheeler had been his tutor and fellow correspondent with botanists in France] . . . read extensively the French scientific books, thus laying the foundation for the scientific work of his later life."

In this same Ionia school he was much influenced by an able and sympathetic English teacher, who quickly realized and stimulated his love for the best in literature, including poetry and related artistic interests. This continued as a formative influence

throughout life. Smith later commented that in these early years he would as readily have become a teacher of literature as a scientist.

Mention should here be made of another association which was to exert an important influence upon Smith's later scientific career. As earlier noted, he worked for the Michigan Board of Health at Lansing, while carrying on his undergraduate studies in the State College. This work was directed by Dr. Henry F. Baker, a recent graduate of the Michigan University Medical School, a man of scientific ability, keenly interested in the advancement of modern sanitation. To aid in such a program Dr. Baker commissioned Smith to review the literature. An important part of this was in European publications, notably German and French. Smith's exhaustive digest and forceful report upon this subject, consisting of some 180 pages, was submitted to the Board at a public meeting in 1884. The associated discussion indicates that Smith's report was accepted as a major contribution. This seems especially significant when one finds on the same program a paper by Dr. Victor C. Vaughan, then one of the keenest younger members of the University medical faculty who, with Frederick V. Novy, was soon to lead in Michigan's notable program in medical bacteriology. The influence of this experience on Smith's later scientific career can only be understood by noting such associations and recalling the date. He was thus in the mid-eighties taking a leading part in digesting and discussing sections of the European medical literature when it was under the formative influence of Pasteur, Lister, and Koch. There is record of Smith's comment that at this time he wished to be a doctor. But this, like his earlier inclination toward language, is chiefly significant as showing how fully he threw himself into the work in hand and how eagerly he met each new intellectual challenge.

A peculiar sequence of such challenges followed in the next year which combined to turn Smith's interests in parasitism and pathology from the diseases of animals to those of plants. The first of these came during the summer and autumn of 1885 with the occurrence of an unusually destructive disease of potato, the

leaf blight and tuber rot.[2] Smith, then transferring from the State College to his senior year as student at the University of Michigan, made an intensive study of this disease in field and laboratory. He accompanied this with a thorough review of the pertinent European literature, including the classical researches of deBary, and published a report of his findings. The second significant event occurred in August, 1885, when the American Association for the Advancement of Science met in Ann Arbor. Smith attended and was elected to membership. The Ann Arbor meeting is notable in the history of American plant pathology because of the report of a committee appointed the preceding year for "The Encouragement of Researches on the Health and Diseases of Plants." This committee there announced that it had aided in the establishment for this purpose of a "Section of Mycology" in the United States Department of Agriculture. This marked the beginning of the Federal program concerning plant pathology in which Smith himself was soon to become the essential research leader. To this work he devoted himself for the next forty years, continuing in active service until a few days before his death. A glance through the bibliography at the end of this memoir gives some concept of the continuity and variety of his contributions. Fortunately, five years before his death Smith consented to make a personal analysis and summary of his scientific work. This "Synopsis" of his researches has since remained exactly as he left it in manuscript form, known only to a few friends. It constitutes such a uniquely valuable review and interpretation of his own work that its publication in connection with this biographical sketch seemed of commanding importance. It has therefore been included as a later chapter of this memoir. The writer's contribution should therefore be accepted as an introduction to Smith's own "Synopsis." While in this he well summarizes his researches, he has not so clearly defined their relative significance. He naturally addressed it to readers presumably informed as to the historical development of parasitology and modestly refrained from comparisons of his

[2] This is caused by a parasitic fungus, *Phytophthora infestans*. It was first known in Europe when, some forty years before, it had destroyed the potato crop of Ireland and thus led to the great famine.

own work with that of others. Space does not permit of adequately supplementing his account with the details often needed to justify such comparisons. Something must, however, be attempted in order that the non-professional reader may understand the nature and value of Smith's leadership in plant pathology.

When he began his work in Washington on September 20, 1886, the general nature of parasitism as exemplified in fungus diseases of plants had been established in Europe under the inspiring initiative of Anton deBary. Farlow had brought the deBary methods from Germany to Harvard a decade before. From his laboratory several capable younger men, trained for carrying on similar work, had already gone to other universities. The Farlow school was primarily concerned with questions of taxonomy and the life histories of the parasitic fungi. Meanwhile from Millardet's experimental work in France in the mid-eighties came methods for control of the mildews of grape and other plants by spraying with copper fungicides. These and other possibilities with specific remedial methods especially stimulated the beginnings of the Federal work at Washington.

Antedating the Federal work and supplementing that of the Farlow school was the leadership of Burrill at the University of Illinois. Beginning in the late seventies he, with his students, led in the study of the parasitic fungi and associated problems concerning plant diseases and their control. These brought him, about 1880, to one of the important advances of the decade in this field. He showed that the serious and perplexing fire blight disease of pear and apple is infectious and that the causal agent is a bacterium. These and some later reports from Italy and France concerning bacterial diseases of plants were, however, not accepted as valid by the leading European bacteriologists and mycologists, especially those of Germany and England. A related challenge came later in this decade from Holland when Adolf Mayer reported the mosaic disease of tobacco to be infectious. Since he could find no fungus he suspected a bacterial parasite, although he failed to demonstrate any such organism. We now know tobacco mosaic as a filterable virus disease. A full decade was needed, however, after Mayer's observations,

before our modern concept as to the character of these "mosaic" and similar virus diseases was even glimpsed.

This hasty sketch indicates the background essential for understanding the significance of Smith's own contributions during his first decade in Washington. He began his work about the time of Mayer's report upon tobacco mosaic. His best efforts during the first six years were devoted to what in his "Synopsis" he terms "one of the most difficult problems imaginable, to wit: a wide-spread destructive disease of peach orchards (The Yellows) in which no parasite was visible." He later adds that he turned after some years from these researches because "the problem appeared to me to be insoluble in our then state of knowledge. For that matter it has remained unsolved up to the present time." He here refers to the fundamental nature of the disease. Without understanding this Smith himself could not be satisfied. But his evidence, as outlined in his "Synopsis," was accepted as final by the growers with whom he worked and talked, as well as by the pathologists who read his detailed reports of progress. Much painstaking experimental work was needed to disprove certain earlier misconceptions as to the cause and possible control measures. On the other hand, his conclusions strengthened the grower's confidence that once established in the orchard it continued its destructive spread. But how? The only way he could pass it from tree to tree was by budding or grafting. This might account for its origin with nursery stock but it left questions unanswered as to its persistent spread through the orchard. Concerning control measures, however, the growers accepted his evidence. Those who had relied upon the futile cultural practices advised by some earlier investigators soon united their efforts in checking the destructive spread of the disease through commercial orchards by compulsory extermination.

American plant pathologists were at that time in process of developing their methodology for the most part with simpler problems. They generally recognized Smith's work with the yellows and related peach diseases as exemplifying the highest of ideals and standards for research in this field. Recent progress with his basic problem concerning the nature of these peach

diseases fully justifies his judgment in the "Synopsis" in 1922 as to the inherent difficulties involved. His closing comment was that "they are now generally thought to resemble mosaic diseases." It is here pertinent to summarize the evidence which has continued to accumulate since Smith's death in substantiation of his early work and later conclusions as to peach yellows. I may, however, well introduce this by recalling a remark made by Smith some forty years ago, soon after he had ceased active work with the peach problems. We were discussing the resemblance in symptoms of peach yellows and the yellows disease of china aster and of ragweed. His closing comment was to the effect that when we understand the cause of the yellows of china aster we may have the key to that of peach yellows.

Before Smith's death L. O. Kunkel [3] demonstrated that aster yellows is caused by a virus. Working since with peach yellows, he has found this also to be a virus disease similar to aster yellows but with characteristics even more difficult of determination. In each case the virus is transmitted by a specific insect vector, a leaf hopper. With aster yellows the relations are further complicated by the fact that the virus is infective only after an incubation period of several days in the insect's body. Kunkel's results to date suggest that an even longer incubation period may be necessary with peach yellows. Recent advances with these yellows diseases are thus cited as indicating the complexities of Smith's first major problem, the soundness of his early work, and the judgment shown in his later surmises.

In addition to Smith's devotion to peach yellows during his early years in Washington he mastered the European literature of mycology, especially as related to diseases in plants, as few Americans had done. His reviews and translations of this period

[3] Dr. Kunkel's researches with these yellows diseases were begun at the Boyce Thompson Institute in 1924 and have later continued at the Rockefeller Institute, Princeton. Several publications have been made of which only two need here be cited:

KUNKEL, L. O. Studies on aster yellows. Am. Jour. Bot. 13: 646-705. 1926.

———. Insect transmission of peach yellows. Contrib. Boyce Thompson Inst. 5: 19-28. 1933.

coupled with the high standards of his own research publications had an immediate and persisting influence upon American investigational work in this field. This was fortunately supplemented by the brief but significant work of Thaxter (1888-1891) on plant diseases at the Connecticut Agricultural Experiment Station. There Thaxter used in his researches upon the potato scab disease the pure culture methods of the bacteriologist. Waite had brought these methods to Smith's attention when he went from Burrill's laboratory to the Federal staff in 1889. Smith's earlier contacts in Michigan with Board of Health problems led him to be further stimulated by his associations with Theobald Smith and Veranus A. Moore, then working next door in the Department of Agriculture on infectious diseases of animals.

This combination of circumstances prepared Smith in 1893 to follow up a "fascinating subject," as he calls it in his "Synopsis," by making the study of bacterial diseases of plants his major field of research for the rest of his life. In this new field he sought, from the beginning, to apply the highest bacteriological standards of the period. This was well exemplified in his series of monographic publications, which appeared during the next three years,[4] each dealing with a single bacterial pathogen. Here again the influence of Smith's intensive and brilliant researches was felt, not only as a standard for such scientific work throughout the Department of Agriculture, but now, with wider significance, setting the pace for the rapidly developing research programs in plant pathology in the several State institutions.

It was such developments that led in the late nineties to the most dramatic incident of Smith's life. In connection with these early researches upon bacterial diseases of plants, Smith with characteristic thoroughness undertook a painstaking study of the world's literature dealing with these diseases. As he states in his "Synopsis," he began the publication of reviews of such literature but soon discontinued the series because he found this earlier work "with a few exceptions not very exact or very con-

[4] See citations in the bibliography concerning *Bacillus tracheiphilus*, 1895; *B. solanacearum*, 1896; *Pseudomonas campestris*, 1897.

vincing." A natural lag in recognition, especially in Europe, of the quite different order of Smith's own work in this new field was to be expected. Had this been shown merely by lack of attention it would doubtless have been accepted, for the time being, with little notice even by Smith himself. But when one of the leading European writers of bacteriological text-books, Professor Alfred Fischer of the University of Leipzig, not only denied the possibility of bacterial diseases of plants but published disparaging comments on the character of Smith's workmanship something was called for in direct reply. In the "Synopsis" Smith makes but brief reference to this published controversy with Fischer concerning the existence of bacterial diseases of plants, except for the comment that "it silenced all the critics and won over the doubting European public." The significance of this bitter polemic in the history of bacteriology of this period is, however, such that any reader technically interested may well glance through the original publications. As the citations listed in the bibliography will show, these appeared, seriatim, in the leading international journal of bacteriology. The effect was not only the prompter attention to and acceptance of Smith's world-leadership in this field of research, but also the stimulation of investigations concerning bacterial diseases of plants in other countries. Naturally it was the younger men, especially in Germany, who gave increasing attention to these studies.

While stressing thus Smith's contributions to work on virus and bacterial diseases, one should not overlook the evidence of his breadth of interest and influence. It was in this same decade, as recorded in his "Synopsis," that he first focused attention upon the obscure but highly important group of fungus parasites responsible for the Fusarium root rots, or "wilt diseases." Nor was this merely accidental. The broader problems were forced upon his attention because he found these fungus wilts occurring upon the same hosts as the bacterial diseases he was then studying, especially in the mustard and nightshade families. Smith here evidences the fact that he was an exceptionally keen field observer and diagnostician. His general paper [5] on soil infesta-

[5] See citation in the bibliography to his paper on "The fungous infestation of agricultural soils in the United States" published in 1899.

tion remains one of the prophetic writings in the field of plant pathology.

At about this date (February-June, 1899), having a half-year leave of absence from my Vermont University duties, I accepted Smith's cordial invitation to transfer my own work upon a bacterial plant disease to his Washington laboratory. This was then located on the second floor of an old brick residence on Thirteenth Street, south of the original administration building of the Department of Agriculture. Up to this time, Smith had worked essentially alone. He trusted no one's aid in any technical laboratory work and only reluctantly consented, after a fortnight's association, to permit me to wash his glassware along with my own. Here he drew the line, however, continuing to sterilize all his own containers and make his own culture media. Soon after that date he opened his research laboratory to younger associates. This is indicated by the names of co-authors of several publications beginning with 1904. This was due, in part, to the increasing diversity in the researches under way. In part it was necessitated by Smith's assumption of a new and great responsibility for the preparation of his monograph, "Bacteria in Relation to Plant Diseases." To appreciate the magnitude of this, the reader unfamiliar with the publication should examine the three quarto volumes, understanding that from first to last Smith attended personally to every detail, giving exacting supervision to whatever he could not himself do.

Soon after the appearance of the first volume of this monograph, Smith began the work upon crown gall, which, with the collaboration of younger associates, was to continue throughout the remaining twenty years of his life. Others had suggested the possibility of plant tumors as having some likeness to cancer in animals. Especial attention in such comparisons had previously been given to the club root disease, which causes tumorous overgrowths in the roots of cabbage, turnip, and other crucifers. This is caused by an ameboid organism, a parasitic slime-mold, which invades the host cells and stimulates them to such pathological overgrowths. But no one had heretofore made intensive comparative studies of such plant and animal "tumors." Anyone knowing Smith would realize how naturally he felt

forced to accept this challenge and how dominantly compelling was the urge, once begun, to follow such studies with the intensity which he did. Whatever else is said, all must recognize this as a timely thing that needed to be done. It is doubtful if anyone would, or perhaps could, in that decade have done it so well. In connection with this, Smith not only mastered to a remarkable degree the voluminous international literature pertinent to cancer but familiarized himself with animal cancer types and tissues.

Reference to Smith's "Synopsis" shows that when this was written (1922) he had not yet seen the evidence accumulating about the location of the crown gall bacteria. In the following year there appeared the independent, almost simultaneous publications of Riker [6] in this country and of Robinson and Walkden [7] in England. These workers showed that the bacteria were located in the intercellular spaces and gave to the mechanism of "secondary tumor" and "tumor strand" formation a new interpretation. They showed that the bacteria were also located inside vascular elements and injured cells. Later the bacteria were observed inside large surface cells that had discontinued cell division.

Perhaps it is idle to speculate upon what might have been the influence on Smith's work with these problems could these facts have been discovered a decade earlier. To the writer it seems probable that, while it would undoubtedly have modified his emphasis upon certain details of his analogy between "tumor strands" in animal and plant tumors, nevertheless, Smith would have persisted in the essential fact-finding phases of his work, just as others are continuing it today. While it might have spared him some arguments with certain animal pathologists, Smith's long and intensive comparative researches with these malignant growths in plant and animal tissues had already won world-wide attention to this subject among cancer-specialists. In

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[6] Riker, A. J. 1923a. Some relations of the crown-gall organism to its host tissue. Jour. Agric. Research 25: 119-132, illus.

———. 1923b. Some morphological responses of the host tissue to the crown-gall organism. Jour. Agric. Research 26: 425-435, illus.

[7] Robinson, W. and Walkden, H. 1923. A critical study of crown gall. Ann. Bot. 37: 299-324, illus.

1913 the American Medical Association awarded him its certificate of honor for his work on "Cancer in Plants." In 1925, only a little over a year before his death, in further recognition of his leadership in this field, he was elected President of the American Association for Cancer Research.

It seems fitting to couple with this specific recognition some consideration of the broader significance of Smith's contribution. Smith himself in all his researches was, subconsciously at least, attacking his problems as a comparative biologist. He was at once most intensive in his personal work and most inclusive in searching biological literature for whatever was pertinent in the work of others. Smith's persistent comparative studies of the diseased tissues in tumorous overgrowths of plant and animal tissues may, therefore, be rightly evaluated as modes of attack upon such fundamental problems in cellular pathology. No previous worker had so recognized the potential worth of the materials and techniques of plant pathology as contributing to the advancement of comparative pathology. It is not without significance in this connection that the Rockefeller Institute of Animal Pathology at Princeton has broadened its scope to include plant pathology. It is also gratifying that the initial problems there undertaken were in continuation of Smith's earlier work with peach yellows.

The final testimonials to Smith's lifelong leadership and winning personality came only about three months before he passed away. At that time the American Phytopathological Society gave a dinner in his honor, followed by addresses concerning the characteristics of the life and work of their honored guest. An engraved brochure was there presented to him. This consisted of a dedicatory statement (1) followed by summaries of the three addresses of the evening: that of Frederick V. Rand, his long-time research associate (2); that of the writer, L. R. Jones, speaking for plant pathology (3); and that of William H. Welch, speaking for human and animal pathology (4).

1. To Erwin Frink Smith, scientist, linguist, poet, friend, who for forty years has devoted his life's service to the broad field of pathology, in grateful appreciation we the members of the American Phytopathological Society dedicate this memorial.

2. What Robert Koch was to the early days of human and animal bacteriology, that and more have you meant to the bacteriology of plant diseases. Almost single-handed you saw it through those first years of speculation and skepticism to its present broad and solid position among the sister sciences.

In your scientific work and influence you have made an indelible impression not alone upon plant science or animal science but upon the whole field of experimental biology. And what is to me most vital and reassuring, through it all you have never for a moment lost sight of the humanities nor of the beautiful things of the mind and of the world without. May I therefore be permitted to add the personal tribute of one who for over fifteen years has worked under the inspiration of your guiding hand.

F. V. R.

3. For leadership in early study of peach yellows, most stimulating example of dogged work upon a baffling problem, with prophetic assurance that knowledge of tobacco mosaic and aster yellows was pertinent to the solution;

For leadership in pioneer studies of bacterial plant pathogens, with classic publications, exacting models for all who followed; again with prophetic vision of the boundless extent of this field;

For zealous devotion in defense of truth;

For assembled contributions to knowledge of bacteria in relation to disease in plants;

For epochal researches on crown gall;

For sympathetic counsel to eager younger scientists, from far and near;

For thus exemplifying the Pasteurian characteristics: clear vision, instant action, intuitive judgment, precise method, tireless endeavor, sympathetic patience, self-sacrificing devotion in service through science;

For these things we delight to honor you:

Pioneer, prophet, exemplar, dean of our Science.

L. R. J.

4. No one in our day has done more to bring the two great divisions of pathology into close relations to their mutual advantage.

Your studies of plant tumors have brought you into the field of onkology in its broadest aspect. Here you take your place in national and international congresses and associations devoted to medical research and here your work is recognized as of the greatest in interest and importance.

While your name is associated especially with the championship of the parasitic theory of the origin of tumors, your studies of the mechanism of tumor formation, of problems of histo-

genesis, of formative stimuli and inhibitions of growth are scarcely of less importance.

We too on the medical side have learned to admire you as a man inspired with the highest ideals of the searcher for truth, and devoted to this search, with the heart, the methods and the loyalty of the ideal man of science.

W. H. W.

The end came a little over three months later (April 6, 1927) at his home in Washington, D. C. The funeral services were conducted on Saturday morning, April 9, at All Souls Unitarian Church in Washington, the Rev. U. G. B. Pierce officiating. In accordance with the known wishes of Dr. Smith, his ashes were scattered over the waters at Woods Hole, Massachusetts, from a promontory where he had loved to sit and muse.

In closing this memoir, recognition should be made of Smith's ever-increasing devotion to the finer cultures of life. Frequent tributes to this may be found in the earlier biographies listed at the close. None of these has more truly glimpsed the complex of Smith's scientific and artistic genius than has that of Rodney H. True, his long-time associate in Federal service. With Doctor True's approval we may therefore well close with the following excerpt from his tribute.

After referring to Smith's breadth of interests outside his laboratory through which he "strove with wonderful effectiveness to defend himself against the harmful results of specialization," True continues:

"He developed a knowledge of French, German and Italian literature that opened to him worlds of intense pleasure. Often have I seen him pursue some theme from language to language with an enthusiasm and facility that showed how deeply he read and thought. He read his Bible in a copy of the Vulgate; and Dante was a favorite with him in Dante's own great language. Goethe was often quoted in the original. Seldom have I known a man, whatever his training and field of work, who brought such joy and understanding to the works of great writers. His library was a sort of map of his mind. In it were all manner of noble things.

"His ear never ceased to find delight in music, more and more as the years went by, be it the music of the great poetry of the past or that poetry expressible in mighty harmonies. He took great delight in beautiful paintings, in sculpture and in architecture. No road along which beauty might enter was blocked.

"I think that while Dr. Smith was a true scientist to the very heart, he felt cramped by the physical world and sought greater freedom in the world of imagination where he could live as every man once in a while feels a desire to live . . . It seems to me that Dr. Smith was organized as artists, rather than scientists, are supposed to be. He was quick, enthusiastic, and strangely appealed to by beauty in all its forms . . . he may have had to learn the lesson of reserving judgment, of remaining skeptical, in short the whole defensive attitude of science. Thus the imagination of the artist was fundamental and by opening the book of nature it revealed to him the far reaches of life."

Synopsis of Researches of Erwin F. Smith

In the United States Department of Agriculture (1886-1922) [1]

To summarize in a few thousand words the research work of thirty-five years, as you have requested, is something of an undertaking.

After a university training which today would be considered very inadequate, I began work in the United States Department of Agriculture in the autumn of 1886 (aet. 32) on one of the most difficult problems imaginable, to-wit: a wide-spread destructive disease of peach orchards (The Yellows) in which no parasite was visible. The losses in Maryland and Delaware, where thousands of acres of peach orchards were cultivated like gardens, were enormous and the work correspondingly urgent, and I entered into it with more enthusiasm than knowledge or good judgment. The results of this work are embodied in three big Department Bulletins and a half dozen or more shorter papers. After some years I abandoned this research and devoted my time to other subjects, mainly, as I have often said, to save my reputation, but really because the problem appeared to me to be insoluble in our then state of knowledge. For that matter it has remained unsolved up to the present time.

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[1] Shortly after the World War, Dr. W. B. Brierley, English mycologist, visited the United States, spending some time in Washington. During this time he was a frequent visitor to Dr. Smith's laboratory and home. Brierley highly esteemed Smith and his work and the feeling was mutual. During one of their friendly conferences Brierley asked him if he had assembled material for an autobiography. Smith replied in effect that no one would be interested in the story of his life, and as to his scientific contributions the published papers would have to speak for themselves. Brierley continued to urge that he owed it to himself and to the scientific world to do something of the sort. Though not fully persuaded, Smith, after further consideration, concluded that perhaps Brierley was right and prepared this "Synopsis." Soon after this was written Dr. Smith gave a typewritten copy of it to each of several associates. Among these was Frederick V. Rand, a long-time member of his staff, to whom he told the circumstances which led him to write it. It has never before been printed. We are indebted to Dr. Rand for furnishing from memory the essentials in this statement.—L. R. J.

I specialized in the university on Peronosporaceae and during the first years of my connection with the Department of Agriculture I spent a part of my time, especially one winter, on *Phytophthora infestans*. I mapped the distribution of potato rot in the United States for the year 1885, and that of *Plasmopora viticola* for 1886, but I gave most of my time to a study of peach yellows (1886-1892) and to peach rosette (1888-1891), two very destructive diseases of the peach now generally thought to resemble mosaic diseases.

In case of peach yellows, known for many years and frequently written upon by horticulturists and others, I described the signs from exhaustive observations, showed that it could not be due to winter injuries, nor to root aphides, one species of which I described as new (Ent. Am. 1890), redemonstrated spread by grafting and budding, showed that the disease could not be cut out of slightly affected trees, nor carried on seed from diseased trees, followed the progress of the disease in hundreds of new cases every year, and by many experiments with fertilizers showed that it could not be due to exhausted soils. I also moved a carload of Delaware soil taken from a badly diseased orchard to Central Michigan and buried it around the roots of many healthy peach trees but no disease resulted. In two dry summers alternating with two wet summers I showed that the cases were most numerous in the dry seasons (Journal of Mycology, Vol. VI). Some thought the disease associated with overbearing but I found that it often began in young trees, and that there were many new cases when there was no fruit, even two years or three years running. Orchard XV of my Bulletin No. 4 (Veg. Path.) may be taken as an example of the destructiveness of this disease in one of the bad districts of middle Delaware. This orchard which never bore heavily, and most years not at all, contained 3,000 trees set 20 feet apart each way, and the cases by years were as follows: 1887 (year trees were planted) 0; 1888, 0; 1889, 3; 1890, 144; 1891, 338; 1892 (dry summer), 1091. Thus in three years over one-half of the orchard, propagated from a neighboring nursery, became diseased. In those years in Maryland (Kent Co.) and Delaware (Kent Co.) I saw the disease destroy many large orchards in seven to ten years from planting,

whereas 50 miles away (Caroline Co., Md.) there were peach orchards 40 years old still entirely free from the disease but which subsequently became infected. I also got, when set into badly diseased orchards, what I considered to be a few undoubted cases in peaches worked on plum roots. The tops came from trees that were outside of the diseased area and that remained healthy.

In case of peach rosette, which is more southern in its distribution and swifter in its action and was then a new disease, I showed how it differs from yellows, proved that it could be spread in the same way by grafting or budding, established that sometimes it did not occur in one side of a tree when it was present in the other side although the following year the entire tree became diseased, showed that when root grafts were made the disease developed later on the top of the plant than when parts above ground were budded with the diseased buds, found numerous gum-pockets in the wood of the diseased roots (wood only of the season in which the disease developed) and in the shrivelling fruits, and showed that mere contact of diseased tissues with wounds would not induce the disease but that some fragment of the grafted wood or bark must heal on in order to transmit the disease, although the tiniest bit was sufficient. There were 124 trees in my first budding experiment all but four of which contracted the disease. The signs of disease appeared first around the inserted diseased buds and a few months later the whole top became diseased. These trees stood in two nursery rows and none of the several thousand other nursery trees developed the disease. The cause of the disease was not determined.

While working on peach yellows in Michigan I discovered a peculiar disease of the peach, then new to the country but which has since attracted considerable attention, and published the first paper upon it. This disease is called "Little peach" because one of its conspicuous signs is the dwarfing of the fruits so that the trees become worthless. The cause of this disease also remains unknown.

During this period I published two papers on the brown rot of the peach (Monilia), one establishing its disastrous prevalence in the eastern United States in 1888 and proving that the

Monilia winters over in the mummied fruits, sporulates again abundantly the following spring in the form of conidia and causes blossom blight and canker of the shoots (Journal of Mycology, Vol. V). The second paper (Journal of Mycology, Vol. VII) gives additional details and figures the blight of the blossoms and the canker of the stems. It was not until some years later that Norton discovered the perfect form of this fungus (Sclerotinia) on mummied fruits two years old.

During this time I also studied gummosis of the peach and "foot rot" of the orange, with Comes' findings in mind, but without being able to convince myself that either one was due to bacteria.

In one of these years (1890) Mr. Walter T. Swingle and myself were sent posthaste into Florida to study a new and destructive disease of orange groves, characterized by the sudden wilting and shedding of the leaves. The disease appeared either first on certain branches only or all at once on nearly the whole tree. The smaller roots were clustered. Many fine orange trees in Central Florida were destroyed by this disease which was generally known as "the wilt." We came to no conclusion as to its cause other than that it appeared to be underground. What trees this disease spared the great freeze destroyed.

In 1892-3 I worked on an Alternaria disease of muskmelons which in Michigan I had seen destroy whole fields. The organism was cultivated from single spores and studied as to its morphology and behavior on culture media. I made many drawings and obtained numerous beautiful infections by spraying pure sporulating cultures on the foliage (Proc. A. A. A. S. for 1893, p. 258), but I never published *in extenso* because I found Victor Peglion in Italy had obtained the same results a year earlier and also, and chiefly, because I could not find any ascospore form of the fungus, which at that time I had thought must necessarily occur.

So closes the first period of my Department researches during which I did much proof-reading, reviewing, translating, and editorial and miscellaneous hack work.

Next I devoted a number of years (1894-1910) to the study of the Fusarium diseases of plants, a subject which was then

very new. There were at this time in the United States a number of destructive diseases of unknown origin, particularly on staple crops in the Southern States, in which I found Fusaria constantly and suspiciously present. I studied and made experiments with the Fusaria present in diseased melons, cotton, cowpeas, potatoes, tomatoes, and cabbage. I isolated the fungus from the interior of these plants in pure cultures derived usually from single conidia and with it produced the disease abundantly in case of several of them, thus showing it to be the parasite. I proved infections from the soil; inability of the various isolations to cross-inoculate, *e. g.,* on soil infected with pure cultures of the melon fungus I grew, from seed, rows of watermelons containing many plants, every one of which contracted the disease, alternating with rows of tomatoes, none of which contracted the disease although they were in the infected soil and only a few inches away from the dying melons; showed that the melon Fusarium was still infectious after being held dry in culture tubes for three years, and in case of the cabbage disease that the organism causing it remained alive and able to infect in soil from a diseased field which had been kept dry in the laboratory for two years. Special attention in a Department Bulletin on the potato Fusarium, published jointly with Deane B. Swingle,[2] was called to this black ring disease of the potato tuber which was then a new disease, at least to scientific men, and while infections were not undertaken the Fusarium was demonstrated to be the only organism constantly present in the diseased blackened vascular bundles and in the light of the many successful inoculations previously obtained on melon it was stated to be the parasite (a conclusion since confirmed by the experiments of others). This first good paper on this widely prevalent potato disease (Bureau of Plant Industry Bulletin 55, 1904) is now seldom referred to because

[2] In 1904 I made with Deane B. Swingle more than 100 freezings of various bacteria in liquid air, and in salt and crushed ice, showing that the critical temperature is around zero Centigrade and that repeated short freezings and thawings are much more destructive than a single longer freezing (Science, March 31, 1905, pp. 481-483). These results were confirmed in 1918 by Hilliard and Davis (Jour. of Bacteriology, pp. 423-431) but no mention was made of our work.

the writer unfortunately resurrected an old name, *Fusarium oxysporum* Schlechtendal, which was practically a *nomen nudum*, and applied it to this fungus.

As a result of these studies, which opened up a new field of plant parasitism, since all members of the form-genus Fusarium had previously been considered to be pure saprophytes, the writer read a paper "On the Fungous Infestation of Agricultural Soils in the United States" at a meeting of the American Association for the Advancement of Science in August 1899, which was soon afterwards published (November, 1899) in the Scientific American Supplement, No. 1246, pages 19981-82, and was the first paper on this subject published in the United States, or anywhere, so far as concerns soil infections due to Fusariums, some of which are as destructive as Peronosporas. In 1910 the writer showed a destructive West Indian banana disease to be due to a Fusarium (*F. cubense* EFS.) and this conclusion has since been confirmed and the disease studied exhaustively by Brandes (Phytopathology, Vol. IX). This soil disease, probably the worst banana disease in the world, certainly the worst in the Western hemisphere, has put thousands of acres out of commission in Central America and in Dutch Guiana in recent years. Dr. Ernst Gäumann (On a vascular bacterial disease of the banana in the Dutch East Indies, No. 48 Med. v. h. Institut voor Plantenziekten, Batavia, 1921) has recently called these conclusions in question but without any first-hand knowledge of the West Indian disease. Through the work of W. A. Orton, whom the writer selected for this purpose, highly resistant cottons, melons and cowpeas have been obtained and are now growing on Fusarium infested soils in the South.

During this period I wrote the mycological and plant pathological definitions of the first edition of The Standard Dictionary (with Walter T. Swingle from D to G and through the remainder of the alphabet alone)—a task of midnight hours.

In 1893, having found a fascinating subject in the cucumber wilt, I became especially interested in bacterial diseases of plants, then a rather new field, full of obscurities, and have done original researches on such diseases every year from that time to the present, having undertaken to monograph the whole group.

During these researches I proved water-pore infections in case of black-rot of cabbage; stomatal infections in half a dozen diseases; and insect transmission in cucurbit wilt, black-rot of cabbage and brown-rot of potato. Merton B. Waite, one of my colleagues, had earlier (1891) proved infection of the floral nectaries by bees and other insects in pear blight due to *Bacillus amylovorus,* and one of my assistants, Dr. Frederick V. Rand, has shown recently not only that my statements respecting summer transmission of cucurbit wilt by *Diabrotica vittata* are correct but also that my suspicions of its being a winter carrier of the bacillus (Bacteria in Relation to Plant Diseases, Vol. II, p. 215) were well founded. What occurs in some human diseases occurs also in case of this beetle. It is a carrier of disease and an intermediate host. It feeds greedily on the wilted leaves which are full of the bacillus and then gnaws healthy leaves to which the bacillus and the disease are transmitted. In most of the beetles this is the extent of their complicity, their intestinal contents soon destroying the ingested bacillus; but in others the bacillus multiplies and persists in their digestive tract during hibernation, i.e., until the following spring when it is voided in their feces and produces on gnawed or otherwise wounded leaves of susceptible plants the first spring infections (Phytopathology, Vol. X, pp. 133-140).

Urged on by Robert Hartig's and Alfred Fischer's denials, I also made many experiments with the olive tubercle using pure cultures plated from tubercles obtained in Italy and in California, repeating and confirming the positive inoculation experiments of Savastano and Cavara and for the first time demonstrating the morphology and cultural characters of the parasite never clearly expressed by the early workers and subsequently brought into much confusion by others.

Another result of these researches was the discovery of the bacterial nature of a whole group of tumors of uncertain origin, commonly known as crown galls. Associated with me in this discovery were Dr. C. O. Townsend and Nellie A. Brown. The results of this work were several papers in journals (Science, Botanical Gazette, Phytopathology [Vol. I], Centralblatt f. Bakt.,

etc.) and Bulletin 213 from the Bureau of Plant Industry, United States Department of Agriculture.

A critical review of the literature of bacterial diseases of plants was begun in 1896 in the American Naturalist but after a few numbers was broken off owing to pressure of researches which suddenly developed and appeared to me to be much more important, particularly as the literature of that time, with a few exceptions, was not very exact or very convincing.

In 1899-1901 occurred my controversy with Dr. Alfred Fischer as to the existence of bacterial diseases of plants (Centralb. f. Bakt. 2te. Abt.). This silenced all the critics and won over the doubting European public. Fischer never forgave me, but I could not do otherwise; nor do I regret the polemic, since it cleared the air and advanced the science.

In 1903 "Bacteria in Relation to Plant Diseases," a monograph, with many plates and text figures, was projected with permission of James Wilson, Secretary of Agriculture, and undertaken in a very liberal spirit by the Carnegie Institution of Washington. Of this monograph three quarto volumes have been published (1905, 1911, 1914) and three more will be required to complete the project. But even if it is not completed I have written many papers on various diseases, a description of which would naturally form part of the concluding volumes, e. g., on blights and tumor diseases, and many good workers are now in the field so that there is not that urgent need for its completion there was for its beginning. I hope, however, to complete at least Vol. IV, the mansucript of which is now well in hand.

Such urgent requests came to me from teachers that "Bacterial Diseases of Plants" (Wm. B. Saunders Co., Philadelphia and London), a text-book with numerous hitherto unpublished observations and 650 illustrations, was published in 1920. The difference between the title of this book and that of the Carnegie monograph shows very well the changed attitude of the public to which the writer conformed, changing from a title of argument and persuasion to one of certainty. This is the first handbook on bacterial diseases of plants.

In 1920 also, and by the same firm, was published "Pasteur, The History of a Mind," the same being a translation of Émile

Duclaux's fascinating account of the development of the scientific spirit in Pasteur. This translation was made so that many young English-speaking laboratory men and women to whom the French text is not accessible might have it in their own tongue, since it is as fascinating as a novel and splendidly emphasizes right methods of work without which there can be no progress in science. Florence Hedges, one of my assistants, was associated with me in its preparation.

Fortunately, I determined from the beginning of my studies of bacterial plant parasites to depend for proof only on experimental evidence derived from pure culture inoculations, and consequently I cannot recall that I have ever asserted a disease to be due to bacteria which was subsequently shown to be due to some other cause unless it be in case of coconut bud rot (Science, March 31, 1905), which is still in dispute, and where my sole dependence was on the microscope and the result of many poured plate cultures made from the advancing margin of diseased tissues. Johnston who worked on it independently came to the same conclusion. Reinking maintains that the primary cause of the Philippine bud rot of coconut is a Phytophthora, but whatever may be the wounding cause, bird, insect, or fungus, I must still think the West Indian bud rot of the coconut as I saw it at Baracoa and Mata in 1904 is due to bacteria, but of course there may be two or more bud rots.

The microscope alone in the hands of an expert pathologist and bacteriologist will often yield fairly conclusive evidence as to the parasitism of an organism but in the hands of a tyro it has often led astray. Hence the utility of the three famous rules of proof devised by Robert Koch, to which the writer added a fourth—reinoculations from the reisolations with positive results, again and again. (See Bacteria in Relation to Plant Diseases, Vol. I, pp. 9-17.)

In recent years so many of these diseases have come to my attention that I must suppose there are many others still undescribed in various parts of the world, and that, as I asserted in 1896 in a time of great scepticism, "there are as many bacterial diseases of plants as of animals" (Am. Nat. 1896, p. 627), only

then I added "in all probability", whereas now we may leave out that qualifying phrase.

Of these bacterial diseases of plants the following may be mentioned as having absorbed a good deal of my time for thirty years and on all of which I have published notes, or one or more papers, in many cases several papers.

I. *Wilt of cucurbits* (1893-1911) due to *Bacillus tracheiphilus* EFS. This is rather widely distributed in the United States and occurs also in Europe, Africa, and Asia. It attacks, wilts and shrivels cucumbers, muskmelons, pumpkins, squashes and some wild plants. The watermelon is resistant. It is a vascular, wound-infection disease which occurs in the forcing house as well as in the field and is distributed especially by leaf-eating beetles (*Diabrotica vittata* and *D. duodecempunctata*). The organism is not evident on the surface of the plant even in late stages of the disease but the spiral vessels and tracheids are then filled with its white slime which is generally very viscid, stretching out in long, delicate threads. It also disorganizes the primary vessel parenchyma forming numerous bacterial cavities. The organism is killed quickly by drying and there is a strain which attacks cucumbers and not squashes.

II. *Brown rot of Solanaceae* (1895-1920) due to *Bacterium solanacearum* EFS. I first described this disease from tomatoes, potatoes and egg plants and subsequently from tobacco (1908) but, thanks to Honing, Wolf, and others, it is now known to attack plants of various families in the East Indies and elsewhere and I have myself worked with it on Euphorbiaceae (Ricinus), Onagraceae (Fuchsia), Leguminosae (beans and peanuts), and Compositae (Helianthus), etc. The organism is a polar flagellate white rod which, however, produces a brown to black stain on various media (agar, steamed potato) and in many of the host plants. It not only attacks and destroys the cultivated plants I have named but occurs on or may be inoculated into various weeds of several families, e. g., Daturas, Ambrosia, Eclipta. On potatoes it attacks and shrivels the shoots and travels down the vascular system into the tubers, the brown rot always appearing first in the vascular ring of the latter and only later coming to the surface. In this disease there is eventually more or less

slimy brownish ooze to the surface of the plants, accompanied by dark leaf and stem stripes which are the stained vascular bundles showing through the uninjured outer tissues. The organism persists in certain soils and tomatoes and tobaccos are often infected from the soil through roots broken at the time of transplanting. The disease often follows the labors of a careless transplanter like a pest but respects the work of a careful man. The disease is more southern in its distribution than the preceding. It occurs in many parts of the middle and southern United States, in the West Indies, in Africa and Asia, and probably in South America. It is very common in the Dutch East Indies and in Japan on tobacco. Warm temperatures are necessary for its rapid development. Under favorable conditions pith and cortex are honeycombed with bacterial cavities. The organism, which is non-liquefying except perhaps slightly in prolonged culture at high temperatures (Nakata), loses virulence readily on media and is sensitive to dry air. There is a strain which splits fat with production of an acid.

III. *Black rot of crucifers* (1897-1911) due to *Bacterium campestre* (Pammel) EFS. Pammel's work on turnips was extended to cabbages, cauliflowers, kale, rape, mustard, etc., with many additions and much field, laboratory and hothouse work. The disease is due to a yellow, polar flagellate, liquefying, starch-destroying organism, which enters through the water pores or through wounds, but seldom through the roots, and multiplies very abundantly in the xylem part of the vascular bundles which take on a dark stain so that usually the attacked leaves of cabbage show a black net-work on a pale green or yellowish ground. There is little ooze to the surface and the disease is not a wet rot, but soft rots may follow it. All cultivated crucifers are subject to it and the organism causing it is carried on the seed. The disease has been widespread and destructive in various parts of the United States and occurs in Europe, as Harding first showed, and in other parts of the world. I have seen it in the West Indies.

IV. *The yellow disease of hyacinths* (1897-1911) due to *Bacterium hyacinthi* Wakker. This disease, apparently confined to the Netherlands, was first studied by the writer on Dutch bulbs

in the United States and afterwards in Holland, Wakker's statements, very good for their time, being confirmed and extended, especially as regards the biology of the parasite, sensitiveness of varieties, manner of infection, etc. A few varieties are very resistant and have retained the resistance for many years; others, which were noted by Wakker as much subject to the disease are still subject or have been discarded, while still others formerly recorded as resistant are now attacked. The organism causing the disease produces longitudinal stripes on the leaves and a bright yellow slime which oozes from the cut vessels of the bulb. It is a feeble liquefier, has less action on potato starch than the preceding or the following, and its action on the hyacinth is slow. It is principally a vascular disease.

V. *Bean blight* (1897-1920) due to *Bacterium phaseoli* EFS. This is a widespread disease in the United States both on bush beans and climbing sorts and often does much damage. It occurs also in Europe, Asia and Africa. The disease attacks leaves, stems and pods. It is especially a disease of warm seasons and moist weather. It is distributed on the seed and stomatal infections are common and are very easily obtained in the hothouse or field by spraying, especially if the soil and air are moist and the temperature is high. It is sometimes found in the vessels but grows most abundantly in the intercellular spaces forming bacterial pockets in the parenchyma and oozing to the surface freely as a yellow slime, drying in crusts. The organism is yellow on media, polar flagellate, starch destroying and much like No. III of this paper, but does not cross-inoculate.

VI. *Cobb's disease of sugar cane* (1901-1914) due to *Bacterium vascularum* (Cobb) Greig Smith. I verified Cobb's conclusions and extended them on cultural material isolated from diseased canes received from New South Wales. I obtained the first clean cut pure culture inoculations in a hothouse in Washington in 1903, and subsequently worked out the cultural characters of the parasite. The signs of the disease are dwarfing, white or yellow striping of the leaves, gumming of the upper leaves with twisting and kinking of the terminal bud, death of the growing point, with appearance of yellow slime in the bundles of leaves and stems. Many of the bundles are also stained red

but this is a host reaction not confined to Cobb's disease. This is a vascular disease, but in the softer parts especially under the terminal bud the parenchyma breaks down into large cavities full of bacteria and fragments of tissue. In my inoculation experiments, which covered a period of four years, some varieties of cane proved much more susceptible than others. The organism is polar flagellate and yellow on various culture media and belongs with the yellow species already mentioned. The disease occurs injuriously in Australia (Queensland and New South Wales) and probably in other cane growing regions of the world but I have not seen typical specimens from either North or South America, and there is some doubt as to other cane regions. The disease is spread in cane cuttings.

VII. *Stewart's disease of maize* (1898-1920) due to *Aplanobacter Stewarti* (EFS) McCulloch. This is a common disease especially on sweet maize in the warmer parts of the United States but it is found also on some varieties of field maize. It occurs also in South Africa and probably in Australia. High temperatures and abundant moisture have much to do with its prevalence. It is much more common on early and choice sweet sorts than on later and coarser kinds. The disease is transmitted on the seed but often it does not appear in the field conspicuously till one or two months after planting. The writer obtained the first convincing infections with pure cultures in 1902, making his inoculations by placing the organism on the tips of leaves extruding water, i. e., in the seedling stage and transplanting to the field some weeks later. The infections are stomatal and probably also by way of the water pores. Dry and cool conditions are very unfavorable to general infection of the plant. When this occurs the plant is dwarfed, the leaves shrivel one after another from below upward, the ears are more or less abortive, the male inflorescence develops prematurely, and on cross section of stems there is an abundant ooze of yellow slime from many vascular bundles. In the husks the bacterial slime forms many small cavities and oozes to the surface freely through stomata, often covering the kernels, but I have found it also in the vascular bundles at the base of the kernels. The writer first described the parasite from cultures sent to him by Stewart for

that purpose and figured it as polar flagellate, but subsequent studies in his laboratory showed this to be an error and the statements in the text-book are more dependable as to morphology and cultural characters than those in Volume III of the monograph. The organism is non-motile (Lucia McCulloch) and only feebly active on potato starch. It attacks leaves, stems, husks, cobs and kernels, and in the latter it persists in a viable condition for a considerable period—more than a year. There are various yellow saprophytic bacteria on the kernels of maize.

VIII. *Mulberry blight* (1905-1921) due to *Bacterium mori* B. and L. emend, EFS. In 1893 Boyer and Lambert published a note on this disease in C. R. of the French Academy and claimed infections with a schizomycete isolated from the diseased tissues. They promised another paper in which they would give details and describe the organism, but never published anything more. In Italy various persons have studied a bacterial blight of the mulberry and described a yellow organism as its cause, but without any clear cut infection experiments. I began work on the American mulberry blight in 1905 but owing to Italian statements the first summer was devoted to yellow schizomycetes which are not infrequent. As none of many inoculations with yellow organisms plated from the diseased tissues gave any positive results I turned my attention thereafter (1908) to a white, non-sporiferous, non-liquefying organism common in the diseased tissues and with it have obtained many good infections, in different years, the last of which were in 1921. I assumed from the beginning that the American disease was the same as the French, an assumption since confirmed by my own experiments and those of Arnaud and the only doubt that now remains is as to whether there may be another bacterial disease of mulberry in Italy due to the yellow sporiferous organism, *Bacillus cubonianus* Macch. This I will not undertake to decide. As Boyer and Lambert obtained infections with the organism they called *Bacterium mori* I think, as I have stated elsewhere, that we may use their name and with a nearly clean slate write a proper description of the organism. This at least is what I have done.

IX. *The black spot and canker of peach and plum* (1902-1922), due to *Bacterium pruni* EFS. I discovered this disease on Japanese plums in the United States (Michigan) but it occurs also in Japan and in both countries attacks both plums and peaches. In the United States the disease occurs from New England to Georgia and westward to beyond the Mississippi. The disease is not a soft rot, but one of meristematic tissues. Old tissues cannot be infected. The signs of the disease are spots on leaves and fruits and cankers on stems which latter carry the disease over winter. In bad seasons the trees are defoliated in late summer and the spots on the fruits render them unsalable. The infections are stomatal. The spots at first are very small, circular and watersoaked in appearance, but they slowly enlarge, coalesce and shrivel so that on the green fruits of the plum there may be numerous round or irregular black sunken spots ¼ inch or less in diameter. European varieties are less subject than Japanese. Generally on peach fruits the spots are smaller but they may be numerous. Often as they approach maturity the spotted fruits crack open inviting the entrance of various fungi. On leaves the shriveled spots drop out easily and the tissue between spots often becomes yellow. On branches also the progress of the disease is slow with formation of numerous small bacterial pockets in the cortex ending by fusion in rough cracks, but even near such pockets the tissues for the most part appear to be alive or to die slowly. I have produced the disease with pure cultures in different years on fruits, leaves and shoots of the plum and on leaves and stems of the peach and have published various notes on the disease in Science and elsewhere and good figures in my monograph (Vols. I, II). I have not yet given a full account of the organism but Rolfs has done so (Mem. 8, Cornell Univ. Agr. Exp. Sta., 1915). It is a yellow polar flagellate species growing readily on a variety of common culture media. Gelatin is liquefied, nitrates are not reduced, and milk is slowly coagulated (lab) and digested with formation of tyrosin, etc. It is easily inoculated through wounds or by spraying. Generally it can be detected on thin sown agar poured plates by the appearance of its colonies which are round and pale yellow, smooth on the

surface but with internal striae visible by oblique light. The organism is not viscid when grown in Uschinsky's solution but is often accompanied by a yellow saprophyte which makes that culture medium extremely viscid so as to resemble white of egg (Bacteria in Relation to Plant Diseases, Vol. I, fig. 11). In young shoots of Japanese plum inoculated on one side only by needle pricks, I have observed that the inoculated side ages faster than the opposite side as shown by the premature formation of lenticels and of cork. In one orchard I observed the west side of fruits to be ten times as spotted as the east side and Halsted observed the same thing in case of the bean blight (No. V). This I attribute to persistence, on the side opposite the morning sun, of rain or dew favoring infection. In one orchard I observed trees on the moister land to be most subject to attack and Kuwatsuka has shown (An. Phytop. Soc. Japan, Vol. I) that wet soil is correlated with wide open stomata and many infections.

X. *The angular leaf spot of cotton* (1900-1920) due to *Bacterium malvacearum* EFS. The name angular leaf spot was given by Atkinson to indicate the limiting action of the large veinlets. He observed bacteria in the spots but his infections were unsuccessful. I cultivated and described the organism, first reproduced the disease by pure culture inoculations and also first demonstrated that the black arm of stems and the rot of bolls are a part of the same disease. I showed also that the cotton gummosis of Asia Minor and the leafspot of South Africa are due to it. We now know that the disease occurs in all the principal cotton growing regions of the world and that beyond much doubt it is commonly distributed on seed. Cook has seen it in China but chiefly on Egyptian cotton and Bovell and Dash have reported it as serious on late cottons in the Barbadoes. It is due to a yellow polar flagellate organism. The infections are stomatal and all parts of the cotton plant are attacked. The disease is much worse in some seasons and in some localities than in others. Many varieties are subject to attack but in different degrees. The disease also appears to pave the way for fungous infections particularly the Colletotrichum rot of the bolls. In severe cases the bolls drop off, or

become one sided with stained lint, the leaves fall early, fewer bolls mature, and the smaller branches break over. In other and perhaps the majority of cases the disease passes almost unnoticed. In rainy weather Faulwetter has shown that the disease may be wind-driven. Good figures with some account of the organism and of the literature will be found in my text-book.

XI. *The angular leaf spot of cucumber* (1906-1915) due to *Bacterium lachrymans* Smith and Bryan. This is a disease confined principally to the foliage which may be severely injured so that the crop is reduced in value or destroyed. As in the preceding the larger veinlets exert a limiting action on the spread of the organism in the tissues. The specific name *lachrymans* refers to the tendency of the parasite to ooze to the undersurface of the spots in copious fluid drops which dry to white crusts. The disease is common in the United States and probably occurs on the cucumber in all parts of the world. The infections are stomatal and the disease is not a soft rot. It is believed to be seed borne. The organism is a slowly-liquefying, white, polar flagellate, capsulate species.

XII. *Stripe disease of broom corn and sorghum* (1904-1922) due to *Bacterium andropogoni* EFS. This produces long red stripes on leaves and stems with copious ooze of the bacteria to the surface drying in reddish crusts so that the bacteria might seem to be red, but the red color is only a copious host reaction and the organism on media is white on agar poured plates, forming small, circular, slow growing, smooth, shining, more or less viscid colonies. The parasite, which is polar flagellate, aërobic, non-sporiferous, non-liquefying and non-nitrate reducing, enters by way of the stomata. It blues litmus milk and has slight action on potato starch. I secured many good infections on broom corn in one of our houses by spraying on the pure cultures diluted with sterile water and some good figures, including pure culture stomatal infections, have been published (Bact. in Rel. Pl. Diseases, Vols. I and II) but I have not yet fully described the organism nor have I seen it in recent years.

XIII. *The bacterial canker of tomato* (1909-1922) due to *Aplanobacter michiganense* EFS. This disease was first studied on material received from Grand Rapids, Michigan, and for

want of a better name was dubbed "The Grand Rapids disease." Subsequently in my text-book I gave it the above name. In large fields about Grand Rapids where tomatoes were grown for canning it proved a very bad disease. I have since received it from New York and Massachusetts and believe it is not confined to the United States. It is a slower disease than the brown rot of Solanaceae (No. II), one leaflet after another wilting and shrivelling rather than all at once. The infections are stomatal and the disease is probably seed borne. The parasite is frequently in the fruits in great numbers and I have seen it in the placenta close to the seeds but not actually in the seeds. To find it *on* or *in* the seeds is undoubtedly only a matter of time. The phloem and other tissues are disorganized and the organism shows a strong tendency to ooze to the surface through fissures in stems, leaves and fruits, the tissues being swollen and whitish before they crack open. The organism is yellow and non-motile. It cannot be plated from the plant unless the media are adapted to its growth. If the agar is too acid or too alkaline no colonies of the right organism will appear. In this connection consult figure 160 of my text-book. It is often accompanied by motile yellow saprophytes but I have never observed the parasite itself to possess any motility nor have we been able to demonstrate any flagella by any of our expert methods, and our non-motile organism continues to be infectious (1922).

XIV. *Lilac blight* (1906-1907) due to *Bacterium syringae* (Van Hall) EFS. Beyerinck isolated the organism and with it reproduced the disease on lilacs in 1899 and 1900. In 1901 Van Hall, using Beyerinck's old cultures, failed to obtain infections so that the personnel at the laboratory in Amsterdam were all sceptical when I began my investigations. I studied the disease in 1906 in a lilac nursery at Naarden. It spots and twists the leaves and runs up and down the young shoots as black stripes often more on one side than the other with distortions, but in bad cases the whole shoot is killed and many cavities full of bacteria are found in the cortex. The parasite, a polar flagellate, green fluorescent species, was isolated in poured plates in Amsterdam at the Willy Commelin Scholten laboratory and the disease was reproduced by needle prick inoculations on

healthy lilac shoots in the garden connected with the Institute. Although I considered the season too far advanced for best results by carefully selecting my shoots I obtained a number of good infections as all knew. In the spring of 1907 I repeated the inoculation experiments on lilacs in Washington with positive results and made some further studies of the organism but did not publish. The organism loses virulence on culture media as Beyerinck and Van Hall first showed. The disease occurs in England, Holland and Germany but I have not seen it in the United States except as I reproduced it here by pure culture inoculations. Güssow published on it in the Gardeners Chronicle in December, 1908.

XV. *Rathay's Disease of orchard grass* (1913) due to *Aplanobacter rathayi* EFS. In 1899 Emerich Rathay of Klosterneuberg, near Vienna, published a preliminary paper on "a bacteriosis of Dactylis glomerata" which interested me tremendously because it appeared to be founded on a new type of bacterial disease. At the time of his death it was known that he had completed the manuscript of a much more extensive paper covering many of the gaps in his first paper but unfortunately this was never published nor is it now in existence. In 1913 I received a disease of orchard grass from Denmark which corresponded in many ways to Rathay's description and the same year I visited Klosterneuberg and saw and photographed alcoholic material preserved by Rathay and also found a little of the disease in the woods on the Kahlenberg where he had collected his specimens. From this fragmentary material I made the note published in Bacteria in Relation to Plant Diseases, Vol. III.

The organism, like *Ap. michiganense,* is sensitive to culture media. The growth is chiefly external, i. e., between appressed parts of the spikelets and upper leaf sheaths and the gumming together of the latter leads to curious knee-shaped bucklings of the stems. No one has reproduced the disease by inoculations and the diseased clumps which I collected on the Kahlenberg and planted in one of our hothouses gave no diseased shoots the following years, possibly because our hothouse conditions were too dry. Since my notes were published, O'Gara has

found a very similar disease on Agropyron in Utah and Hutchinson on wheat heads in Punjab in India.

XVI. *Black chaff of wheat* (1915-1922) due to *Bacterium translucens* var. *undulosum* S., J. and R. This disease came to my attention in 1915. It first attracted general attention that year only in Kansas but we now know that it occurs in all or nearly all of the wheat states beyond the Mississippi. In 1917 I sent several collectors into the Middle West and corresponded with many persons in an effort to learn its distribution and prevalence. Every specimen sent in was numbered and examined and if hopeful cultured from, and in this way we found the disease many times on spring or winter wheat in fourteen states. Along with the field work, laboratory and hothouse and field experiments were undertaken in Washington to determine the cause of the disease. Jones and Reddy also worked on it independently in the West. It is due to a yellow polar-flagellate schizomycete easy to isolate and grow on a variety of media. It infects all parts of the plant beginning with the seedling. It produces water soaked and yellow or brownish stripes on the leaves and sunken black stripes on culms and glumes. It is carried over winter on the kernels; it occurs on their surface as dry films and in bacterial cavities inside of the grains. In severe cases the heads are shortened and the kernels are shriveled. Badly attacked fields have a brownish rather than a golden appearance as the harvest approaches. The bacteria ooze freely from the lesions and dry as tiny films or crusts on leaves, culms, glumes, awns, and berries. From cross sections of diseased leaves, glumes, or kernels mounted in water under the microscope clouds of bacteria may be seen to ooze, if examinations are made at once. The disease has been reproduced by pure culture inoculations in Washington by the writer and by various assistants many times during the last few years. Infections on the leaves are stomatal and probably also through the terminal group of water pores. In the field the disease is a variable one depending largely on weather conditions. Moist seasons favor it and dry ones check it. I have not seen it east of Western Illinois. Its sudden prevalence throughout that region of the United States which received many Russian wheats in recent years makes me

think that it was imported from Eastern Europe. I suspect that the disease occurs also in South Africa. It can be controlled by formalin seed treatment without injury to germination if the presoak method developed by Harry Braun of my laboratory is used.

The organism is closely related to *Bacterium translucens,* the cause of a barley disease. The specific name *undulosum* refers to the fact that on agar poured plates the surface colonies examined by oblique light are seen to be conspicuously internally striate although perfectly smooth by reflected or direct transmitted light (see fig. 13 and other figures of my text-book). Nothing is known as to its effect on flour.

XVII. *Olive tubercle* (1903-1922) due to *Bacterium Savastanoi* EFS. In 1887-9 at Naples, Luigi Savastano made for the time excellent researches on this disease. He found bacterial pockets in the tumors and reproduced the disease with a schizomycete isolated therefrom. Cavara repeated and confirmed Savastano's experiments but neither one gave any good account of the organism which was generally called *Bact. oleae* (Arcangeli) and considered to be yellow, till Schiff-Giorgini stated it to be a white, spore-bearing schizomycete. This species he described very fully but without any attempt at careful infections assuming other authors to have sufficiently established its pathogenic nature. Meantime Robert Hartig and Alfred Fischer both discussed the disease denying that any one had established its bacterial origin. In 1903 and subsequently I produced olive tubercles readily in our hothouses using (1) a non-sporiferous white organism isolated from olive tubercles obtained in California and again (2) using the same organism but plated from olive tubercles collected in Italy. Soon after, I obtained Schiff's organism and repeated most of his cultural experiments finding his statements in general to be correct including sporulation, but with his organism, which was peritrichiate flagellate and had all the characteristics of a common potato bacillus such as *Bacillus vulgatus,* the most painstaking and copious inoculations failed to produce any tubercles even on very young and rapidly growing olive shoots. Inasmuch as Arcangeli's name (*Bacterium oleae*) was given without any cultural characters and without

any evidence as to its pathogenicity or any belief in it, and as his organism was considered by Berlese to be a yellow species and by Schiff-Giorgini to be a white spore-bearing species, I gave to the very different polar flagellate, non-sporiferous organism which I had isolated in pure culture and had proved to be actively pathogenic a new name in honor of Savastano, the man who first showed the tubercle to be due to bacteria. The right organism is sensitive to heat, grows freely in Cohn's solution, blues litmus milk without coagulating it and forms typical, erose margined, non-liquefying white colonies on gelatin plates.

The disease occurs all around the Mediterranean and probably wherever olives are grown. The organism causing it commonly enters through wounds, and in my experiments the first evidences of overgrowth followed within a week or two of the needle pricks while under favorable conditions growth continued for a number of months. Cavities full of bacteria are formed in the tubercles, and the organism is able to invade by way of the spiral vessels with production of new tumors at a distance from the mother tumor as Schiff-Giorgini first showed. It also oozes readily to the surface of the galls in wet weather (Horne) and again enters the plant through wounds. Petri, who has verified many of my statements, claims to have established a symbiotic relationship with an olive insect, *Dacus oleae,* the digestive diverticula of which are full of bacteria. Some varieties of olives are more subject than others. The trees are dwarfed and rendered unfruitful but are seldom killed outright. The tubercle may be either hard and woody or quite soft and cheesey from excess of bark parenchyma but always it contains bacterial cavities more or less brown stained and with water soaked margins. The spiral vessels in which I found invasion of the bacteria with production of secondary tumors are also more or less disorganized and stained brownish. In old tubercles yellow and white saprophytic schizomycetes are common. James Birch Rorer was associated with me in my first studies of this organism.

XVIII. *The sugar beet tubercle* (1910-1911) due to *Bacterium beticolum* S., B. and T. This disease which somewhat resembles the preceding was discovered on sugar beets during

our study of crown gall and was reported on briefly in Bull. 213 (pp. 194-195, pl. XXXIV). The disease came to us from Colorado and Kansas in 1910 and has not been seen since. These beets had a conspicuous nodular growth superficially resembling crown gall, but in the center of the nodules there were areas of softening and cavities with water soaked brownish margins and a mucilaginous stringy content containing great numbers of bacteria. Pure cultures of a yellow, capsulate, polar-flagellate, gram positive, gelatin liquefying, nitrate reducing schizomycete were plated from the center of such nodules and with it the disease was reproduced on sugar beets in Washington. Peklo also reproduced it in Bohemia using transfers from cultures which I had sent to Kràl in Prague. The organism made Uschinsky's medium very viscid and in it enormously thick-walled capsules were formed. The bacterium did not grow in Cohn's solution, tolerated 9% NaCl in bouillon, resisted drying and measured 0.6 to 0.8 by 1.5 to 2μ.

XIX. *Crown gall* (1892-3 and 1904-1922) due to *Bacterium tumefaciens* S. and T. My first acquaintance with this disease was on peach trees from California and the South in 1892-3, at which time an effort was made, chiefly by means of the microscope, to find in the galls a fungous or plasmodial parasite. As nothing constant of this nature was discovered and bacteria were not then in mind the subject was dropped. It was taken up again in 1904 on Paris daisies received from New Jersey with bacteria definitely in mind because the overgrowths superficially resembled olive tubercle in which I was then interested and knew from pure culture inoculations to be due to bacteria. The history of the early work is recorded in Bulletin 213 and need not be repeated here.

Earlier than any positive work in the United States Department of Agriculture, Cavara in Italy studied the disease as it occurs on grapes, isolated a white organism and with it produced a few tumors, but of this I knew nothing until I began gathering together the literature references for Bull. 213 after completion of our first researches.

The general outcome of these researches, continued for many years and still going on, has been an entire revision of views as

to the nature of the disease and as to sanitary measures necessary for its restriction. We now know not only the morphology and biology of the organism causing the tumors but also that the type of the tumor varies with the part infected, that there are several strains of the organism and probably many, that isolations differ in virulence, that some colonies which look all right have no virulence whatever, that on culture media and probably in the plant some strains lose virulence much sooner than others, that isolations are cross-inoculable to a very surprising degree, i. e., to plants of many families, that some plants, immune or nearly immune to certain strains, respond vigorously to other strains, and that some species are resistant to all strains so far as tested, e. g., olive, onion and garlic.

Things not yet determined are the number of strains, the extent of cross inoculability, the cause of resistance, the reason for loss of virulence on media, the nature of certain beet tumors and the question whether right looking but non-infectious colonies from such tumors and occasionally from other tumors are really the parasite deprived of infectious powers by sojourn in the plant under unfavorable conditions or are only deceiving saprophytes, extent of variability of the organism on culture media and in the tumor, production of metastasizing tumors in animals, etc.

The organism is a white, polar-flagellate, short rod, forming usually small, circular, smooth, watery, translucent colonies on agar poured plates. It grows on all the common culture media but must be transferred frequently. In media and in the tumors Y-shaped or other involution forms are common and often the colonies from tumors come up very slowly on poured plates. It does not stain by Gram and we have not been able to stain it in the tissue so as to distinguish it but it can be plated readily from young tumors. For further information, consult Bulletin 213 and the text-book where many interesting details are given.

The disease occurs on many kinds of plants in all parts of the world, most destructively on grapes, almonds, peaches and raspberries. Under favorable conditions the tumor begins to be visible within a week of making the needle pricks and continues to grow for several months or even for several years. One inocu-

lation does not protect from another. Unlike the preceding there are no bacterial cavities nor has the parasite been seen in the intercellular spaces or vessels. In the tumor tissue it occurs inside the cells and does not multiply so as to destroy them but only so as to stimulate them to divide repeatedly. Nellie A. Brown and Lucia McCulloch have been associated with me for many years in the study of this disease and the organism which causes it.

XX. *Soft rots.* The writer has also verified most of the statements of Prof. L. R. Jones on *Bacillus carotovorus,* of F. C. Harrison on *Bacillus solanisaprus,* of Otto Appel on *Bacillus phytophthorus,* of C. J. J. van Hall on *Bacillus atrosepticus,* and of Pethybridge and Murphy on *Bacillus melanogenes,* all of these isolations having passed through my hands. With exception of *B. atrosepticus* I found all of these organisms able to attack actively full grown parenchymatic tissues especially those full of water and to some extent also soft green shoots. They are not vascular diseases. Part of my conclusions have been published in the text-book and others await publication.

XXI. *Fire blight of pome fruits.* In the same way I have verified most of the statements of T. J. Burrill, J. C. Arthur, Merton B. Waite and others, respecting *Bacillus amylovorus* (Burrill) Trevisan, the cause of fire blight of apples, pears, quinces and other pome fruits. Trevisan never saw the disease but only changed the name of the organism. Exclusive of the soft rots this is probably our most destructive bacterial disease. It attacks leaves, shoots, flowers and young fruits and in general any rapidly growing meristematic tissues. Old tissues are not easily infected. Its most conspicuous effects are on shoots of the season but it is not confined to such but often attacks the cortex of large branches or of trunks and roots during the warmer part of the growing season, girdling and killing many trees. In late spring and early summer the tops of trees may be spotted all over with blackened shoots and dead leaves of flower clusters. The organism is transmitted by many leaf puncturing and nectar-sipping insects and enters through the uninjured nectaries or through wounds. It is carried over winter in restricted spots on exceptional trees, as first shown by Waite,

which spots ooze insect-frequented infectious fluids in the spring. During the summer also the organism comes to the surface easily and copiously through rifts and through natural openings (stomata) and is often distributed by the pruning knife. Many varieties of apples and pears are subject to the disease, some much more than others. The disease occurs all over the United States and has been introduced into Japan and New Zealand. I am in doubt as to its distribution in Europe. There are resistant species of Pyrus in Eastern Asia. A summary of my conclusions with many figures will be found in the text-book (pp. 359-388).

The above diseases fall into several intergrading types: (1) Vascular: *a,* xylem diseases, *b,* phloem diseases; (2) parenchymatic: *a,* diseases of immature parenchyma (blights, spots, cankers), *b,* soft rots, able to attack mature fruits and fleshy roots; (3) surface growths between closely appressed organs; (4) tumors of at least two different types: *a,* tubercles, *b,* crown-galls.

The organisms enter the plant in various ways: (1) through natural openings (nectaries, water-pores, stomata, lenticels), or (2) through wounds (broken roots, insect injuries, wind injuries, hail lesions, cuts due to pruning knives, etc.).

The reactions of the plant are changes in form and color, yellowing, reddening, greening, blackening, veining, spotting, twisting, loss of foliage, dwarfing, shrivelling, gum-exudate, cork-formation and in some cases overgrowths with or without excessive multiplication of shoots and roots. One attack of a disease so far as known does not protect from a second attack. Recovered plants may still harbor the parasite.

The schizomycetes causing these diseases are all non-sporiferous so far as known, and are quickly killed by exposure for a few minutes to temperatures considerably under that of boiling water (50° or 60° C. for 10 minutes). Very few of them grow at blood temperatures but many will grow (slowly) at or near 0° C. Most grow readily on a variety of culture media. The optimum growth temperature for most lies between 25° and 35° C. A few are rather sensitive to growth conditions (acids, alkalies, temperatures) and also must be transferred at frequent intervals. Some lose virulence readily on media; others

lose virulence for some species of plants before they do for others. Many are seed-borne or insect carried. Some are carried over winter in cankers.

I recognize three genera based on morphological characters: (1) Bacillus (peritrichiate flagellate); (2) Bacterium (polar flagellate); (3) Aplanobacter (non-motile); and separate the species chiefly on pathogenicity, reaction to stains, to culture media, to acids, alkalies, germicides, temperature (maximum, minimum and optimum for growth), dry air, etc.

The reasons I have given for my views on nomenclature of genera may be found in Bacteria in Relation to Plant Diseases, Vol. I, pp. 154-174, and still hold good. All descriptions in natural history should be based as far as possible on morphology. I have no sympathy with those who would make a genus for every species, nor, on the other hand, with those who would lump everything indiscriminately. Science is not advanced by either process. Nor do I think that chemical and physiological attributes are a satisfactory basis for distinguishing genera, e. g., the species I have mentioned ought not to be put into one genus (Erwinia) simply because they are plant parasites. (Journal of Bacteriology, 1917, p. 547.) Eventually I hope to give a key to all the species parasitic on plants but am not ready to do so now.

In recent years the study of crown gall has absorbed much of my time. As early as 1907 I conceived the idea from the involved microscopic structure of the tumor that its study might throw light on cancer and the more I have studied it the more analogies I have discovered. I have recorded the results of my studies and speculations in Bulletin 255 and in various medical and other journals and have recently summarized the whole subject with good figures in my text-book so that I shall touch on it here very briefly and only do so because any light that can be thrown from any branch of science upon the obscure subject of cancer ought to be welcome.

The crown gall tumor is an astonishing hyperplasia in which there are no bacterial cavities. It is a tumor not subject to physiological control and is of no use to the plant. The bacteria multiply within the rapidly dividing cells, which they do not kill,

but only mildly stimulate. We have not been able to demonstrate them in the tissues under the microscope with any certainty but they can be isolated by the methods of the bacteriologist. With virulent pure cultures and sensitive plants it is possible to obtain 100% of infections with none whatever in the controls. We have done this repeatedly on various plants. The organism causing this tumor is a medium sized, white, polar flagellate rod, able to grow in a variety of culture media. It is a wound parasite and no special carriers have been discovered. Usually the tumor begins to be visible a few days after the needle pricks are made, grows rapidly, if the plant is in good condition, dwarfs, crushes and destroys the surrounding parts and kills or injures the whole plant. Its action on the plant as a whole depends on its location, on the species susceptibility, on individual resistance, on the virulence of the strain, etc. Always in crown gall as in all other parasitic diseases two variable factors are to be kept in mind continually; (1) the virulence of the parasite, (2) the resistance of the host. He who keeps the parasite only in mind can have but a very one-sided and imperfect conception of the etiology of a disease. (The Journal of Cancer Research, Vol. V, pp. 243-260, July, 1920.) Generally the progress of crown gall, especially on trees and shrubs, is slow. The tumor may be largely parenchymatic in which case it dies early leaving an open wound with new tumor tissue developing on its margin, or hard and woody from the inclusion of many tracheids in which case it grows slowly and often persists for a long time. The tumor has a stroma consisting of supporting cells and vessels. It has no capsule and grows from its periphery converting surrounding cells of the same type (cortex cells) into tumor lobes. The primary tumor often develops tumor strands out of which grow secondary tumors having the structure of the primary tumor. Such strands occur in leaves and stems, in the region of the primary vessel parenchyma (near the pith) or in the bark cortex. The cells and vessels of the tumor, often under great pressure, are disoriented as much as in any cancer, and the nuclear parts are in excess taking a deep stain with haematoxylin and other animal tumor stains. The tumor may be cut out but if the excision is not complete it returns. It is the only

plant tumor which at all resembles cancer. As the ordinary tumor develops out of connective tissue (cortex) I have likened it to sarcoma. When the tumor grows in the vicinity of dormant buds or root-anlage they are stimulated into premature but structurally normal development, but when these totipotent or pluripotent cells are actually mingled with the tumor tissue, as often happens, then we have a development in the tumor of great numbers of abortive shoots and roots, so that I have likened this type of crown gall to an embryoma, meaning, of course, a solid malignant tumor in the sense of Wilms and Askanasy.

To the foregoing diseases might be added fragmentary observations on twice as many more, some of which have since been described by my assistants or are now being worked upon and all of which are genuine bacterial diseases. Among these might be mentioned Pelargonium leaf spot, Delphinium leaf spot, Begonia leaf spot, cauliflower leaf spot, rot of iris, rot of celery, soft rot of hyacinth, ash canker, several lettuce rots, wilt of beans, spot disease of soy beans, Tropaeolum wilt, Tropaeolum leaf spot, bud rot of canna, gladiolus disease, oat leaf spots, basal glume rot of wheat, bacterial disease of banana, bud rot of coconut. wild fire of tobacco.

Important researches are now in progress in my laboratory on germicides for seed-borne diseases, on the standardizing of beef infusion culture media, and on the colorimetric and potentiometric pH reactions of all the various organisms we are studying. The last paper published (by F. V. Rand) is on Pecan Rosette, one of the mosaic diseases.

Aside from botanical and bacteriological training the things that have most helped me have been: (1) persistence along a previously determined line of work (a matter of inheritance); (2) fondness for all forms of art and a desire for perfection (again an inheritance); (3) keen vision and ability to discriminate slight differences in form and color; (4) early familiarity with the technic of photography and photomicrography; (5) ability to assimilate quickly the literature of several modern languages. Handicaps have been (1) insufficient mathematical physics; (2) insufficient biochemistry. But perhaps if I had first specialized on these subjects, I should in the end have been

like one of my teachers who decided he would be a naturalist but must first get a good ground-work in Latin and Greek. The result was that he never passed on into a study of nature but became a teacher of the classics. Moral: There is not room in one short life for everything.

As I look back over my work in the U. S. Department of Agriculture I realize that I have been fortunate in being able to devote so large a part of my time to research; in having begun at the right time or in having discovered interesting subjects; in having had pleasant surroundings, congenial associates and faithful helpers; and finally in having had good laboratory and library facilities and great freedom of action. But after all I consider that my most important work has been the stimulating of other persons to undertake researches first in my own laboratory and then through my writings and teachings in many other laboratories.

Finally, after many years, I am again interested in Peronosporaceae, the blue-mold having appeared on tobacco in Florida.

THE PUBLISHED WRITINGS of ERWIN FRINK SMITH

Compiled

by

FREDERICK V. RAND

CONTENTS

Fungus Diseases

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Appendix A. Synopsis of replies to a circular relative to grape mildews and grape rot in the United States. 7 pl. (3 col.) 4 fig. (In: F. Lamson-Scribner . . . Report on the fungous diseases of the grape vine, 136 p.)

Mich. Farmer. March 9, 1886.

The potato rot. A lecture delivered before the Washtenaw Pomological Society by Prof. V. M. Spalding of the University of Michigan. [Followed by extensive remarks by Erwin F. Smith.]

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Secretary, May 1896; cause, "a bacillus the biology of which has not been fully worked out;" "this paper will probably be printed as a part of a bulletin by the U. S. Dept. of Agric."]

1899 U. S. Dept. Agric., Div. Veg. Physiol. and Path. Bull. 17. 1899.
Wilt disease of cotton, watermelon, and cowpea (Neocosmospora nov. gen.). 72 p. 10 pl. (1 col., 1 double).

Sci. Amer. Suppl. 48(1246): 19981-19982. Nov. 18, 1899.
The fungous infestation of agricultural soils in the United States. [Paper read at Ohio State University, Aug. 25, 1899, before Bot. Sect., Amer. Assoc. Adv. Sci. meeting at Columbus, Ohio; "a full account of these diseases will be published in Bull. 17, Div. Veg. Physiol. and Path., U. S. Dept. Agric."]

1904 U. S. Dept. Agric., Bur. Plant Indust. Bull. 55. Feb. 16, 1904.
The dry rot of potatoes due to Fusarium oxysporum. By Erwin F. Smith and Deane B. Swingle. 64 pp. 8 pl. (including frontispiece), 2 fig.

1907 Science 26(663): 347-349. Sept. 13, 1907.
The parasitism of Neocosmospora—Inference versus fact.

1909 ——— 30(758): 60-61. July 9, 1909.
Diplodia disease of maize (suspected cause of pellegra). By Erwin F. Smith and Florence Hedges.

1910 ——— 31(802): 754-755. May 13, 1910.
A Cuban banana disease. [Abst. of paper before Amer. Phytopath. Soc., 1st Annual meeting, Dec. 30-31, 1919; reprinted in West. Ind. Comm. Circ. 25: 325-326. July 5, 1910, under general title: "Banana disease in America and Cuba;" also in: Hawaiian For. and Agric. 8: 33-35. 1911; "the fungus may be designated for the present as Fusarium cubense."]

1921 U. S. Dept. Agric. Dept. Cir. 174. Apr. [20], 1921.
A dangerous tobacco disease appears in the United States. By Erwin F. Smith and R. E. B. McKenney. 6 pp.

——— ——— 176. May 1921.
Suggestions to growers for treatment of tobacco blue-mold disease in the Georgia-Florida district. By Erwin F. Smith and R. E. B. McKenney. 4 pp.

——— ——— 181. June 7, 1921.
The present status of the blue-mold (Peronospora) disease in the Georgia-Florida district. By Erwin F. Smith and R. E. B. McKenney. 4 pp.

Virus Diseases

1888 U. S. Dept. Agric., Bot. Div., Sect. Veg. Path. Bull. 9. 1888.
Peach yellows: a preliminary report. 254 p. 37 pl. (6 col.), 9 col. maps. [Exact date of issue not given but letter of submittal dated Nov. 10, 1888, and "1888" on cover.]

1889-91 Proc. Amer. Pomol. Soc. 22: 38-41. 1889; 23: 21-26. 1891.

1891 The chemistry of peach yellows. I, II. [Papers at 22nd session, Ocala, Fla., Feb. 20-22, 1889, and pub. by Society, 1889; and at 23rd session, Washington, D. C., Sept. 22-24, 1891, and pub. by Society, 1891.]

1890 Journal of Mycology 6(1): 15-16. May 14, 1890.
What to do for peach yellows.

1891 Trans. Peninsula Hort. Soc. [Del.] 4: 55-61. 1891.
Peach yellows. ["Synopsis of an address", 4th annual session, Easton, Md., Jan. 20-22, 1891.]

Journal of Mycology 6(4): 143-148. 6 pl. Apr. 30, 1891.
The peach rosette.

U. S. Dept. Agric., Div. Veg. Path. Bull. 1. 1891.
Additional evidence on the communicability of peach yellows and peach rosette. 65 p. 38 pl. 1891. [1. Peach yellows; 2. peach rosette. Exact date of issue not given.]

1892 Proc. Amer. Assoc. Adv. Sci. 41: 224-225. Aug. 1892.
On the value of wood ashes in the treatment of peach yellows. [Abstract of paper at 41st meeting, Rochester, N. Y., Aug. 1892; pub. by Permanent Secretary, Dec. 1892. "This paper will be printed in substance in Dept. of Agric. Bulletin."]

——— 41: 226. Aug. 1892.
On the value of superphosphates and muriate of potash in the treatment of peach yellows. [Abstract of paper at 41st meeting, Aug. 1892; pub. by Permanent Secretary, Dec. 1892.]

1893 Journal of Mycology 7(3): 226-232. May 15, 1893.
Additional notes on peach rosette.

U. S. Dept. Agric., Div. Veg. Path. Bull. 4. 1893.
Experiments with fertilizers for the prevention and cure of peach yellows, 1889-92. 197 p. 33 pl. (6 fold., 11 col.) [Exact date of issue not given.]

Rept. State Hort. Assoc. Penna. Yr. 1893: 42-49.
Peach yellows. 10 pl. [In: Agriculture of Pennsylvania, 1893.]

1894 U. S. Dept. Agric. Farmers' Bull. 17. May 1894.
Peach yellows and peach rosette. 20 p. 7 fig.

1898 Fennville Herald, Oct. 15, 1898.
Notes of the Michigan disease known as "little peach." [An address before the Saugatuck and Ganges Pomological Society, Fennville, Mich.; reprinted from Fennville Herald, Oct. 15, 1898. 12 p.]

Bacterial Diseases

Miscellaneous Bacterial Diseases

1894 Proc. Amer. Assoc. Adv. Sci. 42: 258-259. Aug. 1893 (1894).
Two new and destructive diseases of cucurbits: (1) The muskmelon Alternaria; (2) A bacterial disease of cucumbers, cantaloupes

and squashes. [Abst. of paper at 42d meeting, Madison, Wisc., Aug. 1893; published by Permanent Secretary, 1894.]

1895 Centralbl. Bakt. II. Abt. 1(9/10): 364-373. Apr. 30, 1895.
Bacillus tracheiphilus sp. nov., die Ursache des Verwelkens verschiedener Cucurbitaceen.

1896 U. S. Dept. Agric., Div. Veg. Physiol. and Path. Bull. 12, Dec. 19, 1896.
A bacterial disease of the tomato, eggplant, and Irish potato (Bacillus solanacearum n. sp.). 28 p. 2 pl. (1 col.)

1897 Centralbl. Bakt. II. Abt. 3(11/12): 284-291. 2 pl. July 7; (15/16): 408-415. Aug. 8; (17/18): 478-486. 1 col. pl. Sept. 10, 1897.
Pseudomonas campestris (Pammel). The cause of a brown rot in cruciferous plants.

1898 U. S. Dept. of Agric. Farmers' Bull. 68. Jan. 8, 1898.
The black rot of cabbage. 22 p.

Proc. Amer. Assoc. Adv. Sci. 46: 274. Aug. 1897 (1898).
Wakker's hyacinth bacterium. [Abstract of paper at 46th meeting, Detroit, Mich., Aug. 1897; published by Permanent Secretary, June 1898.]

——— 46: 288. Aug. 1897 (1898).
On the nature of certain pigments produced by fungi and bacteria, with special reference to that produced by Bacillus solanacearum. [Abst. of paper at 46th meeting.]

——— 46: 288-290. Aug. 1897 (1898).
Description of Bacillus phaseoli n. sp., with some remarks on related species. [Paper at 46th meeting.]

Zeitschr. Pflanzenkr. 8(3): 134-157. 1 pl. July 20, 1898.
Pseudomonas campestris (Pammel) Erw. Smith: Die Ursachen der "Braun-" oder "Schwarz-" Trocken-Fäule des Kohls.

Trans. Peninsula Hort. Soc. [Del.] 11: 142-147. 1898.
Some bacterial diseases of truck crops. [Paper at the 11th Annual session, Snow Hill, Worcester Co., Md., Jan. 12-14, 1898, on "Wilt of the cucumber, brown rot of the potato, and black rot of the cabbage"; published 1898, by "Press of the Delawarean."]

Proc. Amer. Assoc. Adv. Sci. 47: 422-426. Aug. 1898.
Notes on Stewart's sweet-corn germ, Pseudomonas stewarti n. sp. [Paper at the 47th meeting and 50th anniversary of the Association, Boston, Mass., Aug. 1898; published by the Permanent Secretary, Dec. 1898.]

1901 U. S. Dept. Agric., Div. Veg. Physiol. and Path. Bull. 26. Feb. 21, 1901.
Wakker's hyacinth germ, Pseudomonas hyacinthi (Wakker). 45 p. 1 col. pl. 6 fig.

——— 28. Aug. 6, 1901.
The cultural characters of Pseudomonas hyacinthi, Ps. campestris,

Ps. phaseoli, and Ps. stewarti—four one-flagellate yellow bacteria parasitic on plants. 153 p. 1 fig.

1903 U. S. Dept. Agric. Bur. Plant Indust. Bull. 29. Jan. 17, 1903.

The effect of black rot on turnips: a series of photomicrographs, accompanied by an explanatory text. 20 p. Frontispiece. 13 pl.

Science 17(429): 456-457. Mar. 20, 1903.

Observations on a hitherto unreported bacterial disease, the cause of which enters the plant through ordinary stomata. [On Pseudomonas pruni.]

——— 17(429): 457. Mar. 20, 1903.

Completed proof that P. stewarti is the cause of the sweet corn disease of Long Island. [On Pseudomonas stewarti.]

1904 ——— 19(480): 416-417. Mar. 11, 1904.

The olive tubercle. By Erwin F. Smith and James B. Rorer.

——— 19(480): 417-418. Mar. 11, 1904.

The bacterial leaf spot disease. [". . . to call attention to the fact that bacterial infection of plants through the ordinary stomata is not at all infrequent." Several cases mentioned, among them the larkspur leaf spot, for the organism of which the "name of Bacillus delphini is suggested."]

Centralbl. Bakt. II. Abt. 15(22/23): 279-736. Dec. 10, 1904.

Ursache der Cobb'schen Krankheit des Zuckerrohrs.

1905 Science 21(535): 481-483. Mar. 31, 1905.

The effect of freezing on bacteria. By Erwin F. Smith and Deane B. Swingle. [Paper at 6th Annual meeting, Society of American Bacteriologists.]

——— 21(535): 488-489. Mar. 31, 1905.

Exhibition of cultures on starch jelly and on silicate jelly. [Abstract of paper at 6th Annual meeting, Soc. Amer. Bacteriologists.]

——— 21(535): 500-502. Mar. 31, 1905.

The bud rot of coconut palm in the West Indies. [Abstract of paper at 8th Annual meeting, Society for Plant Physiology and Morphology, Dec. 28-30, 1904; "The disease is the result of a bacterial rot of the terminal bud."]

——— 21(535): 502. Mar. 31, 1905.

Bacterial infection by way of the stomata in black spot of the plum. [Abst. of paper at 8th Annual meeting, Soc. Plant Physiol. and Morphol. Dec. 28-30, 1904.]

——— 21(535): 502-503. Mar. 31, 1905.

Burrill's bacterial disease of broom corn. By Erwin F. Smith and Florence Hedges. [Abst. of paper at 8th Annual meeting, Soc. Plant Physiol. and Morphol. Dec. 28-30, 1904.]

Centralbl. Bakt. II. Abt. 15(7/8): 198-200. Sept. 23, 1905. 1 pl.

Some observations on the biology of the olive-tubercle organism.

1906 Science 23(585): 424-425. Mar. 16, 1906.

Channels of entrance and types of movement in bacterial diseases. [Abst. of address before the Society for Plant Physiol. and Morphol.]

1908 U. S. Dept. Agric., Bur. Plant Indust. Bull. 131. Part IV. May 13, 1908.

Recent studies of the olive-tubercle organism. p. 25-43.

——— 141. Part II. Aug. 31, 1908.

The Granville tobacco wilt. p. 17-24.

1909 Science 30(763) : 223-224. Aug. 13, 1909.

Seed corn as a means of disseminating Bacterium stewarti. [Abst. of paper before the Society of American Bacteriologists, Dec., 1908.]

——— 30(763) : 224. Aug. 13, 1909.

The occurrence of Bacterium pruni in peach foliage. [Abst. of paper before Soc. Amer. Bacteriol., Dec., 1908.]

1910 Science 31(802) : 748-749. May 13, 1910.

Bacillus phytophthorus Appel. [Abst. of paper before the American Phytopathological Society, First Annual Meeting, Dec. 1909.]

——— 31(803) : 792-794. May 20, 1910.

Bacterial blight of mulberry. [Abst. of paper before the Amer. Phytopath. Soc., Dec. 1909; Bacterium mori (B. & L.), emend. E.F.S.]

——— 31(803) : 794-796. May 20, 1910.

A new tomato disease of economic importance. [Abst. of paper before Amer. Phytopath. Soc., Dec., 1909: preliminary description of Bacterium (?) michiganense.]

1912 Phytopathology 2(4) : 175. August 1912.

Bacterial mulberry blight.

——— 2(4) : 175-176. Aug. 1912.

Bacillus coli, a cause of plant disease. [Smith here publishes a disclaimer from A. W. Giampietro that he reached independently the conclusion that onion rot is due to B. coli, as he was quite aware that John R. Johnston had discovered coconut bud-rot to be due to that organism.]

——— 2(5) : 213-214. Oct. 1912.

Isolation of pathogenic potato bacteria: A question of priority.

1914 ——— 4(1) : 34. Feb. 1914.

Identity of the American and French mulberry blight.

1915 Annals of the Missouri Botanical Garden 2(1/2) : 377-401. Feb.-Apr. 1915.

A conspectus of bacterial diseases of plants.

Journal of Agricultural Research 5(11) : 465-476. 7 pl. Dec. 13, 1915.

Angular leaf-spot of cucumbers. By Erwin F. Smith and Mary Katherine Bryan.

1917 ——— 10(1) : 51-54. 5 pl. July 2, 1917.

A new disease of wheat. [Black chaff.]

U. S. Dept. Agr., Bur. Plant Indust., Plant Disease Survey. Plant Disease Bulletin [1](2) : 40. Sept. 1, 1917.

Black chaff. [Statements by Smith respecting the bacterial disease of wheat described by him in the preceding entry.]

1918 Science 48(1228) : 42-43. July 12, 1918.

Brown rot of Solanaceae on Ricinus. By Erwin F. Smith and G. H. Godfrey.

U. S. Dept. Agr., Bur. Plant Indust., Plant Disease Survey. Plant Disease Bulletin 2(6) : 98-99. Map. July 15, 1918.

Black chaff. [Note on the new bacterial disease of wheat, mostly on its distribution and on isolations.]

1919 Science 50(1280) : 48. July 11, 1919.

The black chaff of wheat. [Bacterium translucens var. undulosum n. var. described.] By Erwin F. Smith, L. R. Jones, and C. S. Reddy.

——— 50(1288) : 238. Sept. 5, 1919.

Bacterium solanacearum in beans. By Erwin F. Smith and Lucia McCulloch.

1921 Journal of Agricultural Research 21(4) : 255-262. 13 pl., map. May 16, 1921.

Bacterial wilt of castor bean (Ricinus communis L.). [On Bacterium solanacearum.] By Erwin F. Smith and G. H. Godfrey.

1924 Phytopathology 14(1) : 48. Jan. 1924.

A bacterial disease of broomcorn and sorghum. [Abst. of paper before Amer. Phytopath. Soc.] By Charlotte Elliott and Erwin F. Smith.

1925 Revue Gén. Sci. 36(5) : 134-139. Mar. 15, 1925.

Les maladies bactériennes des plantes. [With résumé in: Revue Path. Vég. et Entomol. Agric. 12: 82-91. Jan.-Mar., 1925.]

1929 Journal of Agricultural Research 38(1) : 1-22. 9 pl. (2 col.). Jan. 1, 1929.

A bacterial stripe disease of sorghum. [Extension of paper at 1924 meeting, Amer. Phytopath. Soc., supplemented by reference to an earlier manuscript by the late Erwin F. Smith, covering a review of the early literature and the investigations conducted by him and his assistants, 1904-1908; all color and photographic work by James F. Brewer.] By Charlotte Elliott and Erwin F. Smith.

Books

1905 Bacteria in relation to Plant Diseases. Vol. I, xii, 285 pp. 31 pl., 146 fig., Sept. 1905.

Methods of work and general literature of bacteriology exclusive of plant diseases; bibliography pp. 203-266.

1911 ——— Vol. II, viii, 368 pp., 20 pl. (partly col.), 148 fig., Oct. 30, 1911. History, general considerations, and vascular diseases.

1914 Bacteria in relation to Plant Diseases. Vol. III, viii, 309 pp., 45 pl. (partly col.), 138 fig., August 4, 1914.

Vascular diseases—continued. Carnegie Institution of Washington: Washington, D. C.

1920 An Introduction to Bacterial Diseases of Plants. xxx, 688 pp. Frontispiece (portrait of Burrill), 453 fig. 1920.

[Literature references at end of most of the chapters.] W. B. Saunders Co.: Philadelphia and London, 1920.

Crown Gall (Plant Cancer)

1907 Science 25(643) : 671-673. Apr. 26, 1907.

A plant-tumor of bacterial origin. [Bacterium tumefaciens n. sp. described.] By Erwin F. Smith and C. O. Townsend.

Centralbl. Bakt. II. Abt., 20(1/3) : 89-91. Dec. 6, 1907.

Ein Pflanzentumor bakteriellen Ursprungs. [On Bacterium tumefaciens.] By Erwin F. Smith and C. O. Townsend.

1909 Science 30(763) : 223. Aug. 15, 1909.

Etiology of plant tumors. [Abst. of paper before Society of American Bacteriologists, Dec., 1908.]

1911 Phytopathology 1(1) : 7-11. 2 pl. Feb. 1911.

Crown gall of plants.

U. S. Dept. Agric., Bur. Plant Indust. Bull. 213. 215 pp. 36 pl. Feb. 28, 1911.

. . . Crown gall of plants: its cause and remedy. By Erwin F. Smith, Nellie A. Brown, and C. O. Townsend.

U. S. Dept. Agric., Bur. Plant Indust. Circ. 85. 4 pp. June 20, 1911.

. . . Crown gall and sarcoma.

1912 Science 35(892) : 161-172. Feb. 2, 1912.

On some resemblances of crown-gall to human cancer. [Presidential address, Botanical Society of America, Washington, D. C., Dec. 28, 1911; reprinted as Publication No. 52, Bot. Soc. Amer., 1912.]

Phytopathology 2(3) : 127-128. June 1912.

The staining of Bacterium tumefaciens in tissue.

U. S. Dept. Agric., Bur. Plant Indust. Bull. 255. 61 pp. 109 pl., 2 diagr., June 29, 1912.

. . . The structure and development of crown gall; a plant cancer. By Erwin F. Smith, Nellie A. Brown, and Lucia McCulloch.

Centralbl. Bakt. II. Abt., 34(14/17) : 394-406. July 20, 1912.

Pflanzenkrebs versus Menschenkrebs. [Footnote: "Vortrag des abtretenden Präsidenten der Botanical Society of America, Washington, D. C., Dez. 28, 1911. Infolge einer Einladung waren auch Mitglieder der folgenden Vereine anwesend: Sect. G, A.A.A.S.; Soc. Amer. Bacteriologists; und Amer. Phytopath. Soc."]

Phytopathology 2(6) : 270-272. Dec. 1912.

Etiology of crown galls on sugar beet. [Comments on Karl Spizer's article: "Über die Bildung des Zuckerrüben-Kröpfes."]

1913 Nat. Geogr. Mag. 24(1): 53-70. 12 pl. Jan. 1913.

[The Structure and development of crown gall.] The discovery of cancer in plants. An account of some remarkable experiments by the U. S. Department of Agriculture. With photographs by Dr. Erwin F. Smith. [Summarized from U. S. Dept. Agric., Bur. Plant Industry Bull. 255, with reproduction of many of its plates.]

Proc. 17th Internat. Congr. Med., London, pp. 281-298, Aug. 1913 (1914).

. . . Cancer in plants. [Sect. III, General Pathology and Pathological Anatomy. Part II, pub. 1914. Independent paper presented Monday afternoon, Aug. 11, 1913.]

1914 Compt. Rend. 1er Congr. Internat. Path. Comparée [Paris], (17-23 Oct., 1912) 2: 984-1002, 1914. [Preprint, Paris, 1912, 19 pp.]

Le cancer: Est-il une maladie du règne végétal?

1916 Science 43(1106): 348. Mar. 10, 1916.

Crown gall of plants and cancer. [Note on the closer tying up of crown gall to cancer.]

Jour. Cancer Research 1(2): 231-309. 25 pl. Apr. 1916.

Studies on the crown gall of plants: its relation to human cancer. [With bibliography of other papers bearing on the subject, by the author and his associates, p. 258; plates included in pagination.]

Jour. Agric. Research 6(4): 179-182. 6 pl. Apr. 24, 1916.

Crowngall studies showing changes in plant structures due to a changed stimulus. (Preliminary paper.)

Science 43(1121): 871-889. June 23, 1916.

Further evidence that crown gall of plants is cancer. [Paper read before Washington, D. C., Acad. Sci., May 11, 1916.]

Proc. Natl. Acad. Sci. 2: 444-448. Aug. 1916.

Further evidence as to the relation between crown gall and cancer. [Paper read before Academy, Apr. 18, 1916.]

Science 44(1139): 611-612. Oct. 27, 1916.

Tumors in plants. [First report of tumor production by products of bacterial growth only.]

1917 Jour. Agric. Research 8(5): 165-188. 62 pl. Jan. 29, 1917.

Mechanism of tumor growth in crown gall. [Literature cited, pp. 185-186.]

Proc. Natl. Acad. Sci. 3: 312-314. Apr. 1917.

Chemically induced crowngalls.

Proc. Amer. Philosoph. Soc. 56: 437-444. Aug. 3, 1917.

Mechanism of overgrowth in plants. [Paper read before the Society, Apr. 13, 1917.]

Bull. Johns Hopkins Hosp. 28(319): 277-294. 28 pl. Sept. 1917.

Embryomas in plants (produced by bacterial inoculations). [Ex-

pansion of part of an address before Johns Hopkins Medical Society, Dec. 18, 1916.]

1918 Mem. Brooklyn Bot. Garden 1: 448-453. July 1918.
The relations of crown-gall to other overgrowths in plants. [Literature cited, p. 453.]

1919 Proc. Natl. Acad. Sci. 5: 36-37. Feb. 1919.
The cause of proliferation in Begonia phyllomaniaca. [Paper read before the Academy, Nov. 18, 1918.]

1920 Archives Dermatol. and Syphilol. 2(2): 176-180. Aug. 1920.
Production of tumors in the absence of parasites. [Varieties of tumors in plants—Experimental tumors in plants; paper read before Section on Dermatology and Syphilology, 71st Annual Session, American Medical Association, New Orleans, Apr. 1920.]

1921 Jour. Agric. Research 21(8): 593-598. 10 pl. July 15, 1921.
Effect of crowngall inoculations on Bryophyllum.

1922 Jour. Cancer Research 7(1): 1-105. 28 pl., 4 fig. Jan. 1922.
Appositional growth in crown-gall tumors and in cancers. [Plates and legend pages in pagination; literature, pp. 47-49.]
Phytopathology 12(6): 265-270. 5 pl. June 1922.
Fasciation and prolepsis due to crowngall.

1923 Journal of Radiology 4(9): 295-317. 8 pl. Sept. 1923.
Twentieth century advances in cancer research (with special reference to etiology). [Paper at Annual Meeting, Radiological Society of North America, Detroit, Mich., Dec. 7, 1922.]

1924 Journal of Cancer Research 8(2): 234-239. July 1924.
Crown-gall and its analogy to cancer: A reply. [A reply to Levin and Levine's paper: "Malignancy of the crown-gall and its analogy to animal cancer."]
Rev. Path. Vég. et Entomol. Agric. 11(4): 219-228. Oct.-Dec. 1924.
Le crown-gall.

1925 Jour. Heredity 16(2): 60-62. Feb. 1925.
The causes of cancer: A review [of B. J. Ellis Barker] (with Introduction by W. Arbuthnot Lane): "Cancer: How it is caused; how it can be prevented."].
Science 61(1581): 419-420. Apr. 17, 1925.
Cancer in plants and in man. [Note by Smith on Ferdinand Blumenthal's work; note signed, "President of the American Association for Cancer Research, Berlin, March 5, 1925."]
Science 61(1589: 595-601. June 12, 1925.
Some newer aspects of cancer research. [Opening address of the President, 18th Annual Meeting, Amer. Assoc. for Cancer Res., Navy Medical School, Washington, D. C., May 4, 1925.]
Journal of Heredity 16(8): 272. 1 pl. (frontispiece), Aug. 1925. [Plate, with descriptive text.]
Tumor formation in Bryophyllum.

1926 Jour. Heredity 17(4) : 112. 1 pl. (frontispiece), Apr. 1926. [Plate with descriptive text.]

Fasciation of dahlia.

Science 63(1637) : 505. May 14, 1926.

Changed structure due to a modified environment: A study of labile protoplasm in Helianthus annuus L. [Abst. of paper before National Academy of Sciences, Washington, D. C., Apr. 26-28, 1926; on crown-gall bacterial inoculations, and on proliferation induced by mechanical stimuli.]

American Naturalist 60(668) : 240-256. May-June 1926.

Recent cancer research. [Footnote: "Address given at the Symposium on the Cancer Problem, American Society of Zoologists, Dec. 30, 1925."]

Phytopathology 16(8) : 491-508. 5 fig., Aug. 1926.

A begonia immune to crowngall: with observations on other immune or semi-immune plants. ["The first of a series of potentiometer studies."] By Erwin F. Smith and Agnes J. Quirk.

1927 Mem. Natl. Acad. Science [Washington, D. C.] Vol. 22, 4th Memoir, 1 pl. l., 50 pp. 43 pl., 1927.

. . . Tumors, cysts, pith-bundles, and floral proliferations in Helianthus. [Description of plates, pp. 8-50; literature references, p. 5; paper presented at the Annual Meeting of the Academy, 1924.]

The Smith-Fischer Controversy

1899 Centralbl. Bakt. II. Abt. 5(8) : 271-278. Apr. 30, 1899.

Are there bacterial diseases of plants? A consideration of some statements in Dr. Alfred Fischer's Vorlesungen über Bakterien. [With reply by Alfred Fischer. Die Bakterienkrankheiten der Pflanzen. Antwort an Herrn Dr. Erwin F. Smith, Assistant Pathologist, U. S. Dept. of Agriculture, Washington, D. C. 5(8) : 279-287.]

——— 5(23) : 810-817. Dec. 1, 1899.

Dr. Alfred Fischer in the role of pathologist.

1901 ——— 7(3) : 88-100. Feb. 7; (4) : 128-139. Feb. 23; (5/6) : 190-199. 11 pl. Mar. 14, 1901.

Entgegnung auf Alfred Fischer's "Antwort" in Betreff der Existens von durch Bakterien verursachten Pflanzenkrankheiten. II.

Miscellaneous Scientific Writings*

* For the years 1872-1886, Dr. Smith kept a scrap-book in which he pasted clippings of newspaper articles and poems written by him. This book is on file in the U. S. Dept. of Agric. Library, having been presented to the Library by Mrs. Erwin F. Smith.

1881 Catalogue of the phanerogamous and vascular cryptogamous plants of Michigan, indigenous, naturalized, and adventive. By Charles F. Wheeler and Erwin F. Smith. 105 p. Col. map. W. S. George & Co., State Printers and Binders, Lansing, 1881. [Also pub. in: Ann. Rept. Sec. State Hort. Soc. Mich. 10: 427-529. 1880 (1881), with caption, "Michigan flora, Prepared for the Michigan Horticultural Society by Charles F. Wheeler and Erwin F. Smith, Hubbardston, Michigan."]

1885 Ann. Rept. Mich. State Bd. Health, Suppl. (Sanitary Convention, Lansing), pp. 104-106.

Sewerage and water-supply. Discussion at a Sanitary Convention held at Lansing, Michigan, March 19 and 20, 1885.

——— Suppl. (Sanitary Convention, Ypsilanti), pp. 83-168. Lansing, 1885 (1886).

The influence of sewerage and water-supply on the death rate in cities. [Read at the Sanitary Convention at Ypsilanti, Michigan, July 1, 1885.]

Sanitary News 6: 179, Sept. 26, 1885.

Does hygiene pay? By Max von Pettenkofer of Munich. Translated by Erwin F. Smith of Lansing, Mich.

1890 Entomol. Amer. 6(6): 101-103. June; (11): 201-208. Nov. 1890.

The black peach aphis: a new species of the genus Aphis. [Aphis persicaeniger n. sp.]

1894–95 [Mycological and plant pathological definitions, in cooperation with Walter T. Swingle in "A Standard Dictionary of the English Language."] 2 v. and Supplement to the Subscription Edition. N. Y., Funk and Wagnalls, 1894-1897.

NOTE: Dr. Smith in his "Synopsis of Researches of Erwin F. Smith in the U. S. Department of Agriculture, 1886-1922" states that the definitions beginning with D-G were written in cooperation with Walter T. Swingle. The list of the editorial staff accompanying the Supplement to the Standard Dictionary gives the letters C-H after the name of Walter T. Swingle.

The botanical club check list: a protest. 16 pp. Privately printed. Washington, D. C., July 22, 1895.

U. S. Dept. Agric., Farmers' Bull. 33. 1895. 24 pp. 21 fig. [Date of issue not given.]

Peach growing for market.

1896 American Naturalist 30(353): 372-378. May; (354): 451-457. June; (355): 554-562. July 1896.

The path of the water current in cucumber plants.

Asa Gray Bulletin 4(3): 25-28. May; 4(4): 37-43. July 1896.

Hints on the study of fungi. I, II. [A general paper on methods and apparatus, based on Smith's experience and primarily for "beginners."]

U. S. Dept. Agric., Div. Veg. Physiol. and Path., Bull. 11. 45 pp. 1896. [Date of issue not given.]

Legal enactments for the restriction of plant diseases. A compilation of the United States and Canadian laws.

1898 Trans. Mass. Hort. Soc. Yr. 1897. Part I: 117-133. 1898.

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Demonstration of photosyntax by bacteria. [Review of Th. W. Engelmann.]
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Ferns of Nicaragua. [Review of B. Shimek.]
——— 32(376): 284-287. Apr. 1898.
Lessons with plants. [Review of L. H. Bailey.]
——— 32(377): 365-369. May 1898.
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Sulphur bacteria. [Review of Miyoshi.]
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Ripening of cheese. [Review of Olav Johan-Olsen.]
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Recent inexpensive popular literature on mushrooms.
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Merrill on Lower California. [Review of George P. Merrill, on the ecology of the region.]
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Whitney on Florida. [Review of Milton Whitney on the soils, and particularly on the plant associations of the region.]
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fact, the best brief paper we have on the work of Pasteur, and the writer of this note believes many will like to have it in an English dress.—E.F.S."]

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Nature Magazine 8(6): 346-347. Dec. 1926.
Louis Pasteur. Portrait.

Non-Scientific Writings

1915 For Her Friends and Mine: A book of aspirations, dreams and memories. Printed privately, Washington, D. C., 381 pp., 13 text cuts by Erwin F. Smith, 1915. [With portrait of "Charlotte May Buffett, some-time wife of Erwin F. Smith," with her biography; 12 original odes and songs and 197 sonnets by Erwin F. Smith; and 58 translations of poems from the German, French and Italian.]

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Some thoughts on old age. [Address, May 4, 1924, at Annual Dinner, Botanical Society of Washington, as Guest of Honor, ending with original poem.]

SKETCHES ON THE LIFE AND WORK

of

ERWIN FRINK SMITH

Compiled

by

Frederick V. Rand

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[Reminiscences of Dr. Erwin F. Smith.] *Byôchû-gai Zasshi (Journal of Plant Protection)* 14(7) : 371-374. Portrait. July 1927. [In Japanese.]

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In memoriam: Erwin Frink Smith. 1854-1927. *Phytopath.* 18(5) : 475. May 1928.

Degrees, Honors, and Society Memberships

University of Michigan, B.S. in Biology (1886), Sc. D. (1889), LL.D. (1922) ; University of Wisconsin, Sc. D. (1914).

Associate Editor, Centralblatt für Bakteriologie (II. Abt., first 25 volumes) ; Trustee, Marine Biological Laboratory, Woods Hole, Massachusetts (three terms) ; Certificate of Honor, American Medical Association, 1913, for cancer research in plants.

Member of: American Academy of Arts and Sciences (Fellow), American Association for the Advancement of Science (Fellow ; President Section G, 1906), American Association for Cancer Research (Vice President, 1924; President, 1925), American Association for Medical Progress

(Life Member), American Philosophical Society, American Phytopathological Society (President, 1916), American Pomological Society (Life Member), Botanical Society of America (President, 1910), Council for National Defense, International Conference (Third) on Genetics, London, 1906, International Congress (First) of Comparative Pathology, Paris, 1912, International Congress (Seventeenth) of Medicine, London, 1913, National Academy of Sciences (Chairman, Botanical Section three years), National Association for the Study and Prevention of Tuberculosis, Society of American Bacteriologists (President, 1906), Society for Plant Morphology and Physiology (President, 1902), German Central Commission for Cancer Research and Control (Foreign Associate), Russian Botanical Society (Honorary Member, Mycological Section), Arts Club (Washington, D. C.) (member Executive Committee for Erection of a National Peace Carillon in Washington), Cosmos Club (Washington, D. C.), The Literary Society of Washington, D. C., National Arts Club (New York), National Carillon Association (an incorporator), and Phi Delta Theta Fraternity.